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Assessment of the Effect of Co-Digestion of Chicken Dropping and Cow Dung on Biogas Generation

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Abstract - Biogas production from 5 batch digesters containing varying ratios of mixture of chicken droppings and cow dung was studied for a period of 30 days at ambient temperature. Results from this study show that co-digestion of chicken droppings and cow dung increased biogas yield as compared to pure samples of either chicken droppings or cow dung. The maximum biogas yield was attained with mixtures in the proportions of 1:4. Several regression models were used to adequately describe the cumulative biogas production from these digesters. The polynomial correlation with R2 = 0.98 seemed to be more reliable in predicting gas production in anaerobic digestion of animal wastes. This tool is useful in optimizing biogas production from energy materials, and requires further validation and refinement. Hopefully, this study advances this increasingly growing area of animal wastes research.

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Abstract - Biogas production from 5 batch digesters containing varying ratios of mixture of chicken droppings and cow dung was studied for a period of 30 days at ambient temperature. Results from this study show that co-digestion of chicken droppings and cow dung increased biogas yield as compared to pure samples of either chicken droppings or cow dung. The maximum biogas yield was attained with mixtures in the proportions of 1:4. Several regression models were used to adequately describe the cumulative biogas production from these digesters. The polynomial correlation with $R^2 = 0.98$ seemed to be more reliable in predicting gas production in anaerobic digestion of animal wastes. This tool is useful in optimizing biogas production from energy materials, and requires further validation and refinement. Hopefully, this study advances this increasingly growing area of animal wastes research.

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I. Introduction

Nigeria is abundantly blessed with different types of energy resources. The climate permits average solar radiation as high as 5.538kwh/m^2/day (World Energy Council, 1993), making the country operate mainly under mesophilic temperature at ambient conditions. This energy needs to be tapped especially as the energy supply of the country is grossly inadequate. Consequently, biogas production via anaerobic digestion can be a good resource channel if properly harnessed as in the case of China and India. Moreover, the effluent of this process is a residue rich in essential inorganic elements like nitrogen and phosphorus needed for healthy plant growth known as biofertilizer which when applied to the soil, enriches it with no detrimental effects on the environment (Bhat et al., 2001). This will further argument the inadequate supply of chemical fertilizers which are very expensive in spite of the fact that the country is a net food importer.

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Anaerobic digestion (AD) is a technology widely used for treatment of organic waste for biogas production. Anaerobic digestion that utilizes manure for biogas production is one of the most promising uses of biomass wastes because it provides a source of energy while simultaneously resolving ecological and agrochemical issues. The anaerobic fermentation of manure for biogas production does not reduce its value as a fertilizer supplement, as available nitrogen and other substances remain in the treated sludge (Alvarez and Lide'n, 2008).

Biogas production is a complex biochemical reaction found to take place under the action of delicately pH sensitive microbes mainly bacteria in the presence of little or no oxygen. Three major groups of bacteria (hydrolytic, acidogens/acetogens and methanogens) are responsible for breaking down the complex polymers in biomass waste to form biogas at anaerobic conditions and animal manure has been established as major sources of this gas (Bori et al., 2007).

Numerous studies had been conducted by several researchers in order to optimize biogas yield in Anaerobic digestion. For example, the anaerobic digestion of solid refuses like municipal solid wastes (Owens and Chynoweth, 1993; Watson et al., 1993; Welland, 1993; Beukering et al., 1999; Rao et al., 2000; Kivaisi and Mukisa, 2000; Lopes et al., 2004; Nordberg and Edstron, 2005;Igoni et al., 2008; Ojolo et al., 2008;), Barcelona's central food market organic wastes (Mata et al., 1992), Canteen wastes (Krishna et al., 1991), Market wastes (Ranade et al., 1987), Water hyacinth (Lucas and Bamgboye, 1998; Katima, 2001; Kivaisi and Mtila, 2001; Patil et al., 2011), Sugar mill press mud waste (Sanchez et al., 1996), fruit and vegetable processing wastes (Knol et al., 1978; Lane, 1984; Sumitradevi and Krishna, 1989; Mata et al., 1993), and animal wastes (Matthew, 1982; Abubakar, 1990; Lawal et al., 1995; Machido et al, 1996; Itodo and Kucha, 1998; Zuru et al.,1998; Sadaka and Engler, 2000; Bujoczek et al., 2000; Castrillon et al., 2002; Kivaisi, 2002;Gelegenis et al., 2007, Ojolo et al., 2007, Li et al., 2009; Budiyono et al., 2010; Ofoefule et al., 2010; Yusuf et al., 2011;) have been reported.

The main objective of this research is to employ anaerobic digestion process as a sustainable technology for digesting the animal wastes (Chicken droppings and Cow dung), produced in large amounts from poultry farms and Abbatoirs respectively, and to provide the renewable source of energy (biogas) that can reduce the potential green house gas emission. The specific objectives are (i) To optimize the biogas evolution from the animal waste. (ii) To analyze the operational parameters, such as pH, total solid, volatile solid, and ash content for the stability of anaerobic digestion system. (iii) To get an understanding of the anaerobic digestion of the animal wastes under ambient temperature conditions by conducting a large scale study and hence to investigate the biogas yield.

II. Materials and Methods

a) *Substrate preparation and Characterization*

The chicken droppings used for this study was collected from Phinoma poultry farms Nig. Ltd at Enugu Ngwo, Enugu State while cow dung was obtained from Abattoir at Sam Ugwu way, off Ogoja Road, Abakaliki, Ebonyi State. Chemical analyses of these substrates were carried out to determine their total solid, volatile solid, and ash content. The Total solid and volatile solid were determined in accordance with procedure outlined in standard methods (Meynell, 1982). The ash content of the undigested animal wastes were determined using AOAC (1990) method. The pH was measured using digital pH meter.

b) *Experimental design*

The experimental design for the anaerobic digestion of chicken droppings and cow dung was carried out at ambient temperature that ranged between 22°C to 35°C in a series batch digesters with 4.5 litre capacity each. The compositions of the digesters are presented in table 1.

Table 1 : Digesters composition

Chicken Droppings (g)	Cow Dung (g)	Quantity of water (L)
200.00	0.00	2.80
180.00	20.00	2.80
160.00	40.00	2.80
140.00	60.00	2.80
120.00	80.00	2.80
100.00	100.00	2.80
80.00	120.00	2.80
60.00	140.00	2.80
40.00	160.00	2.80
20.00	180.00	2.80
0.00	200.00	2.80

The main experiment apparatus consists of biodigester and biogas measurement. Biodigester were made from five improved-glass–ware and plastic calibrated prototypes. Biogas formed was measured by 'liquid displacement method'. The digesters were set up as described by (Itodo et al.,1992), (Chellapandi, 2004), and (Momoh and Nwaogazie, 2008).

Data Analysis: The data generated was analyzed by adopting regression models presented in table 2. Where K_T can be represented as total biogas yield, R as retention time for substrate loadings, and a, b, c are regression constants to be determined using SPSS computer software.

Table 2 : Regression models used in this work

Model Type	Regression Equation	Source
Linear	$K_T = a + bR_s$	Angstrom, 1924
Quadratic	$K_T = a + bR_s + cR_s^2$	Akinoglu and Ecevit, 1990
Polynomial	$K_T = a + bR_s + cR_s^2 + dR_s^3$	Samuel, 1991
Logarithmic	$K_T = a + b\log(R_s)$	Ampratwum and Dorvlo, 1999
Linear-Logarithmic	$K_T = a + bR_s + c\log(R_s)$	Newland, 1988
Exponential	$K_T = ae^{(bR_s)}$	Elagib and Monsell, 2000
Power	$K_T = e^a R_s^b$	Coppolino, 1994

III. Results and Discussion

From the experiment performed in the laboratory, a set of results were obtained that contain cumulative biogas yields for different substrate loadings. Thus, the results of biogas production from chicken droppings and cow dung is documented in Table 3. The cumulative volume of gas was plotted against mixture of chicken dropping and cow dung (Fig. 1).

Table 3 : Volume of gas produced for different substrate loading

S/N	Chicken dropping to cow dung ratios (g)	Cumulative Gas Vol. (L)
1	200:00	1.8600
2	180:20	1.8600
3	160:40	2.0150
4	140:60	2.0630
5	120:80	1.8500
6	100:10	0.3050
7	80:120	2.1850
8	60:140	2.4100
9	40:160	2.7050
10	20:180	2.0670
11	00:200	0.8300

It was observed that Biogas production was slightly slow at the beginning and the end period of observation. This is predicted because biogas production rate in batch condition is directly proportional to specific growth rate of methanogenic bacteria in the biodigester (Nordberg and Edstrom, 2005). Comparing with the pure samples, mixing pig and cow dung generally increased biogas yield. The maximum biogas yield was attained with mixtures in the proportions of 1:4. From Table 3, the 100% chicken manure produced more gas per unit weight as compared to the 100% cow dung. This concurs with Hobson's (1981) findings that attributed the lower production to low biodegradable material in the cow dung. However, Yeole and Ranande (1992) attributed the higher biogas yield from the chicken dropping to the presence of native micro flora in the chicken dropping while Fulford (1988) attributed it to the low carbon-nitrogen ratio.

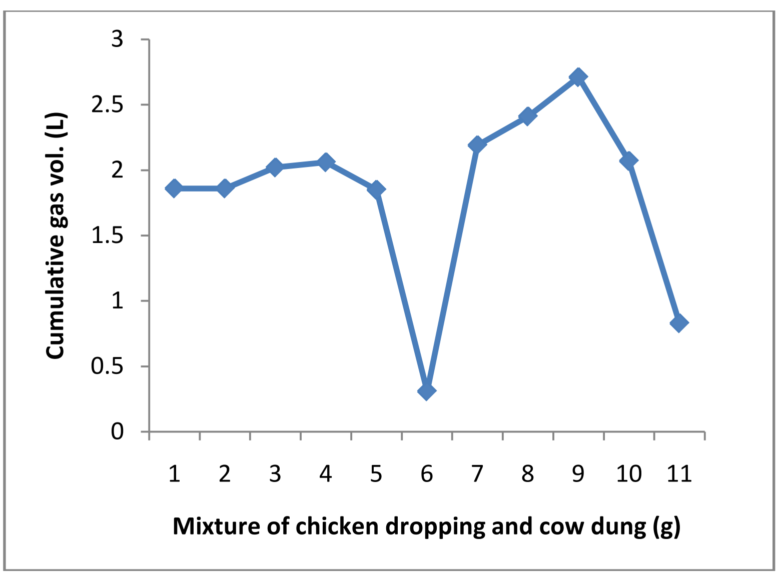

Fig.1 : Cumulative gas volume against mixture of chicken dropping and cow dung

Effect of pH, TS, VS, ash content, on gas production: pH (%), TS (%),VS (%), and ash content (%), for chicken dropping and cow dung are presented in table 4. Optimum biogas production is achieved when the pH value in the digester is between 6 and 7 (Garba, 1996). Low pH value inhibits methanogenic bacteria and methanogenesis (Vicenta, 1984). The high pH value recorded in this study could be attributed to large ammonia losses resulting from C/N ratio of poultry waste (Gray et al, 1971). Determination for total solids of waste is an effective way of finding out the amount of nutrient that will be available for bacterial action during digestion. The total solids in this study are within the range for biogas production when compared with (Ofoefule et al., 2010). The amount of methane to be produced depends on the quantity of volatile solid that is the amounts of solids present in the waste and their digestibility or degradability (Sarba, 1999). Again, the volatile solids are within the range for biogas production (Ofoefule et al., 2010). Higher ash content also corresponded with higher volatile solids content as can be seen from table 4. Cow dung has higher potential for organic manure compared with chicken dropping because of its higher ash content.

Table 4 : Physiochemical properties of the undigested wastes

Waste Sample	pH	TS (%)	VS (%)	ASH (%)
Chicken dropping	9.39	83.80	17.20	37.50
Cow dung	9.53	77.38	36.38	41.00

Analysis of the predictive model: The daily and cumulative biogas generation monitored for different substrate loadings were used for developing predictive models for the generation of biogas for different substrate loading for various retention time. The various functions, which include linear, quadratic, polynomial, logarithmic, linear-logarithmic, and exponential were determined statistically using SPSS software. The regression models that give the highest level of coefficient of determination between the type of regression model and the data generated from the experiments were determined. After carrying out this analysis, a comparative study of R^2 values was observed. The highest values of R^2 were chosen as the best fit to the experimental data. The equations derived from the application of table 2 for biogas production are presented in table 6.

The best fit was observed only in the case of polynomial correlation with R^2 = 0.78 compared to quadratic one with R^2 = 0.59. So, polynomial function seemed to be more reliable in predicting gas production in anaerobic digestion of animal wastes.

Table 6 : Results of model analysis

Regression equations	R^2
$K_T = 0.0461 + 0.7494R_s$	0.53
$K_T = 0.0631 + 0.3549R_s + 0.2341R_s^2$	0.59
$K_T = 0.0558 + 0.7489R_s + 0.3234R_s^2 + 0.1231R_s^3$	0.78
$K_T = 0.1232 + 0.0748\log(R_s^2)$	0.43
$K_T = 0.1232 + 0.0431R_s + 0.2342\log R_s$	0.47
$K_T = 0.0322e^{0.0212R_s}$	0.34

IV. Conclusion

Biogas production from co-digestion of chicken dropping and cow dung was established here to be feasible at ambient temperature. Comparing with the pure samples, mixing pig and cow dung generally increased biogas yield. The maximum biogas yield was attained with mixtures in the proportions of 1:4. Co-digestion of chicken dropping and cow dung is therefore, one way of addressing the problem of lack of enough feedstock for biogas production in Nigeria. Mathematical models derived using regression analysis indicated that biogas production of animal wastes can be predicted based on digestion time. The polynomial function seemed to be more reliable in predicting gas production in anaerobic digestion of animal wastes. This tool is useful in optimizing biogas production from energy materials, and requires further validation and refinement. Hopefully, this study advances this increasingly growing area of animal wastes research.

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