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QUANTITATIVE AND QUALITATIVE EVALUATION OF BIOGAS FROM FARM WASTES IN UDI, ENUGU STATE

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Abstract
The production of biogas from cassava peels with cow dung, poultry droppings and swine dung in the ratio of 1:1 for fresh sample and 1:2 for dry sample was investigated using 2.8 liter batch type anaerobic digesters with a retention period of 30 days. The cumulative biogas yields from the fresh samples were 30.8+2, 30.8+3, 29.6+2, 31+3, 47.3+3, 32.3+3 and 52.7+2cm^3/g over digestion period. However, the highest volume of gas generated 52.7+2cm^3/g was obtained from the digester containing equal proportion of fresh cassava peels and swine dung.
Keywords: Blending wastes, Simultaneous Digestion, Optimization, Biogas.

Introduction

There are three major stages involved in the process of biogas production; aerobic phase or fermentation, hydrolysis phase and anaerobic bacteria phase, made up of acetogenesis and methanogenesis phases. At methanogenesis phase, ninety percent of methane yield takes place. 70% acetic acid formation at acetogenesis phase (second step) is the factor that defines the speed of methane formation (Abubakar *et al*., 2004). This gas can be used as natural gas for technological purposes, heating or electricity production. It can be stored, pumped, used as vehicle fuel or sold to neighbours. Biogas as a renewable energy source could be a relative means of solving the problems of rising energy prices, waste treatment/management and creating sustainable development. In the nearest future, it is believed that biogas will replace the use of fossil fuel as major energy source (Ofoefule and Uzodinma, 2008). Any organic matter with the exception of mineral oil can be used as feed stock for anaerobic digestion to produce biogas.

The main objectives of this work are as follows:

- To produce biogas from farm waste such as cow dung, swine dung, poultry droppings and cassava peels as a substitute for fossil fuel consumption.
- To enumerate, isolate and characterize microorganisms in cow dung, swine dung, poultry droppings and cassava peels before, during and after digestion.
- To monitor the temperature and pH changes during gas production.
- To determine the effect of single waste substrate and co-digestion of these wastes on biogas production.
- To determine the physicochemical characteristics of the waste before, during and after the gas production.

Materials And Methods

The cassava peels used in this study were obtained from the local garri processor, while the poultry droppings, swine dung and cow dung were obtained from Nebo farm in Udi town and Ogbette main market abbatoir in Enugu state, Nigeria. The cassava peels were collected in November 18, 2009 for drying while the animal wastes (cow dung, swine dung and chicken droppings) were collected fresh on December 8, 2009 for biogas production. The samples were collected in bulk quantities using sterile plastic containers with lid. Samples were then sent to laboratory for processing and analysis.

Microbial Analysis

Processing of Samples

Four waste samples assessed for microbial load were: cassava peels (CP), cow dung (CD), poultry droppings (PD), and swine dung (SD)

Serial Dilution of Samples

The samples were each chopped mechanically and thereafter pounded using mortar and pestle and stirred to break into smaller particles to ensure consistency of mix. Isolation and enumeration of microorganisms in the samples were carried out using a ten-fold serial dilution method as reported by Fernado and Westlake (1981).

Enumeration of Bacterial

This was carried out by pour plate techniques (Fernado and Westlake, 1981).

Enumeration of Fungal

The medium of choice was potato dextrose agar supplemented with 0.5ml of streptomycin to inhibit any bacterial contaminants. The enumeration of heterotrophic fungi was done using pour plate technique. Dilution of 10^{-6} were used for aerobic fungi enumeration. The plates were kept incubated at room temperature for 5 days. Plates for isolation of anaerobic fungi were incubated in the anaerobic jar for 7 days. At the end of incubation period, the fungal colonies were examined and counted (Fernado and Westlake, 1981).

Characteristics and Identification of Bacterial

The isolates were characterized and identified using the taxanomic and identification biochemical test schemes after morphological and microscopic examination (Barrow and Feltham, 2003).

Biochemical Test

The tests carried out under the biochemical for the identification of the bacterial isolates was as described by Barrow and Feltham, 2003.

Characterization of Fungal Isolates

Pure fungal isolates were characterized and identified based on their cultural and morphological features such as described in the taxanomic schemes of Beneke and Rogers (1970).

Characteristics of Yeasts and Moulds

The colony morphology, spore and sugar tests were used as basis of identification of yeast growth on glucose yeast extract agar containing 1% chloramphenicol (GYE A) (Barrow and Feltham, 2003).

For moulds, growth on acidified malt extract agar plate was sub cultured using slide culture technique. The colour and growth pattern of the isolate were used as basis of identification (Barrow and Feltham, 2003).

Physicochemistry Analysis

The physical and chemical composition of the feed stock was carefully evaluated before, during and after digestion using standard procedures described by Barrow and Feltham (2003).

Qualitative Laboratory Analysis for Composition of Biogas

Biogas volume was measured using a method by which deflated poly vinyl chloride balloon was fitted over the opening of the digesters. Biogas production was indicated by a gradual inflation of the balloon. The deflated balloon was measured as Xg, then, upon production of biogas, the balloon was unfixed and measured as Wg. The difference Vg was regarded as the volume of the biogas generated from the digester, while the biogas composition was measured with Hand held GFM, 416 series biogas analyzer.

Waste Treatment and Preparation of Feedstock:

Each of the wastes (the dry waste dryness was maintained at 8% moisture content) were thoroughly grounded and mixed with water separately in bowls in the ratio of 1:2 (Adelekan, 2000). Renewable energy specifies that if the dung is dry, the quantum of water has to be in the ratio of 1 : 2 while fresh dung has to be in the ration of 1 : 1 (Ofuefule et al, 2008).

The cassava peels was sun-dried for seven days, manually homogenized using mortar and pestle thereafter soaked in water (in ratio 1 : 2) for 24 hours. This action was intended to allow cassava peels to ferment and detoxify the substrate due to the presence of cyanogenic glycosides that can inhibit biogas production (Wantanee et al, 2004).

Results

Biogas Production Generated from Fresh and Dry Waste Materials

Table 1 (with fresh materials) shows that in digesters D to G highest biogas production was achieved within 6-10 days of the reaction, 16-20 days for digesters A, and 11-15 days for digester B and C. Gas production could only commence from the 6th day in digester A. The daily gas production over a thirty day digestion mean volume in the digesters stand at 8.3+2, 30.8+3, 29.6+2, 31+3, 47.3+3, 32.3+3, 52.7+2 cm^3/day, respectively.

While in table 1 (with dry materials) shows that biogas production was constant for 6-15 days, and reaching the climax within 16-20 days before falling in digester A. In digester G, the highest production was achieved within 6-10 days. In digester C, highest gas production started from the onset of the experiment ie within the first 1-5 days and reduced from 6-10 days. The results revealed that among dry single animal substrates, cow dung had the highest gas production followed by poultry droppings and the swine dung had the least

Table 1: Biogas Production

Digester ↓ / Days →	1 -5	6 – 10	11 – 15	16 – 20	21 – 25	26 - 30	Cumulative Gas Yield cm^3/g	Mean value Gas Production cm^3/g
A	(11)	(21)	(21)	(24)	(11)	(6)	(94)	(15.7±2)
	0	8	10	13	10	9	50	8.3±2
B	(33)	(35)	(23)	(20)	(17)	(10)	(138)	(23±3)
	25	38	44	4	27	11	185	30.8±3
C	(33)	(20)	(15)	(16)	(17)	(10)	(111)	(19±3)
	27	30	39	38	34	10	178	29.6±2
D	(25)	(35)	(20)	(16)	(13)	(9)	(118)	(20±3)
	39	45	40	39	12	9	184	31±3
E	(40)	(51)	(32)	(25)	(19)	(11)	(178)	(30±3)
	51	68	52	49	39	25	284	47.3±3
F	(43)	(53)	(42)	(37)	(34)	(29)	(238)	(40±3)
	40	51	37	31	21	14	194	32.3±3
G	(42)	(50)	(41)	(33)	(26)	(23)	(215)	(35.8±2)
	65	72	69	51	33	26	316	52.7±2

Numbers bracketed = biogas production from dry waste materials
Numbers un-bracketed = biogas production from fresh waste materials

A - Fresh Cassava peel
B - Fresh / dry Cow dung
C - Fresh / dry Poultry dropping
D - Fresh / dry Swine dung
E - Fresh / dry Cassava peel + Fresh / dry cow dung
F - Fresh / dry cassava peels + Fresh / dry poultry dropping
G - Fresh / dry cassava peels + Fresh / dry swine dung

pH changes of fresh and dry feed stocks during digestion

Table 2 (with fresh materials) shows that pH increased as the retention time increased. Digestion A, containing fresh cassava peel had the least pH change ranging between 4.2 to 6.8 throughout the digestion period. While in table 4 (with dry materials) the same profile of pH increase was as in fresh materials with a little difference in digester A with least pH increase change ranging between 5.9-6.8 throughout the digestion period. In the dry samples, the pH of the digesters ranges from 6-8 throughout digestion period. Only the pH of digester A was below 6 during the first week.

In the fresh samples, the pH of digestion A was almost constant throughout the digestion period. The pH reading of digestion A, B and C were constant and almost the same for retention time of 3 weeks, and pH between 4 and 6.8. But pH reading of D and E were between 7-8.

Table 2: pH changes of fresh and dry feed stocks during digestion

Digester ↓	RETENTION TIME → 0	1	2	3	4
A	(4.2) 4.2	(5.9) 4.6	(6.3) 5.2	(6.5) 6.8	(6.8) 6.8
B	(5.6) 5.6	(5.3) 5.5	(6.5) 6.6	(7.9) 8.0	(7.0) 7.0
C	(5.6) 5.6	(7.3) 5.5	(6.5) 5.5	(7.8) 7.0	(7.8) 7.8
D	(5.6) 5.6	(7.5) 5.5	(6.5) 5.5	(7.5) 7.9	(7.9) 8.1
E	(5.6) 5.6	(6.9) 5.5	(6.8) 5.5	(7.4) 7.6	(7.5) 7.8
F	(5.6) 5.6	(6.9) 6.2	(7.2) 6.9	(7.5) 7.9	(7.8) 8.1
G	(5.6) 5.6	(7.4) 6.0	(7.7) 6.4	(7.9) 7.7	(8.1) 8.1

Numbers bracketed = pH change of fresh feed stock in the digester
Numbers un-bracketed = pH change of dry feed stock in the digester

Temperature Changes of Fresh and Dry Feed Stocks During Digestion

Table 3 (with fresh materials) shows that optimum temperature range was from 29-34.5^{o}C, temperature rose gradually, reaching climax on the 15th day of the operation before gradually falling,.

In the fresh cassava peel and fresh swine dung, temperature differences were not significant, but temperature fall in digester containing fresh swine dung was sudden.

Comparing the temperature changes in different co-digestion of fresh cassava peel + swine dung and dry cassava + swine dung, there were no significant difference in temperature within 1-25 days of operation. From 25th day of the operation, the temperature fall in dry sample was more than as in fresh sample.

Table 3: Temperature Changes of Fresh and Dry Feed Stocks During Digestion

Digester ↓ Temperature / Days →	1	5	10	15	20	25	30
A	(29.0)	(29.8)	(30.0)	(34.2)	(33.5)	(32.5)	(31.0)
	29.0	29.5	30.3	35.5	33.5	32.0	29.8
B	(29.0)	(30.0)	(31.0)	(34.2)	(33.0)	(32.0)	(31.0)
	29.0	30.5	30.7	34.0	33.0	32.8	30.2
C	(29.0)	(30.0)	(31.0)	(34.0)	(33.0)	(32.0)	(32.0)
	29.0	30.5	30.8	34.0	33.0	32.8	30.5
D	(29.0)	(29.8)	(31.0)	(34.5)	(33.0)	(32.5)	(32.5)
	29.0	30.5	31.0.	34.5	33.0	32.7	30.0
E	(29.0)	(29.8)	(31.0)	(34.5)	(33.0)	(32.0)	(31.5)
	29.0	30.5	31.0	34.0	32.0	32.5	31.0
F	(29.0)	(29.8)	(30.0)	(34.5)	(33.0)	(32.0)	(32.5)
	29.0	30.5	31.5	34.0	32.5	32.5	30.5
G	(29.0)	(29.8)	(31.0)	(34.0)	(33.0)	(32.5)	(32.0)
	29.0	30.5	31.5	34.5	33.0	32.3	30.5

Numbers bracketed = Temperature change of fresh feed stock in the digester
Numbers un-bracketed = Temperature change of dry feed stock in the digester

Cultural, Morphological and Biochemical Characteristics of Micro Flora Before and After Digestion of the Waste Samples

Table 4 shows that bacteria isolated before, during and after digestion of the substrates were mostly gram positive rod of which the first five (Methanobrevibactor sp, Acetobacter sp, and Methylemonas sp) out of the fourteen isolates were anaerobes while the other nine isolates (Bacillus sp, Micrococcus sp, Pseudomonas sp, Ruminococcus sp, Cellumonas sp, Clostridium sp, Lactobacillus sp, Staphylococcus sp and Streptococcus sp) were aerobes. Weekly total viable count of both bacteria and fungal during digestion reduced with increase in retention time.

Table 4: Cultural, Morphological and Chemical Characteristics of Microflora Isolated from Waste Samples.

BACTERIA

`Colony Morphology	Cell Morphology	Spore Formtn	Gram Rxn	Coagulas	Oxid	Cit	M.R	V.P	Idole	NO_3	H_2S	Urease	Dext	Glu	Malt	Lac	Suc	Nanmito	Preba ble Organism
Creamy, flat, Dry colonies	Rods	+	+	-	-	+	-	-	-	+	+	+	A	A	A	A	A	A	Bacillus polymyra
Gray, Spreading Colony	Rods	-	-	-	-	-	-	-	-	-	-	-	Ag	Ag	A	Ag	A	A	Acetobacter aceti
Dry, Creamy Colonies	Rods	+	-	-	-	-	-	-	-	-	-	-	A	-	A	-	-	A	Methylomonas Methenica
Creamy Round Colonies	Rods	+	-	-	+	-	-	-	-	-	-	+	-	A	A	A	-	-	Methenoserc ina hungati
Yellowish Colonies	Rods	+	-	-	-	-	-	-	-	-	-	-	-	A	A	Ag	-	A	Methenoserc ina barker i
Bluish Round Flat Colonies	Rods	+	-	-	-	-	-	-	-	+	-	-	-	A	A	A	-	Ag	Methanobre vibacter ruminatum

FUNGAL

`Colony Morphology	Types of Stoma	Special vegetative Structure	Special Reproductive Structure	Prebable Organism
Creamy Developing Lacey Appearance	Large Mycelial Element	Giant Cells	Blastospores Single forming along pseudonym celium	Candida
White, Grayish Brown Colony	Filamentous	Stolons Rhizoids	Tall sporangia spores in groups, brown-black sporangia	Rhizopus stolonifer
Light Colour, Moist, Shiny, Yeast-Like Turns Greenish	Septate Hyphae	Septate Dark Crooked and Lateral Oval Spores	Spores found at the tip of conido spores	Cladosporium
Half-Moon Shape Colony, White at the Colony Center with Pink at the Periphery	Septate Hyphae	Condidiophove Long and Septate	Large stickle canoe shape multi-septate macroconido	Fusarium sp.
White Fluffy Turns Gray	Non-Septate	No Rhizoids	Bearing sporangium	Mucor sp
Smooth Colonies, Moist, White to Cream Colour	Multi-Budding are seen	Ascospores are formed	Ascospores are formed	Saccharomyces

Key: Ag = Acid and Gas
A = Acid - = Negative + = Positive

Physicochemical Composition of the Feedstock

Table 5 shows the various quantities of chemical substances of the waste samples. These have proven to be the driving forces that determine the performances of waste samples for biogas yield. The higher the adequate quantity of the chemical substances in a waste sample suggests a higher yield in biogas.

Co-digestion of fresh cassava peels and swine dung possesses virtually more percentage quantity of most of all the chemical substances enlisted in table 7 than any other waste, and hence achieved the highest biogas yield in the conducted studies.

Table 5: Physicochemical Analysis of Undigested Fresh and Dry Wastes used as feedstock

	UNDIGESTED FRESH WASTER DRY WASTE							UNDIGESTED					
Parameters	**CP**	**CD**	**PD**	**SD**	**CP + CD**	**CP + PD**	**CP + SD**	**CP**	**CD**	**PD**	**SD**	**CP + CD**	**CP + PD**	**CP + SD**
% Moisture	15.4153	23.60	18.24	39.70	24.41	18.91	15.32	14.25	22.60	16.20	38.50	21.40	16.70	13.30
% Organic Carbon	31.70	53.90	8.94	52.91	64.10	9.20	69.80	35.80	51.40	32.20	49.40	60.10	57.70	65.66
%Total solids	48.74	77.4	13.90	55.90	71.90	71.90	70.10	65.31	77.10	13.84	55.81	69.70	68.70	69.50
Total Nitrogen	1.80	2.24	3.56	2.91	3.32	5.72	3.82	1.67	2.06	2.36	2.14	3.01	4.85	3.24
C/N Ratio	38.70	24.10	15.11	22.50	26.70	21.70	28.69	36.20	35.60	12.80	21.69	23.47	20.67	27.11
% K potassium	1.1	0.48	1.42	0.88	2.14	22.4	2.91	0.70	0.58	0.89	0.93	1.89	1.91	1.95
%P	1.6	0.56	2.06	0.96	1.57	1.73	1.67	0.80	0.69	1.12	1.02	1.48	1.58	1.43
% NO3	0.16	5.40	0.83	7.02	5.92	2.33	8.22	0.12	5.94	0.56	7.56	6.91	2.41	8.37
Zn (mgkg)	125	1.2	486	1376	141	1202	1482	113	96	362	1094	131	1121	13.11
Cu (mg/kg)	15	18.7	82	426	19.0	71	311	12	12.90	52	286	17.11	68.0	289
Mn (mg/kg)	180	147.6	638	376	130.7	189.11	266	172	133.5	442	215	127.11	168.88	240
%Na	0.15	0.84	0.63	0.21	0.43	0.88	0.77	0.13	0.23	0.30	0.13	0.20	0.34	0.70
Ph (mg/kg)	16.7	21.90	25.4	4.7	23.33	27.61	4.9	14.80	19.97	22.19	3.0	21.77	23.51	3.20

%ash	52.6	9.25	28.74	8.74	10.10	29.10	9.77	48.70	8.87	26.61	7.62	8.12	35.51	7.70
Ph	4.6	5.5	5.6	7.5	6.5	6.8	6.2	5.4	7.0	7.6	8.1	7.6	8.1	8.1
% Volatile solid	33.33	35.33	7.02	17.02	30.70	40.53	41.52	30.11	31.24	6.9	15.720.08	28.72	34.90	38.88
% Fat content	0.78	0.75	0.35	0.1	0.75	0.05	0.15	0.161	0.46	0.71		0.11	0.31	0.54

Key:

CP - Cassava Peel
CD - Cow Dung
PD - Poultry Dropping
SD - Swine Dung

Percentage Composition of Biogas

Table 6 shows that low value (10%) methane was achieved in the first week in the digesters. In the same first week also significant quantities of carbon(iv)oxide and other noncombustible gases were produced in the biodigester. While on the fourth week 53% methane was realized. The result confirmed that biogas is a mixture of different gases, methane, hydrogen, carbon(iv)oxide, hydrogen sulphide and ammonia.

Table 6: Analysis of Biogas production from Blend of Flesh Cassava Peels and Flesh Swine Dung.

	Percentage Composition of Biogas			
Gas Properties	**1st Week**	**2nd Week**	**3rd Week**	**4th Week**
Methane	10	23	41	53
Carbon(iv) Oxide	65	52	43	32
Hydrogen Sulphide	3.1	2.7	1.83	1.62
Ammonia	2.7	2.0	1.4	1.1
Water Vapour	1.6	1.5	1.4	1.3
Hydrogen	1.1	1.0	0.9	0.8
Gas Content (Cm^3/g)	83.5	82.2	89.51	89.82

Discussion

The advantages that accrued from the technology of simultaneous digestion of more than one type of waste in a unit digester are numerous. These observed advantages agreed with the discoveries of earlier researchers, and they include better digestibility, enhanced biogas

production as well as more efficient utilization of equipment and cost sharing. Studies also have shown that co-digestion of several substrates, for example, human and plantain peels, spent grains and rice husk, pig dung and cassava peels, and amongst others, have resulted in improved methane yield by as much as 60% compared to that obtained from single substrate, Ilori, et al, 2007.

The results obtained in this study also revealed that generally highest biogas production in the digesters was achieved at the range of retention time of 6-25 days (table 1). These days also corresponded to the periods of temperature climacteric. These results were in agreement with the results produced by earlier researchers who had successfully shown that higher biogas production had a positive correlation to higher temperature low retention time (Berker, 2001).

The microflora obtained before digestion period were of a high percentage than after digestion (table 4). This result agreed in part with earlier findings of Uzodimma et al, (2008) and Ilori et al (2007) who observed a reduction in microbial population before and after digestion from 11.6 x 10^5 cfu/ml to 2.1 x 10^5cfu/ml. The reasons for this differences in microbial population was attributed to pH, volatile solid and temperature. This was confirmed by results obtained by Anon (1989).

In this study, digestion of fresh cassava peels with flesh Swine dung had the highest cumulative gas volume from the profile of changes in the two weeks of digestion, in view of the fact that blending of the cassava peels with these animal wastes stabilized the waste for biogas production. This could be as a result of its high fibre and carbon contents. Swine in this part of the country are fed with spent grains occasionally, which may contain a lot of fibre. The C/N ratio and total solid (TS) level of swine dung is in consonance with the optimum requirement for biogas production as shown on Table 5, at temperature 29 – 35^{o}C (Table 3) with highest biogas production, while pH was within 4-7 throughout the duration (Table 2). The result shows that methane gas, carbon (iv) oxide, hydrogen, nitrogen, hydrogen sulphide and ammonia make up biogas produced in this study (Table 6).

Conclusion

As public recognition of the consequences of environmental pollution has increased, so has the enactment of restrictive antipollution laws. Such laws have led to renewed studies on waste treatment, disposal, recycling and reuse of waste.

Hence, cassava peels which are considered as a poor biogas producer and nuisance can be converted to a useful source of energy by combining it with any other animal wastes as observed in this investigation. It should be noted however that development of biogas does not eliminate wastes but it does make them easier to manage.

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