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Biogas Production from Farm Waste (Cassava Peels and Swine Dung): Co-Digestion and Prospect on Economic Growth

Mayen G Ben[1] and Emmanuel I Michael[2*]

[1]Department of Science Laboratory Technology, Akwa Ibom State Polytechnic, Ikot Osura, Nigeria

[2]Department of Applied Microbiology and Brewing, Nnamdi Azikiwe University, Nigeria

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***For Correspondence**

Michael EI, Department of Applied Microbiology and Brewing, Nnamdi Azikiwe University, Nigeria,
Tel: +2348064665949.

E-mail: emmanuelmichael001@yahoo.com

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ABSTRACT

Biogas production from organic materials is a trending and prospective renewable energy production approach for electricity generation and can thereby ameliorate the greenhouse gas emissions. This scientific investigation was carried out on biogas production, a natural gas, obtained from equal weight of fresh and dry substrates (Cassava peels/Swine dung) using 2.8 liter batch type anaerobic digesters. The prototype metallic bio-digesters were fed with wastes for the retention period of 30 days within a mesophilic temperature range. The biogas yield was significantly ($p \leq 0.05$; t-test) influenced by the type of waste used. The cumulative average yield from fresh samples was 8.3, 30.8, 23.6, 29.8, 49.3, 32.8 and 52.7 cm^3/g while the dry sample was 15.7, 23.0, 24.7, 19.3, 29.7, 40.3 and 35.8 cm^3/g over the digestion periods. However, the highest volume of gas generated 52.7 cm^3/g. The physico-chemical nature of respective feedstock in the digesters revealed an initial drop in pH from acidic range to a steady increase of 4.2-8.2 at end of digestion. The temperature remained relatively constant throughout digestion period ranging from 29°C – 32°C . Microorganisms isolated were mainly anaerobes and methanogens such as *Clostridium sp. Methanococcus sp.* and *Methanobacterium sp*. The rising cost of fossil oil, potentially diminishing with petroleum and allied products as well as desert encroachment have provided the need to consider alternative source of energy and revenue to boost our economy. Results obtained from this scientific research suggest that Nigeria can generate wealth from wastes through biogas production and other by-products

INTRODUCTION

The increasing emission of greenhouse gases in the last few decades has been a major concern universally. Considering the rapid world population growth and increase in consumption energy, higher standard of living, there is an obvious need in reducing the emissions of greenhouse gases which is an adverse pollutant with deleterious effect on humanity. Biogas is a composition of colourless, odourless and flammable gases derived from organic waste materials during anaerobic digestion. The overall composition of biogas is typically 50 – 70% methane, 30 – 40% carbon (IV) oxide as well as traces of nitrogen, hydrogen and hydrogen sulphide [1]. Biogas is mostly known as sewage gas or marsh gas. The basic microorganisms involved in the process of biogas production are categorized into four group. Decomposition of waste involves three anaerobic stages (hydrolysis, acidification and methanogenesis) of biochemical processes with release of biogas. The organic substances are biodegraded externally by specific cellular enzymes in the initial phase. The intermediate is converted to low molecular weight compounds by acid producing bacteria in an anaerobic condition which facilitate methane production by specific microorganisms. Firstly, reconstruction of substances with high molecular weight (carbohydrate, protein, celluloses, fats) and breaking them down through enzymatic activities into low-molecular compounds such as monosaccharide, fatty acids, amino acids and water. Hydrolytic bacteria produces enzymes that decomposes substrates to small molecules of water soluble molecules as well as polymers to be converted into monomers. During hydrolytic reaction, partial anaerobiosis occur due to oxygen consumptions and thereby enhancing a suitable anaerobic environment for the production of methane by methane producing bacteria. The second phase is the production of acids (formic, propionic, acetic, butyric, lactic and caproic acids) ketone, alcohol (propanol, glycerin, methanol and acetone), carbon (IV) oxide, carbon, hydrogen sulphide and ammonia. This stage is also known as acidogenesis. Specific bacteria produce methane and are involved in the third stage where decomposed compounds have low molecular weight to produce CH_4 and CO_2 [2]. The produced gases can be ascertained by anaerobic microbes counting and/or the volume of CH_4 [3].

Previous scientific investigation been carried out revealed basic metabolism in different anaerobic digestion processes, but limited essential microorganisms are responsible for these processes, bacteria and archaea have been isolated so far as well as the dynamics and interactions between these microorganisms [4-6]. Diverse chemical reactions and interactions occur microorganisms such as methanogens, non-methanogens as well as other substrates fed into the digester during experimental setup [7]. Several macro- and micronutrients are necessary for growth, proliferation and survival of specific microorganisms. Macronutrients such as phosphor, carbon and sulfur are very effective. The demand for excess nutrients is very low due to less developed biomass, with sufficient nutrient ratio of C: N: P:S=600:15:5:1. The growth rate of microorganisms are dependent on trace elements like iron, nickel, cobalt, selenium, molybdenum, and tungsten. Acetic acid, carbon (IV) oxide and hydrogen are initial products for methane formation by acid-forming bacteria [8,9]. This phase is known as acetogenesis. Methane, carbon (IV) oxide and water formation is known as methanogenesis and the last phase. Scientifically, ninety percent of methane, 70% form acetic acid. The acetic acid formation (Third step) is the factor that facilitate methane formation. Waste generated from industries and cities contributes to the present environmental pollution. The ongoing processing of cassava results in the production of peels, chaff, fibre and spoilt as well as unwanted tubers. However, larger remnant of the cassava proportion are indiscriminately disposed into the environment as solid waste [10]. Recycling of waste has several economic benefits such as: gas generation, ecological cleaning, production of bio-fertilizer, electricity/heat generation and as vehicle fuel [11]. Due to the current economic situation and circumstances of high constant diesel fuel price, the usage of methane serves as an attractive/alternative cost of conventional energy source. In this research work, biogas production using farm waste (Cassava peels and Swine dung) served as a substitute to generate fossil fuel through co-digestion of these wastes.

MATERIALS AND METHODS

Collection Waste and Materials

The cassava peels used for this study was collected from the local garri processor, while the swine dung was obtained from Ene farm, Akadi farm in Itak, Uyo, Akwa Ibom State. The cassava peels were dried and fresh swine dung. Bulk samples were in quantities using a sterile plastic container with lid. The containers were labelled separately and samples were transported to Microbiology and Central Research Laboratory for analysis.

Microbiological Analysis

Preparation of waste

In this study, two samples were used namely: Cassava peels (CP) and Swine dung (SD).

Microbial analysis

Isolation and enumeration of microorganisms in cassava peel and swine dung were obtained using a ten-fold serial dilution method. Total viable counts (TVC) for the pure, waste blend slurries and microbial load of the samples were obtained the using the modified Miles and Misra (1938) method described in Okore [12]. Purification and maintenance of pure microbial cultures were carried out by repeated sub-culturing on freshly prepared nutrient agar **(Table 1)**. Pure cultures were stored in McCartney bottles and maintained in the refrigerator (5 °C - 7 °C).

Table 1. Design and composition of fresh agricultural waste substrate for biogas production.

Digester(s)	Cassava Peels (CP)	Swine dung (SD)	Volume of water(ml)	Total weight (g)
A	800	-	800	1600
B	-	-	800	1600
C	-	-	800	1600
D	-	800	800	1600
E	400	-	800	1600
F	400	-	800	1600
G	400	400	800	1600

Table 2. Design and composition of agricultural waste substrate for biogas production.

Digester(s)	Cassava peel (CP)	Swine Dung (SD)	Volume Of Water (ml)	Total (Weight)
A	400	-	800	1200
B[a]	-	-	800	1200
C[b]	-	-	800	1200
D[c]	-	400	800	1200
E[d]	200	-	800	1200
F[e]	200	-	800	1200
G[f]	200	200	800	1200

g

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Biogas Production from Dry Media Materials

Digester design

Design and composition of Agricultural waste for biogas production was employed using digesters (2.8 litres of reagent bottles) and were made airtight using rubber corks overlaid with plasthecene case **(Table 2)**. Two holes were bored on the rubber cork. One hole for the thermometer, the other a tube fitted through the hole was passed into a fabricated 500 cm^3 graduated cylinder with an outlet carrying a stopper (regulator) to which a tyre tube was connected. This served as a gas storage device. The cylinder was inverted over an acidified water in a plastic bowl. The cylinder was used as a measuring scale and a gas collector. The acidified water was prepared by adding 0.06 ml sulphuric acid (H_2SO_4) with 11.2 g of sodium chloride (NaCl). This was used to prevent dissolution of the gas released into water. The digesters were corked to generate anaerobic condition. Biogas production was recorded at interval of six (6) days for period of 30 days. Evaluation of biogas production during the period was recorded on volume basis by water displacement [13,14].

RESULTS AND DISCUSSION

Biogas Bags (Confirmatory Procedure)

Digesters were used for the confirmatory biogas procedure. In this method deflated poly vinyl chloride balloons were fitted over the openings of the digesters. Daily production of biogas was indicated by a gradual inflation of the balloons.

Parameters of Biogas Production

The following parameters were analyzed: pH, temperature, organic carbon, moisture content, total solid, total nitrogen and ash content **(Tables 3-5)**.

Qualitative Analysis

The biogas produced was analyzed for its composition using hand-held GFM416 Gas analyzer as earlier reported by Ofoefule et al. [15]. Each gas was subjected to laboratory chemical test to indicate and confirm their presence.

Cultural and Morphological Characteristics of Bacteria and Fungi Isolates from the Waste Samples

Microorganisms isolated were mainly anaerobes and methanogens such as *Clostridium sp. Methanococcus sp*. and *Methanobacterium sp.* They have high biogas production ability with significant potentials to biodegrade these waste for biogas production. A total of fourteen morphologically and physiologically different bacterial species were isolated in this work. The organisms were mostly Gram positive rods **(Table 6)**. Five of the isolates were anaerobes. A total of nine fungal species belonging to four genera were isolated from the digesters during the fermentation period. Aerobes and anaerobes isolated before, during and after digestion are *Pseudomonas, sp*, *Bacillus sp, Micrococcus sp, Proteus sp, Staphyloccocus sp, Lactobacillus sp, Streptococcus sp, Clostridium sp, Methylomonas sp, Ruminococcus sp, Methylomonas sp, Ruminococus sp, Acetobacter sp, Methanosarcina sp, Methanococcus sp,* and *Methanobrevibacter sp.* Fungi isolated before, during and after digestion were *Candida sp, Rhizopus sp, Cladosporium sp, Fusarium sp, Mucor sp, Penicillium sp, Saccharomyces sp* and *Actinomyces sp*.

Biogas Production

The daily production and accumulation over a thirty-day digestion period with cumulative yield measured in cubic centimeter per day (cm^3/day). The mean volume of gas production from different digesters containing fresh/dry swine dung, cassava peels and mixture of both. It was observed that the combination of both waste commenced biogas production within 24 hours in the digester while gas production in digester containing fresh cassava peels alone started production on the 6th day **(Figure 1)**. This was probably due to the reduction in acidic content of the peels arising from the non- pretreatment of peels before charging into digester. The following results of biogas production were obtained from different digesters: were 8.3 ± 2.9, 30.8 ± 5.0, 23.6 ± 3.0, 20.8 ± 7.9, 49.3 ± 5.8, and 52.7 ± 7.9 cm^3/day (fresh) and 15.7 ± 2.9, 23.0 ± 3.9, 24.7 ± 3.5, 19.3 ± 3.5, 29.7 ± 5.9, 40.3 ± 5.0 and 35.0 ± 4.2 cm^3/day (dry media). The data of cumulative biogas yield from digesters containing fresh cassava peels and swine dung revealed that dry cassava peels produced more biogas (15.7 ± 2.9 cm^3/day) than the fresh cassava peels (8.3 ± 2.9 cm^3/day) with (23.6 ± 3.9 cm^3/day) for fresh/dry (19.0 ± 3.5 cm^3/day) swine dung **(Figure 2)**. Data obtained from co-digestion of fresh and dry cassava peels with swine dung were (5.2 ± 7.9 cm^3/day) and (35.8 ± 4.3 cm^3/day) respectively **(Table 7)**.

It was observed that dry cassava peels alone in digester had a high value of gas production and reduction in hydrocyanic acid that might have accounted for the delayed onset of gas production and reduced volume of gas yield in fresh media. The result revealed that the dry media of swine dung had low yield of gas production **(Table 8)**.

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Table 3. Biogas generated from fresh media materials (cm^3/day).

Digester/Period (days)	A Cassava Peels (CP)	B Swine Dung (SD)	C Cassava Peels + Swine Dung(CP+SD)
1-5	0	39	65
6-10	8	45	72
11-15	10	40	69
16-20	13	39	51
21-25	10	12	33
26-30	9	9	26
Cumulative gas yield (cm^3/day)	50	184	316
Mean volume of gas production (cm^3/day)	8.3	29.8	52.7

Table 4. Biogas production generated from dry media material (cm^3/day).

Digester/Period (days)	Aa Dry Cassava Peels (CP)	Bb Dry Swine Dung (SD)	Cc Dry Cassava Peels + Swine Dung(CP+SD)
1-5	11	25	42
6-10	21	35	50
11-15	21	20	41
16-20	24	16	33
21-25	11	13	26
26-30	6	9	23
Cumulative gas yield (cm^3/day)	94	116	215
Mean volume of gas production (cm^3/day)	15.7	19.3	35.8

Table 5. Biogas yield from gas bags (fresh sample).

Measurement /waste types	Retention time (day)	Cassava Peels (CP)	Swine Dung (SD)	Cassava peels + swine dung (CP+SD)
Total weight of bag (Wg)	1	1.9	6.0	13.6
Weight of bag (Xg)	2	0.6	0.6	0.6
Volume of gas produced (Vg = W-X)cm^3/g	3	1.3	5.4	13.0

Table 6. Biogas yield from gas bags (dry sample).

Measurement /waste types	Retention time (day)	Cassava Peels (CP)	Swine Dung (SD)	Cassava peels + swine dung (CP+SD)
Total weight of bag (Wg)	1	2.6	8.6	10.8
Weight of bag (Xg)	2	0.6	0.6	0.6
Volume of gas produced (Vg = W-X)cm^3/g	3	2.0	8.0	10.2

Table 7. Analysis of biogas production from blend of cassava peels and swine dung.

Gas properties	Percentage composition of biogas			
	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	1.81	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
Molecular weight IBM/mole	28.10	27.2	26.2	26.18
Specific gravity = 1	0.904	0.904	0.904	0.904
Density at STP, IBM/ft^3	0.073	0.073	0.073	0.073
Heat value BTU/ft^3	6,894	6,941	7,665	8,937
Energy content STP, BTU/ft^3	447	473	581	652
Gas content ft^3-IBM-Or	46.6	47.1	48.8	59.0

Table 8. Laboratory analysis for composition of biogas.

GASES	TEST	INFERENCE
Methane (CH_4)	Unknown gas from digester + calcium oxide and concentrated hydrogen tetraoxosulphate (vi) acid as drying agent. Unknown gas is collected in glass storage device with tap to control the gas. The tap is turned on a lighted splinter is used	Great blue flame confirms the presence of methane
Hydrogen (H_2)	Unknown gas from digester + lighted splinter	It burns with a pop sound confirms the presence of H_2
Carbon(iv)oxide (CO_2)	Unknown gas from digester + calcium hydroxide (lime water)	Solution turns milky confirms the presence of Co_2
Hydrogen sulphide (H_2S)	Unknown gas from digester + potassium permanganate (iii), in a test tube	Deep purple turns pale pink, confirms the presence of H_2s
Ammonia (NH_3)	Unknown gas from digester + conc. Hydrochloric acid	Thick white fume formation confirms the presence of NH_3

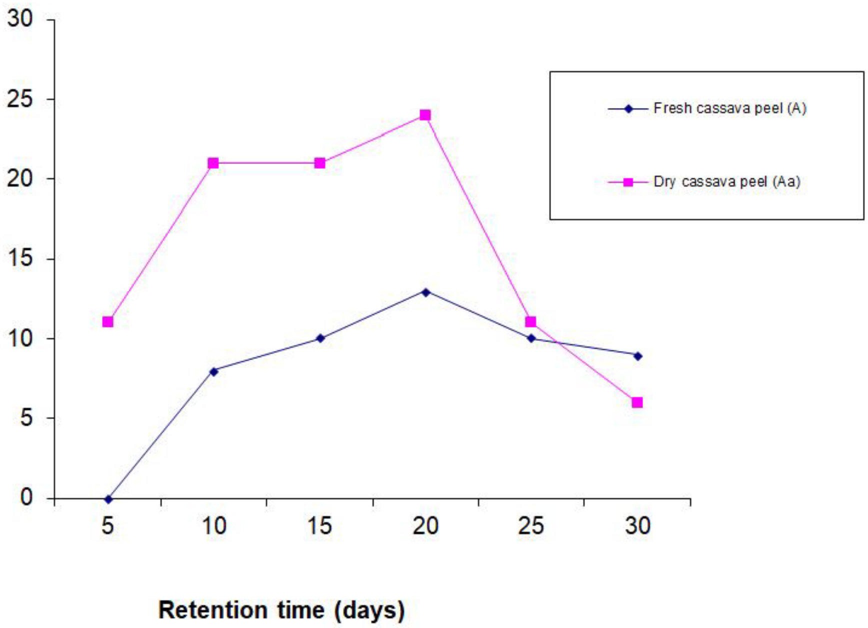

Figure 1. Retention time for biogas production using cassava peels.

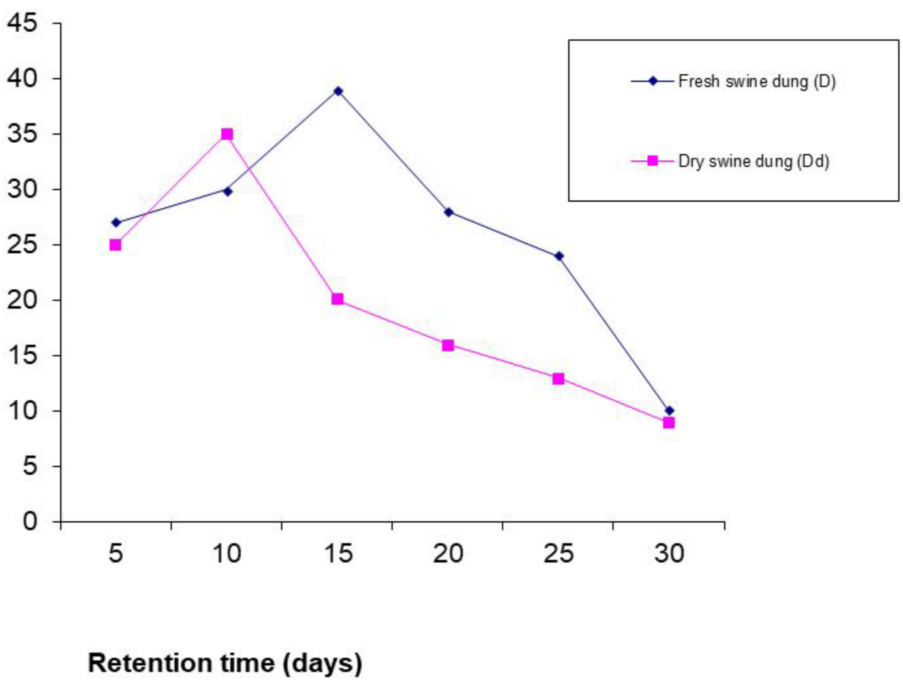

Figure 2. Retention time for biogas production using swine dung.

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CONCLUSION

The present study concluded that indigenous microorganisms available in farm waste (Cassava peels and Swine dung) possess naturally existing machinery to produce biogas, which is a cost effective when compared to the conventional method of alternative energy production. Developing countries in Africa such as Nigeria where electricity and heat are sparse and biological waste is profuse, utilization of anaerobic digestion process could be the light at the end of the tunnel.

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