BIOGAS OPTIMIZATION POTENTIALS OF COW DUNG, PIG DUNG AND POULTRY DROPPINGS WITH SUGAR CANE BAGASSE AND WATER MELON PEEL

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Abstract: The potentials of optimizing biogas production using cow dung, pig dung and poultry droppings with sugar cane bagasse and water melon peel were studied. Proximate analyses as well as total solids, volatile solids, carbon content, and nitrogen content were determined on the wastes while microbial level, pH and temperature were determined on the slurry. The wastes were subjected to anaerobic digestion for 40 days at mesophilic temperature range of 20.5 to 48.5^{o}C. Relative humidity, ambient temperature, pH, slurry temperature, and volume of gas were monitored and recorded on daily basis. The composition of gas generated from the mixture was 58.1-64.8% CH_4, 31.0-37.7% CO_2, and 0.8-1.4% H_2S and 1.2-1.6% CO. The physico-chemical analysis of the feedstock in the digester revealed an initial pH of 5.43 which later went to 8.40 and later dropped to 5.25. Cumulative biogas yield of the blend with sugar cane bagasse, water melon peel and poultry droppings was higher than those of the blend with pig dung, sugar cane bagasse and water melon peel as well as the one with cow dung, sugar cane bagasse and water melon peel. However, the blending of bagasse and water melon peel with cow dung did not improve or optimize the biogas yield; instead, a steady state was established. This may be due to mutual inhibitions. Onset of gas flammability was observed on the 4th day for poultry droppings and its blends while for cow dung, pig dung and their blends it was observed on the 5th day. From the gas production analysis, the total volume of biogas was maximum in digester IV (138.2L) compared to digester II (16.6L), III (33.7L) and digester I (110.8L).
Keywords: Biogas, blends, gas analyses, optimization, retention time

Introduction

There is an urgent need for alternative energy sources as a result of the dwindling energy resources which has become a global concern. This has made it imperative to search for new sources of domestic energy. The quest for wood as a source of domestic energy has led to deforestation and erosion in the southern parts and near desertification in the northern parts of the country (Ilochi and Nwachukwu, 1989). Raw materials for biogas production cover a wide range of feedstock including animal wastes, household wastes, crop residues, sewage sludge, food waste, and wastewater (Suneerat *et al.*, 2009). Manure component (carbohydrates, proteins, and lipids) carbon is ultimately transformed into methane (CH_4) and CO_2 (carbon dioxide) (Masse *et al*, 2011).

In Nigeria, identified feedstock substrate for an economically feasible biogas production includes water lettuce, water hyacinth, dung, cassava leaves and processing waste, urban refuse, solid (including industrial) waste, agricultural residues and sewage (Akinbami *et al.*, 1996; Okagbue, 1988; Ubalua, 2008). It has been estimated that Nigeria produces about 227,500 tons of fresh animal waste daily. Since 1kg of fresh animal waste produces about 0.03 m^3 biogas, then Nigeria can potentially produce about 6.8 million m^3 of biogas every day from animal waste only. In addition, 20 kg of municipal solid waste (MSW) per capita has been estimated to be generated in the country annually (Mathew, 1982).

Some significant researches have been done on reactor design by some Nigerian scientists that would lead to process optimization in the development of anaerobic digesters. Plastic bio-digester had been designed and constructed and was used to produce biogas with spent grains and rice husk mixed together (Ezekoye and Okeke, 2006). Seeding of co-digested pig waste and cassava with wood ash was reported to result into significant increase in biogas production compared with unseeded mixture of pig waste and cassava peels (Adeyanju, 2008). These laboratory studies demonstrated the potential of biogas production from agricultural waste, industrial and urban waste and animal waste in Nigeria.

Biogas can be defined as a colorless, flammable gas produced via anaerobic digestion of animal, plant, human, industrial and municipal wastes amongst others, to give mainly methane (50-70%), carbon dioxide (20-40%) and traces of other gases such as nitrogen, hydrogen, ammonia, hydrogen sulphide, water vapour.

Co-digestion has been defined as the anaerobic treatment of a mixture at least two different substrates with the aim of improving the efficiency of the anaerobic digestion process (Neczaj *et al.*, 2012). The composition of biogas largely depends on the type of substrate used for its formation. Biogas is about 20 percent lighter than air. It burns without smoke and is non-toxic. It is also an odorless and colorless gas that burns with clear blue flame similar to liquefied petroleum gas (LPG) (Karki *et al.*, 2005). Methane produces more heat than kerosene, wood, charcoal and cow-dung chips. The ever increasing demand for energy, and the need to keep our environment clean as well as the reduction of green house gas effect, necessitated this work. The main objective of this work is to optimize biogas production by co-digestion of sugar cane bagasse and water melon peels respectively using cow dung, pig dung and poultry droppings. Anaerobic digestion of bagasse is a technology that has been shown to effectively address many of the problems associated with sugarcane bagasse waste and management such as waste accumulation which is not environmentally desirable as bagasse takes too long to break down and air pollution which originates from uncontrolled burning of bagasse.

The chemistry of digestion process in the production of biogas involves hydrolysis, acidogenesis, acetogenesis and methanogenesis. The factors affecting the biogas production are mainly caused by the characteristics of the feedstock and operating condition of the process. The parameters that can often determine the performance of the digester include pH, temperature, solids retention time (SRT), volatile fatty acids (VFA) and organic loading rates (Choorit and Wisarnwan, 2007).

Materials and Method

Procurement of materials

The bagasse used for this study was collected from bagasse dump site around Ose market at Onitsha, Anambra State, while cow dung, pig dung and poultry droppings were collected from Nsukka market in Enugu State, Nigeria. Water melon waste was collected from its dump at Ikpa market in Nsukka Local Government Area of Enugu State.

Equipment used for this study include metal prototype digesters of 50L capacity Ohaus Weighing balance MB 25, made in U.S.A; Vecstar Furnace, made in England; Memmert Oven, made in England, Water trough, graduated transparent plastic bucket, Thermometer, Thermo-Hygrometer. Jenway pH meter, hose pipe and Biogas burner.

Date collection and analysis

Proximate analysis was among the most important analysis carried out on the raw wastes. Proximate analysis involved the determination of the major components of the wastes under study and they include moisture, fat, ash (mineral), protein, carbohydrate, and fibre. Other analyses include: volatile solids, total solids, relative humidity, and carbon content. Microbial analysis was carried out on the slurry.

AOAC (1990) method was used for moisture determination, ash and crude fibre. Crude fat and protein content were done according to Pearson (1976) method. The carbon determination was carried out by the wet oxidation method of Walkley and Black (1934).The volatile solid is the true organic matter available for bacterial action during digestion. Meynell's (1982)method was used for both total and volatile solids determination. The daily ambient temperature and relative humidity were recorded using a thermo-hygrometer. The slurry temperatures were recorded using liquid in glass thermometer (-10 to 110^{0}C).The pH was recorded using Jenway pH meter (Model 3510; made in EU).

Soaking and ash treatment

Soaking was done using 30L buckets. 2kg of sugar cane bagasse was weighed using Ohaus weighing balance and then poured into the 30L bucket containing 15L of water. Four buckets labeled I, II, III, and IV were used for this operation. The sugar cane bagasse in the buckets labeled I, II, III and IV was soaked for 7 days in order to soften the fibrous material of sugar cane bagasse for easy decomposition by microorganisms.

Weighing and charging of wastes

50 kg of a metal prototype digester labeled I was charged with 4.69kg of sugar cane bagasse, 4.69 kg water melon peels, and 28.12 L of water in the ratio of 1:3 (waste to water) and its pH at the point of charging was 5.83. 50 kg of a metal prototype digester labeled II was charged with 3.28 kg of sugar cane bagasse, 3.28 kg water melon peels, 2.82 kg cow dung and 28.12 L of water in the ratio of 1:3 (waste to water) and its pH at the point of charging was 5.74. 50 kg of a metal prototype digester labeled III was charged with 3.28 kg of sugar cane bagasse, 3.28 kg water melon peels, 2.82 kg pig dung and 28.12 L of water in the ratio of 1:3 (waste to water) and its pH at the point of charging was 5.43. 50 kg of a metal prototype digester labeled IV was charged with 3.28 kg of sugar cane bagasse, 3.28 kg water melon peels, 2.82 kg poultry droppings and 28.12 L of water in the ratio of 1:3 (waste to water) and its pH at the point of charging was 5.15. This quantity (waste and water) constitutes 75% of the whole digester while the 25% space left was for the biogas.

Biogas volume measurement and flammability

Gas production measured in liter/total mass of slurry was obtained by the downward displacement of water by the gas using a trough and a calibrated transparent bucket (Itodo *et al.*, 1995). The volumes were recorded after each measurement. Gas flammability was monitored with the aid of a biogas burner.

Results and Discussion

Nutritional and physical properties of the waste are shown in Tables1 and 2.Digester I consists of sugar cane bagasse, water melon peel and water while Digester II consists of sugar cane bagasse, water melon peel, cow dung waste and water. Digester III consists of sugar cane bagasse, water melon peel, pig dung waste and water while Digester IV consists of sugar cane bagasse, water melon peel waste, poultry droppings and water. The pH of the slurry in all the digesters ranged from 5.15 - 5.83 on day one but as fermentation progressed, the pH value of the slurry rose to 6.05 which was acidic and to 8.40 which was alkaline. The reason for the low pH at the initial period of digestion of waste may be attributed to the fact that initially, the acidogens were breaking down the organic matter and producing volatile fatty acids. As a result, the acidity of the medium increased and the pH fell below neural. Later, the acid formers were most probably displaced by the methane forming bacteria. This accounted for the breakdown of acids by the methane-forming bacteria to methane and the gradual rise of pH values from 6.53 – 8.40.

The anaerobic fermentation study was investigated within the daily ambient temperature range of 24.2 to 38.9°C and slurry temperature range of 20.5 to 48.5°C for both the control and the variants. This study showed that biogas production started on the 5th day and reached its apex on the 19th day for digester I while in digester II its peak was on 17th day. For Digester III, it started on the 5th day and attained maximum on the 16th day while in digester IV gas production started on the 4th day and reached its peak on the 15th day.

Table 1: Nutritional composition of waste samples in each digester.

Blends (Digester)	Protein (%)	Fat content (%)	Ash content (%)	Fibre content (%)	Moisture content (%)
I (WMP + SCB)	7.78	2.1	10.55	28.98	26.92
II (WMP +SCB+CD)	7.16	1.55	8.38	22.39	42.31
III (WMP+SCB+PD)	6.54	1.55	13.19	20.11	23.08
IV(WMP+SCB+POD)	10.13	1.50	14.66	26.22	26.92

Table 2: Physical Properties of Waste samples in each digester

Blends (Digester)	Total Solid (%)	Volatile Solid (%)	Carbon content (%)	Nitrogen content (%)	Carbon:Nitrogen (C:N ratio)
I (WMP + SCB)	71.64	56.02	27.13	1.245	27:1
II (WMP +SCB+CD)	57.86	44.01	24.64	1.145	24:1
III (WMP+SCB+PD)	74.98	50.00	24.89	1.047	24:1
IV (WMP+SCB+POD)	75.00	57.49	33.97	1.621	33:1

WMP +SCB = Water Melon Peel + Sugar cane bagasse; WMP +SCB + CD = Water Melon Peel + Sugar cane bagasse + Cow Dung; WMP +SCB + PD = Water Melon Peel + Sugar cane bagasse + Pig Dung; WMP +SCB + POD = Water Melon Peel + Sugar cane bagasse + Poultry droppings

Fat content was similar in digesters II (1.55%) and III (1.55%), respectively and in digesters I (2.1%) and IV (1.50%) which showed the highest content of fat was in digester I while digester IV showed the lowest. Ash was highest in digester IV (14.66%) followed by digester III and I (13.19% and 10.55%, respectively) while digester II had the least (8.38%). Moisture was quite low (23.08%) in digester III compared to digester II (42.31%) while digester I and IV were the same (26.92% and 26.92%), respectively. Protein contents were low in digester III (1.047%) compared to digester IV, I and II (1.62%, 1.245% and 1.145%, respectively). Fibre was much higher in digester I (28.98%) and in digester IV (26.22%) while digester II is low (22.39%) and lowest in digester III (20.11%). Total solids was highest in digester IV (75%), followed by digester III (74.98%), digester I (71.64%) and lowest in digester II (57.86%). Carbon content was highest in digester IV (33.97%), high in digester I (27.13%) and low in digesters II, III (24.64% and 24.89%, respectively). Volatile solids in digester I, II, III, IV were (56.02%, 44.01%, 50%, 57.49%, respectively) which showed that volatile solid was highest in digester IV followed by I and III while it was lowest in digester II. From the gas production analysis, the total volume of biogas was maximum in digester IV (138.2L) compared to digester II (16.6L), III (33.7L) and digester I (110.8L); this may be due to higher nitrogen content in poultry droppings as compared to other feedstocks in digester II, III and I. The higher biogas production from poultry droppings could also be attributed to the available nutrient in the droppings. Also, it can be observed in digester IV that total viable microbial count was the highest; this may be due to high C:N ratio that aided the growth of micro-organisms and consequently biogas production. This showed that biogas was fully optimized in digester IV throughout 40 days of this research. In digester III, the total volume of gas produced was minimal; this may be due to optimal total viable microbial count, C:N ratio as well as high volatile solid. As such Pig Dung in digester III optimized biogas production as shown in Fig 1. In digester II, Cow Dung did not optimize biogas yield; this may be due to the C:N ratio which did not aid the growth of microorganism, as well as low volatile solid. Also, the volume of gas produced may be due to drop in pH value which was the evidence that the acidogens once displaced the methanogens thereby inhibiting methanogenesis and adversely affecting biogas generation from the waste. The pattern of gas production suggested that Cow Dung was not a good inoculum for sugar cane bagasse and water melon peel waste (Ofomatah and Okoye, 2013) since the commencement of gas flammability for the system was delayed after charging the digester. In digester I, the gas production was high though the process was unstable due to higher production of volatile fatty acids.

Table 3: Percentage gas composition in each digester.

Gas composition	CO_2(%)	H_2S(%)	CO(%)	CH_4(%)
1	33.8	0.8	1.2	62.5
2	37.5	1.4	1.6	58.1
3	36.2	1.1	1.3	60.3
4	31.0	1.4	1.3	64.8

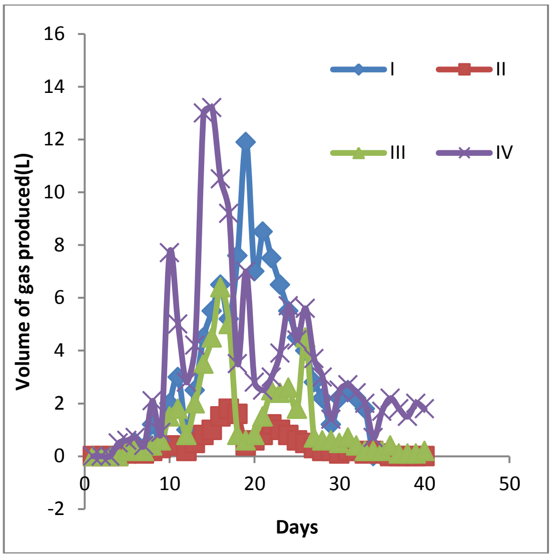

Fig 1: Volume of biogas produced in all the digesters vs Days.

Conclusion

The result of this research on the production of biogas from cow dung, pig dung and poultry droppings has shown that flammable biogas can be produced from these wastes through anaerobic digestion. The study revealed further that cow dung, pig dung and poultry droppings as animal waste had great potentials for generation of biogas and its use should be encouraged due to its early retention time and high volume of biogas yields. The blending of bagasse and water melon peel with cow dung did not seem to enhance or optimize biogas production by bagasse, instead, it led to a steady state and inhibition as well as introduction of pathogens while blending of bagasse and water melon peel with pig dung and poultry droppings, respectively led to the optimization of biogas production.

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