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Biogas production from blends of field grass (*Panicum maximum*) with some animal wastes

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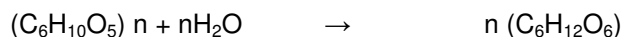
An investigation was carried out on the production of biogas, a low natural gas, from equal blending of field grass (F-G) with some animal wastes which include cow dung (G-C), poultry dung (G-P), swine dung (G-S) and rabbit dung (G-R). The wastes were fed into prototype metallic biodigesters of 50 L working volume on a batch basis for 30 days. They were operated at ambient temperature range of 26 to 32.8°C and prevailing atmospheric pressure conditions. Digester performance indicated that mean flammable biogas yield from the grass alone system was 2.46±2.28 L/total mass of slurry while the grass blended with rabbit dung, cow dung, swine dung and poultry dung gave average yield of 7.73±2.86, 7.53±3.84, 5.66±3.77 and 5.07±3.45 L/total mass of slurry of gas, respectively. The flash point of each of the systems took place at different times. The field grass alone became flammable after 21 days. The grass- swine (G-S) blend started producing flammable biogas on the 10th day, grass-cow (G-C) and grass-poultry (G-P) blends after seven (7) days whereas grass-rabbit (G-R) blend sparked on the 6th day of the digestion period. The gross results showed fastest onset of gas flammability from the G-R followed by the G-C blends, while the highest average volume of gas production from G-R blend was 3 times higher than that of F-G alone. Overall results indicate that the biogas yield and onset of gas flammability of field grass can be significantly enhanced when combined with rabbit and cow dung.

Key words: Animal wastes, biogas production, onset of gas flammability, biogas yield, waste blends.

INTRODUCTION

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. Generally, the production of this gas involves a complex biochemical reaction that takes place under anaerobic conditions in the presence of highly pH sensitive microbiological catalysts that are mainly bacteria. The major products of this reaction are methane (CH₄) and carbon dioxide (CO₂) (Hashimoto et al., 1980). Three important nutrient polymers such as carbohydrates, proteins and lipids are required for the reaction to take place and these are broken down by the anaerobes in a 3-stage digestion process as in example shown below:

1. Hydrolysis



2. Acidogenesis/Acetogenesis



3. Methane formation (methanogenesis)



Other gases found in trace levels from the reaction are H₂S, CO, NH₃, N₂, H₂ and water vapour. The levels of these gases depend on the nature of the waste.

A biogas system becomes flammable when its methane content is at least 45% (Http. Design-Tutor htm....2003). Methane has a heating value of 22MJ/M³ (15.6 MJ/kg) (FAO, 1979). Consequently, biogas can be utilized in all energy consuming applications designed for natural gas (Ross, 1966). Certain wastes like agricultural/crop wastes may not be classified as hazardous but because of their high waste volume, their treatment is considered necessary in order to alter their physical, chemical and biological

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cal character to make them safer for disposal (Arvanitoyannis and Tserkezou, 2008). Biogas technology has in the recent times also been viewed as a very good source of sustainable waste treatment/management, as disposal of wastes has become a major problem especially to the third world countries. The effluent of this process is a residue rich in essential inorganic elements needed for healthy plant growth known as biofertilizer which when applied to the soil enriches it with no detrimental effects on the environment (Energy commission, 1998). The raw materials used in many places for the gas production include agricultural wastes such as animal manures and some crop residues. However, the rate and efficiency of digestion of feedstock depends on its physical and chemical form. Plant materials especially crop residues are more difficult to digest than animal manures. This is because hydrolysis of cellulose materials of crop residues is a slow process and can be a major rate determining step in anaerobic digestion process. Raw plant materials are bound up in plant cells usually strengthened with cellulose and lignin which are difficult to digest. In order to let the bacteria reach the more digestible foods, the plant material must be broken down (Kozo et al., 1996; Fulford, 1998). Furthermore, the imbalance in the ratio of carbon to nitrogen of the plant raw materials can limit the rate of organic conversion into methane. The most suitable plant species for biogas production are those rich in biodegradable carbohydrate such as sugars, lipids and proteins and poor in hemi-cellulose and lignin which are highly difficult to biodegrade (El bassam, 1998). Crop residues have been utilized for biogas production. These include: rice husk (Eze, 1995; Uzodinma et al., 2007), grass from different species (Mahñert et al., 2005) and other terrestrial plant wastes (Maishanu and Sambo, 1991), (Lucas and Bamgboye, 1998). Animal wastes that have been utilized for biogas production include cattle of different types (Nwagbo et al., 1991; Garba et al., 1996; Zuru et al., 1998; Itodo and Kucha, 1998). Optimization of biogas process can be in form of blending, size reduction, pre-decaying in water, chemical treatment (NaOH, Ca (OH)₂, KOH, etc) addition of inoculum and metals (CO, Ni, Fe, Ca, Mg) to the wastes at the required levels, etc. Field grass is readily available in the tropics because of tropical rainy climates and even constitutes a nuisance in the environment as a waste. Domestic animals are commonly raised in the environment and the disposal of their dung has also been a source of problem in the society. However, these wastes can be converted to a renewable energy source. Investigations initially carried out on anaerobic digestion of field grass indicated that it was ordinarily difficult to biodegrade, has low pH (at the initial stage of the gas production) with consequent low yield of biogas, slow onset of gas flammability and short retention time. Hence, the present study was undertaken to verify the effect on these parameters, when field grass (F-G) is combined in equal ratio with the dung of some domestic animals. Hence, field grass was combined with the dung

of swine (G-S), Cow (G-C), rabbit (G-R) and poultry (G-P) in the ratio of (1: 1).

MATERIALS AND METHODS

Waste collection and materials

The field grass used for this study was collected from the compound of the National Centre for Energy Research and Development, University of Nigeria, Nsukka. The poultry and swine dung were procured from Animal and Veterinary farms, University of Nigeria, Nsukka while the cow dung was obtained from an abattoir at Nsukka town. The rabbit dung was obtained from local rears of rabbit at University of Nigeria. Other materials used were weighing balance (50kg capacity, "Five Goats" with model No: Z051599), water troughs, graduated white plastic buckets, K-- thermocouple thermometer (...Hanna HI 8757...), Jenway digital pH meter 3510, hose pipes and biogas burner fabricated locally.

Waste preparation

The grass wastes obtained from the compound was allowed to degrade for one month before they were then cut into pieces (about 2"). They were then soaked in water for one week followed by charging into digesters.

Charging of pre-decayed grass waste

The pre-decayed F-G was charged into a fermenter of 50 L capacity while the waste blends (G-S, G-R, G-P and G-C) were charged separately into other digesters of same capacity. The moisture content of the feed stocks determined the water to waste ratios used for charging the digesters. All the wastes (both the pure and waste blends) were mixed with water in the ratio of approximately 1:2.7; hence 10 kg of waste was mixed with 27 kg of water. The experiment was batch operated under the ambient temperature and atmospheric pressure conditions of the environment for 30 days. Volume of gas production, ambient and slurry temperatures were monitored on a daily basis while pH of the biogas systems were monitored at a four day intervals until each system became combustible. Flammability check for each of the digesters was carried out on a daily basis. The experiment was carried out between April and May, 2007.

Analyses of wastes

Proximate and ultimate analyses

Ash, moisture and fiber contents were determined using AOAC method of 1990. Fat, crude nitrogen and protein contents were determined using Soxhlet extraction and micro-Kjedhal methods described in Pearson (1976). Carbon content was done using Walkey and Black (1934) method, Energy content was carried out using the AOAC method described in Onwuka (2005) while Total and Volatile solids were determined using Meynell (1976) method.

Biochemical analysis

The pH of each of the digester system was monitored at 4 days interval (twice a week) until the onset of gas flammability for the field grass alone using Jenway, 3510, digital pH meter.

Microbial analysis

Total viable counts (TVC) for both the pure and the waste blend

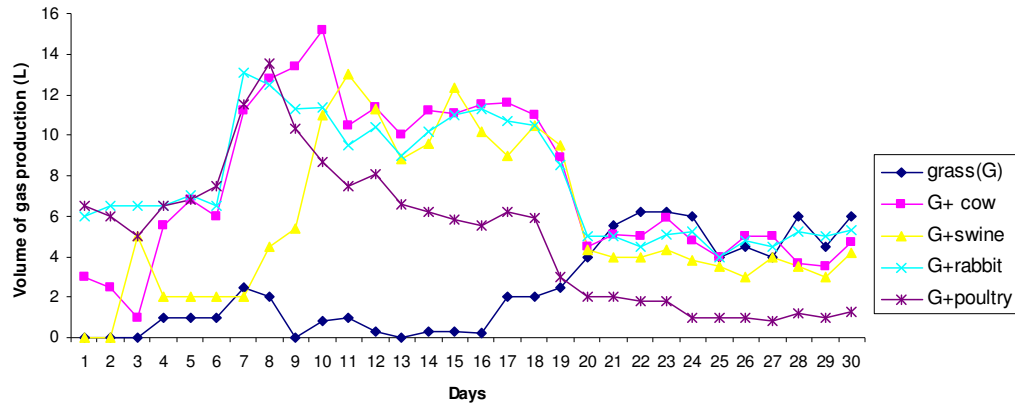


Figure 1. Daily biogas yield.

Table 1. Time lag, cumulative and mean volume of biogas production.

Parameters	F-grass	G-rabbit	G- swine	G-poultry	G-cow
Time Lag (days)	22	5	9	6	6
Cumulative gas yield (L/total mass of slurry)	73.80	232.00	169.70	152.00	225.80
Mean volume of gas production (L/total mass of slurry)	2.48	7.73	5.66	5.07	7.53
Standard Deviation	±2.28	±2.86	±3.77	±3.45	±3.84

slurries were carried out to determine the microbial load of the samples using the modified Miles and Misra (1938) method described in Okore (2004).

Data analysis

The data obtained from the volume of gas production were subjected to statistical analysis using SPSS package 15.0 version.

RESULTS AND DISCUSSION

All experiment was carried out under daily mean ambient temperature range of 26 to 32.8°C throughout the period of gas production. The results of the experiment carried out for the 30 days indicated that blending of field grass with the animal dung affected the total biogas yield and onset of gas flammability for each of the biogas systems. Daily biogas production from the grass waste and the various blends are graphically shown in Figure 1. Biogas production from G-R, G-P and G-C commenced within 24 h of charging the respective digesters while gas production started on the 3rd day for the G-S system and on the 4th day for the F-G system.

The production of flammable biogas took place at different time lags (Table 1). The F- G system became flammable 22 days post charging period with low average biogas yield of 2.46 L (Table 1). This may be because the grass waste had high carbon and fiber contents (Table 2) which indicates that it contains a lot of cellulose, hemi-celluloses, pectin, lignin and plant wax. Lignin and plant wax are very difficult to biodegrade and can be a

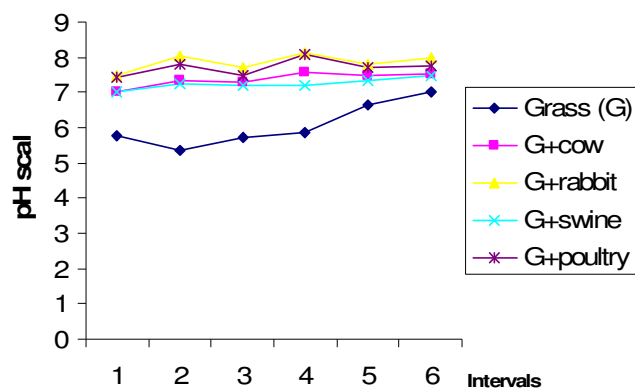
major rate determining step in anaerobic digestion process (Kozo et al., 1996). Again, the pH of the grass waste at charging was 5.40 and only increased a little until the third week when it got to 6.66 at the point of flammability. In the first week of charging the wastes, the pH of all the blends ranged between 7.00 and 7.49 while F-G was 5.77 (Figure 2). Various research reports have affirmed that the methanogenic bacteria which are obligate anaerobes are highly pH sensitive and survive optimally in the pH range of 6.5 to 7.5 (Anonymous, 1989). The amount of carbon and nitrogen in the waste also affects the growth of the biocatalysts. The carbon to nitrogen ratio (C/N ratio) of undigested F-G was below optimum ratio which has been given to fall within the range of 20 to 30:1 (Kanu, 1988; Anonymous, 1989). The energy content of this grass waste was also slightly lower than that of the blends (Table 2). The mean biogas yield of G-R, G-S, G-P and G-C blends are shown in Table 1. Their onset of gas flammability also took place at different times. While the G-R blend commenced flammable gas production on the 6th day of charging the waste, G-C and G-P blends started flammable gas production on the 7th day whereas G-S blend became flammable on the 10th day. The mean gas yield for the G-R blend was highest followed by that of G-C while its onset of gas flammability was the shortest. This result could be as a result of its volatile solids (the biodegradable portion of the waste) which were also the highest among the blends (Table 2). Both cow and rabbit are rumen animals which digestive systems contain obligate anaerobes. Rumen animals already have the native microbial flora within their diges-

Table 2. Physico-chemical properties of the undigested grass waste and the blends.

Parameters	Field grass (F-G)	G - rabbit	G- swine	G- poultry	G- cow
Moisture (%)	4.20	8.95	8.00	6.10	10.20
Ash (%)	26.00	11.80	18.05	22.50	13.95
Fibre (%)	55.15	39.18	50.00	35.25	32.90
GrudeNitrgen (%)	0.92	1.76	1.20	1.92	1.50
Grade Protein (%)	5.75	11.00	7.50	12.03	9.38
Fat Content (%)	1.20	0.25	0.65	0.50	1.10
Carbon Content (%)	40.82	44.53	25.85	37.35	42.43
Energy Content Kcal/g	3.33	3.85	3.36	3.36	3.55
C/N ratio	16.20	25.30	21.54	19.50	28.29
Total Solids (%)	95.80	91.05	92.00	93.90	89.80
Volatile Solids (%)	69.80	79.25	73.95	71.40	75.85

Table 3. Total viable counts for the field grass and waste blends, during the digestion period (Cfu/l).

Period	F-grass	G-rabbit	G-swinE	G-poultry	G-cow
At Charging	4.20×10^5	1.25×10^7	3.74×10^5	1.21×10^7	5.16×10^6
At point of Flammability	2.00×10^6	5.50×10^7	4.40×10^7	4.50×10^7	1.50×10^7
At Peak of Production	7.90×10^6	1.25×10^7	4.75×10^7	1.20×10^7	6.00×10^7
Towards end of Digestion	2.35×10^6	4.20×10^6	2.50×10^6	2.25×10^6	3.50×10^6

**Figure 2.** pH changes for grass- animal during digestion.

digestive systems so that the presence of these microbes in their faeces (as reflected in Table 3) would have created a favorable environment that aided faster digestion, shorter onset of gas flammability and highest average yield of biogas for the G-R and G-C blends. However, feeding pattern for the two animals may be responsible for the difference in the yield of biogas. While rabbit is fed purely on fresh grass, cow may be given other feed material such as Bambara nut flour waste. Also, high fiber and carbon contents meant that more nutrients were available for the microbes in the system from the initial stage of the digestion process. The energy and carbon contents of the G-C blend (undigested) were quite high when compared with the other waste blends (Table 2). Its C/N ratio was

also the closest to the required optimum range of 30:1. G-P and G-C systems commenced flammable gas production the same day. Cow dung has been established by researchers as being superior in quality biogas production over other wastes (Odeymi, 1987). Its average biogas yield was close to that of G-R blend but became flammable the same day with the G-P blend. Fresh Poultry waste used in biogas production has longer onset of gas flammability and short retention times. This phenomenon has been attributed to the production of excess ammonia as a result of high levels of protein and nitrogen in poultry waste which tends to intoxicate the system (Ofoefule and Uzodinma, 2006; Energy Commission, 1998). Earlier work reported by Waksman and Hutchings (1936) pointed out the significance of organic sources of nitrogen in the decomposition of lignin in plant materials. They asserted that lignin-decomposing microbes prefer organic protein nitrogen to inorganic forms. Tinsley and Nowakowski (1959) also submitted that application of poultry faeces to waste slurry brought an abundant and vigorous micro-flora immediately into contact with feedstock substrate. They further explained that as uric acid was decomposed, ammonia was produced which diffused rapidly so that the cellulose-decomposing organisms were well supplied with nitrogen from an early stage. Therefore, blending poultry waste with the F-G may have aided onset of gas flammability for G-P blend even though poultry is not a rumen animal. G-S blend started producing flammable gas on 10th day though the blend should initially contain the native microbial flora. This may be attributed to the feeding pattern of swine in

this part of the country. Swine in this environment are normally fed with rice husk- spent grain which was observed in the swine waste and contains a lot of lignin and wax which cannot be easily hydrolysed at the initial stage of the digestion process. This may have contributed to the delay in onset of gas flammability for the G-S. Adequate physicochemical properties: nutrients, C/N ratio, etc, are known to favour biogas production (Table 2). This may be responsible for the higher yields of biogas production observed for the grass blends when compared with that of field grass alone. The total viable counts (TVC) at each stage of the digestion for all the systems indicated lowest count for the unblended field grass (Table 3).

Conclusion

The result of the investigation shows that the biogas yield of field grass could be optimized by combining it with rabbit, cow, swine and poultry wastes. The grass-rabbit blend gave the best results in terms of onset of gas flammability and average volume of biogas yield. This was followed closely by the grass- cow blend. Overall results indicate that the low flammable biogas production of the field grass could be enhanced significantly in the presence of rabbit and cow dung. Consequently, apart from chemical treatment, energy could also be tapped from field grass by blending it with the wastes from these domestic animals that are readily available. The performance of other ratios will constitute a separate report.

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