Development Of Enhanced Substrate From Fresh Elephant Grass For Biogas Production

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Abstract: Cow dung, which is a by-product of grass-eating, digestion and excretion by cow, is often hard to find in some places. This situation has therefore created a yawning gap for the use of mechanical and biochemical processes to mimic grass-eating, digestion and excretion of dung as an alternative way to provide the needed sustainable feedstock for biogas production. This research seeks to convert efficiently grass; elephant grass (pennisetum purpureum) in particular, to biogas. The purpose of the research is to provide a sustainable alternative to cow dung. Elephant grass was obtained, crushed with pulverizer, pre-treated with native potash (as to enhance pH) and inoculated with predetermined quantity of liquid mixture of cow dung from already running digester. After a retention time of 3 to 4 days, copious quantity of biogas started forming. There were however other trials involving the use of: grass and native potash alone, inoculated grass alone, and raw grass only, none of which produced flammable gas, except CO_2 only. Our results confirm that biogas of high methane content (64.3%) can be produced from elephant grass using the above stated method. It's therefore also confirmed that grass-to- gas conversion is realizable.

Index Terms: alkaline pre-treatment, Biogas Technology, Biomass Biodegradation, Methane Content, Renewable energy, System Optimization, alkaline pre-treatment

1 Introduction

Although cow dung and cow manure have been widely used for biogas generation, the paucity of the feedstock makes it necessary for the development of sustainable alternative. Though grass is a good feedstock for biogas production, it has inhibiting characteristics in the nature of acidic pH. Thus the reduction of the acidity of grass as to make it seemly for gas production sharpens the focus of this research. Whereas biogas has been produced from animal dung, kitchen wastes and similar wastes, the problem remain the issue of sustainability of these sources of waste. And whereas grass is readily and copiously available in all seasons of the year, especially in rainforest and some part of the middle belt, and whereas it is possible to enhance the pH of grass, the use of grass to generate gas is an appealing option. Majority of the research work on conversion of grass to gas are foreign based and appear to lack the native potash that comes from palm trees that grows well in the tropics. Seeing from that standpoint, it is not likely that they will be in a position to undertake research using the native potash as in the current study. Again, whereas past researchers have used $Ca(OH)_2$ and NaOH to get the pH of grass slurry to the appropriate acidic characteristic eigenvalue for biogas production, this current study uses an entirely different approach by introducing locally available hydroxide (native potash).

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It is noteworthy to point out that a major shortcoming in the use of $Ca(OH)_2$ and NaOH, is that both are imported and are not readily available locally. Most organic matter has propensity to produce energy in form of biogas, through biodegradation of such matter at recommended optimum temperature and pH ranges by some specialized microorganism. Biogas has been produced from bio-degradable waste such as cow dung; other animal droppings; kitchen waste; sewage sludge; energy – rich, non edible vegetables (e.g. water hyacinth) etc. For most potential feedstock, sustainability has been the issue. Biogas production from organic waste, by the activities of microorganisms or bacteria during anaerobic digestion of usually waste organic matter, is seen as value adding process [18]. Although improvement in biogas technology has been achieved through various means: type and combination of substrates or feedstock [15], [17] and [21]; Feed pattern or/and rate [21]; scaling up; application of economy of scale; and optimization of the system parameters and operating conditions (e.g. temperature, pH, substrate concentration, Total Organic Carbon (TOC) content, optimum particle size, Total Solids (TS), Total Volatile Solids (TVS)) [5], [11], [2], [6], [10]; sustainability of supply of this biomass in the needed quantity, time and location has been a major issue of concern in biogas technology [12], [3] and [27]. Despite the huge potentialities and biomass resources for anaerobic digestion in Africa, [7] noted that the dissemination rate of biogas in Africa is struggling to meet biogas market demand. This may be as a result of over dependency on cow dung or cow manure for feedstock in biogas production. In order to improve the efficiency of this readily available biomass in biogas production, [24] and [22] considered pre-treatment of substrate (feed stock) as method of improving performance. Not all biomass, especially those of plant origin, can be biodegraded for biogas production in their natural state. [9] highlighted the need to employ standard measures for classification of biomass and assessing biodegradability of the selected biomass. Efficient degradation of lignocellulosic biomass has been achieved through; careful analysis of the makeup of the plant cells, then the improvement of the genetic makeup of the microorganism(s) for better degradation of the biomass, or/and development of conducive environment for the microorganism(s) to work on the biomass, [13], [16], [14],

[20],[26],[4],and[23]. Also enzymatic cocktails that can be introduced commercially for biodegradation of biomass has been developed in recent past [19]. Production of biogas from grass – a lignocellulosic biomass, has been achieved and reported; Aquatic grasses [1]; water hyacinth [25]; Elephant grass and Guinea grass [28]; Sudan grass [8] among many others. The foregoing review of past studies indicates that although some foreign authors have researched the use of grass for gas production, but it is found that really have they applied native potash as enhancer. The study therefore seeks to efficiently convert grass to gas with the help of locally sourced pH enhancer.

2. Material and Methods

2.1 Sample Collection and Preparation

Fresh elephant grasses were harvested from a nearby bush in Nibo, in Awka – South local government area of Anambra state in Nigeria. The harvested grasses were cut into smaller pieces and weighed, measuring 7769 grams altogether. The grasses were then pulverized and mixed with 11 litres of water. After 3-4 days of fermentation, the substrate was distributed into four (4) digesters of twenty - litre capacity, and each digester containing about 1942.2g of the organic matter. Three and a half (3.5) litres of water was then added to each digester making the solution up to 10.6 litres in each digester.

2.2. Physiochemical Parameters

2.2.1 Nitrogen and Protein Content

The AOAC 1984 method was employed. The digestion of the sample (0.5gram) with hot concentrated sulphuric acid in the presence of metallic catalyst was carried out in 30ml kjehdal flask. The organic nitrogen in the sample which was converted to NH_3 remained in the solution as ammonium sulphate. This was made alkaline and then distilled to release ammonia, and the produced ammonia is trapped in dilute acid and then titrated. The percentage of Nitrogen and protein content in the sample was computed by equation (1 and 2 respectively)

$$\text{Nitrogen content } (\%) = (titre\ value \times 0.01 \times 14 \times 4) \times 100 \quad (1)$$

$$\text{Protein content } (\%) = \text{Nitrogen content } (\%) \times 6.25 \quad (2)$$

2.2.2 Ash Content

Using Vecster furnaces set at 500^{0}C, some quantity of the sample was measured out in a crucible of known weight and inserted into the furnace and heated until constant weight after ashing. The ash content was computed based on wet matter;

$$ash\ content\ (\%) = \frac{w_3 - w_1}{w_2 - w_1} \times 100 \quad ; \quad (3)$$

w_1 is weight of the crucible; w_2 is weight of the substrate and crucible before heating (ashing); and w_3 is the weight of the substrate and crucible after heating (ashing). All measurement is in grams.

2.2.3 Moisture Content

The sample was placed in a Petri dish and dried in a hot air oven to constant weight at 105^{0}C for 24 hrs period. The weight of the fresh grass, the empty dish and the dried grass was measured and recorded and the moisture content of the grass was computed by equation (4)

$$moisture\ content\ (\%) = \frac{m_1 - m_2}{m_1 - m_0} \times 100 \quad (4)$$

Where, m_2 is the weight of the dry sample and the dish after drying, m_1 is the weight of the fresh sample of grass and the Petri dish before drying, and m_0 is the mass of empty dish.

2.2.4 Total Volatile Solid

This is computed using the values obtained during moisture content and ash content analysis and based on wet matter as shown in equation 5

$$\text{Total volatile solid } (\%) = ((\frac{w2 - w3}{w2 - w1)} \times 100)) - mc \quad (5)$$

Where; w_1, w_2 and w_3 retains same definition as given in equation (3) and mc is moisture content of the substrate in percentage of wet matter weight

2.2.5 Total Carbon Content

The wet sample of the feedstock was measured out (2gram) and heated over a Bunsen burner in a foil of known weight until it was charred. The weight of the sample after charring was measured as the total carbon. Thus the total carbon content (%) is given as;

$$\text{Total Carbon Content } (\%) = \frac{(w_3 - w_1)}{(w_2 - w_1)} \times 100) \quad (6)$$

Where w_1 is weight of the foil, w_2 is the weight of the substrate and foil before heating (charring), and w_3 is the weight of the substrate and foil after heating (charring), all in grams.

2.3 Digester Experimental Procedure

Four (4) experimental runs, each made of 20 litre capacity locally made digester, were developed. They were labelled GOA, GOB, GIA and GIB. An alkaline solution of 0.1% w/v was made by adding 30gram of native potash (locally known as Ngu in south eastern part of Nigeria) in water and made up to 300ml, and added to the substrates in digesters GIA and GIB. The addition of the native potash solution raised the pH of the substrates from 5.2 to 5.7. The four digesters were monitored for 19 days, checking their pH, internal and ambient temperature, as well as running flame test. At the end of the 19 days, the digesters did not produce flammable gas. The pH level of substrates in digesters GIA and GIB were subsequently increased from 4.8 to 7.2 respectively, by adding 115g of the native potash to each digester. Also digesters GOB and GIB were then seeded with 20ml of substrate from already running digesters containing cow dung. The digesters were further monitored for another 4 weeks.

2.4 Biogas parameters measured

The daily biogas production volume was measured using water displacement method, and the quality of the gas produced analyzed using gas chromatography at Springboard Lab. The ambient temperature, digester internal/ substrate temperature, and substrate's pH were measured daily using general purpose liquid-in - glass thermometer (0 to 100^{0}C) and pHep pocket–sized pH meter (0 – 14 pH).

3. Result and Analysis

The result of the Physiochemical parameters of grass computed and evaluated using the methods stated in section 2.2 is presented in table 1.

Table 1: *composition of the fresh grass (elephant grass)*

Moisture Content (%)	Total Solids (%)	Volatile Solid (%)	Ash Content (%)	Total Carbon Content (%)	Nitrogen Content (%)	pH (raw grass)
68.4	31.6	29.6	2	10	2	5.2

From table 1, it can be deduced that 93.7% of the total solids are volatile. Also, grass in its fresh form have low carbon-nitrogen ratio and will affect digestion efficiency, thus the need to decompose the grass, reducing the nitrogen content as well as improving the pH which was found to be too acidic for methanogenesis, see table 2.

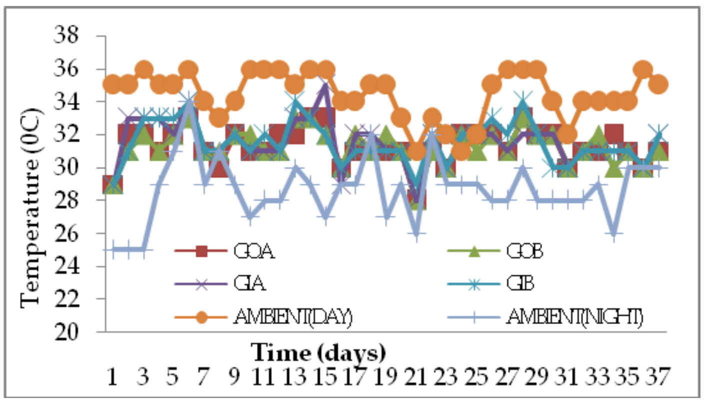

Figure1. *Digester's Internal and Ambient Temperatures*

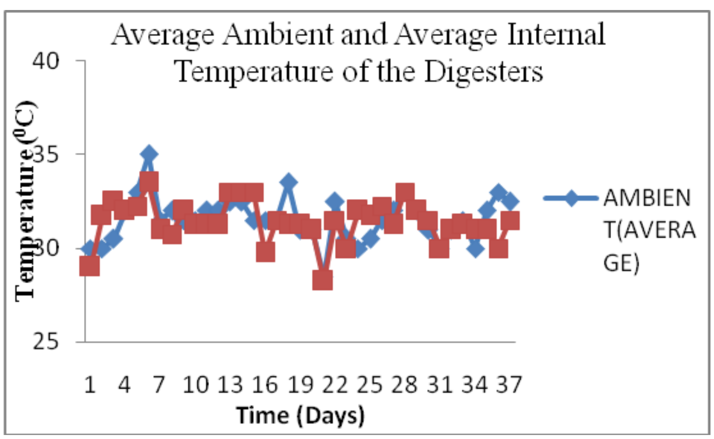

Figure 2*: Digester's Average Internal and Ambient Temperatures*

According to the data in Fig. 1 and 2, the ambient temperature ranges from 32^{0}C to 36^{0}C in the day, 25^{0}C to 34^{0}C at night, and an average of 28.5^{0}C to 35^{0}C. The rainfall affected the temperature slightly on the days rain fell. The system operated at mesophilic temperature range. The temperature variation was uniform across the digesters and the average internal temperature of the digesters correlates strongly (above 0.70) with the average daily temperature (day and night). This shows good digester's heat absorption and retention capacity.

Table 2: *Result of the Experimental Run*

	Digester not pre-treated with local potash (Acidic pH)	Digester pre-treated with local potash (Basic pH)
Not seeded with microorganism	GOA: No flammable gas produced	GIA: No flammable gas produced
Seeded with microorganism	GOB No flammable gas produced	**GIB: Flammable gas (Methane) was produced**

From the result in table 2, only digester GIB, pre-treated by adding ngu for improved pH, as well as seeding with the necessary microorganism (methanogens), produced flammable gas (methane). The biogas production was inhibited in digester GOB due to the acidic pH of the substrate, not minding the introduction of methanogens through seeding. Also, digester GIA with the correct pH range could not produce biogas due to absence of the required methanogens, while combined effort of lack of methanogens and wrong pH range is suspected to have inhibited production from digester GOA. It could then be deduced from the result that the addition of the native potash helped in improving the pH of the substrate, making it suitable for the activities of the introduced methanogens (previously absent in the grass).

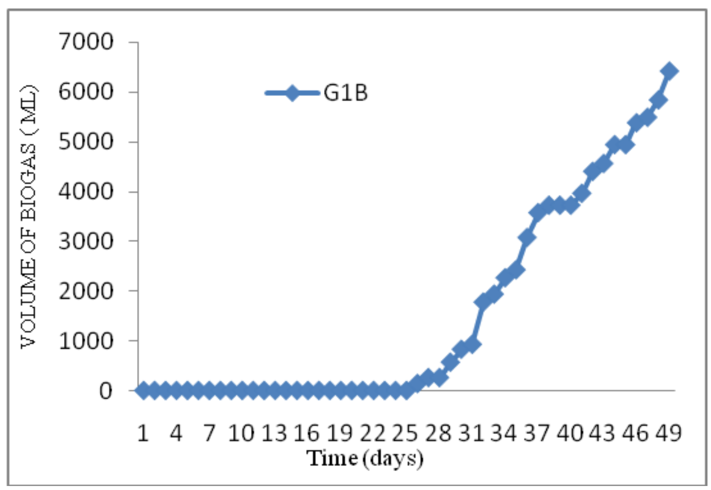

Figure 3: *Cumulative Biogas Production for Digester GIB*

The cumulative and daily biogas production from digester GIB before and after the treatment is shown in Fig. 3 and 4. From the result, the highest daily biogas production (850ml) was observed on the 32nd day, which is the 13th day after the dozing of the digester with native potash and seeding of the digester with liquid from the digester containing cow manure. The pH and temperature at this optimum biogas production point is 6.8 and 31^{o}C respectively.

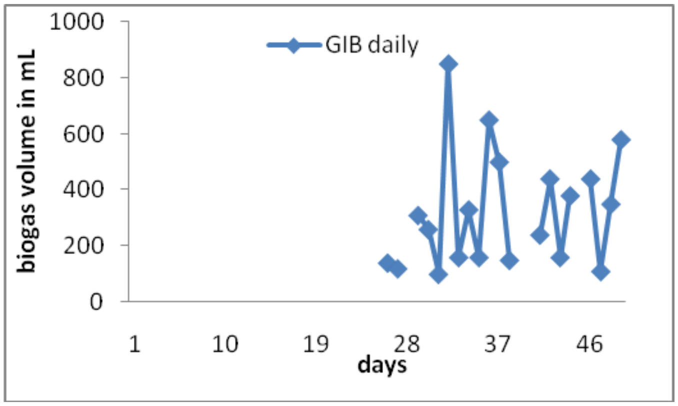

Figure 4: *Daily biogas production from Digester GIB*

Before the 19th day there was no biogas production. Production started 3 days after the pH improvement and seeding of the digester with needed microorganism. The production fluctuates as seen in Fig. 4 with the optimum production on the 32nd day. Flame test were carried out to ascertain the flammability of the produced gas before measurement commenced, this was done intermittently to be assured that produced gas was still flammable, thus the gap in the graph in Fig. 4.

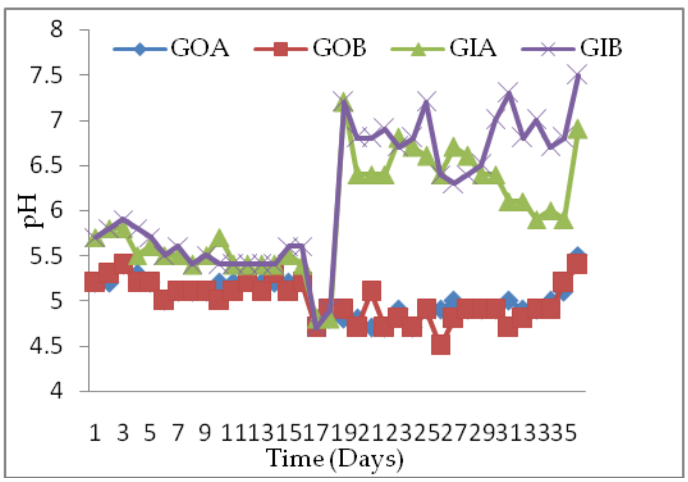

Figure 5: *pH of Substrates in Different Digesters*

The progression in pH of the substrates in the digesters is presented in Fig. 5. The dozing with ngu improved the pH of substrates in digesters GIA and GIB from 5.4 to 7.5 on the 19th day, and fluctuates within 6.3 to 7.5 and 5.9 to 7.5 for GIB and GIA respectively. Only the pH of the substrate in digester GIB seems to be increasing towards basic solution, while GIA that was also dozed with ngu showed a decreasing trend towards acidic solution. The other digesters GOA and GOB maintained acidic pH all through. Although GOB was inoculated (seeded), because of the acidic substrate, the methanogens could not survive or work actively in conversion of the acetones to methane and carbon dioxide, making the system acidic.

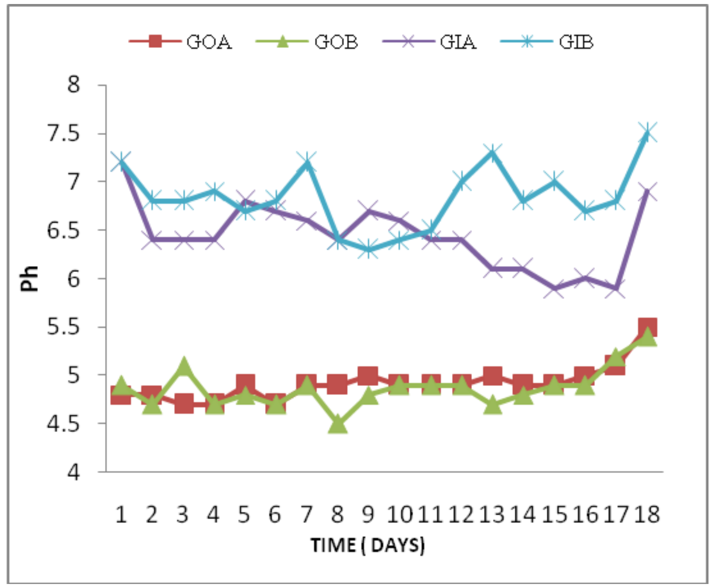

Figure 6: *pH of Substrates after Seeding (after the 19th day)*

The pH of the digesters was plotted against time in Fig. 6. It was discovered from the polynomial models generated using trend line that the pH of the digesters seeded with microorganism seems not to have good R^2 when plotted against time unlike their counterpart (GOA and GIA) as seen in equation 7 to 10. It was suspected that the normal effect of decomposition on ph can be time dependent, while activities of the methanogens makes the change in pH over time irregular.

$$Y_{(GOA)} = 1E\text{-}06x^6 - 5E\text{-}05x^5 + 0.001x^4 - 0.012x^3 + 0.080x^2 - 0.239x + 4.988 \quad (7)$$
$R^2 = 0.899$

$$Y_{(GOB)} = -2E\text{-}06x^6 + 0.000x^5 - 0.002x^4 + 0.032x^3 - 0.187x^2 + 0.433x + 4.564 \quad (8)$$
$R^2 = 0.650$

$$Y_{(GIA)} = 1E\text{-}05x^6 - 0.000x^5 + 0.016x^4 - 0.184x^3 + 1.059x^2 - 2.819x + 9.101 \quad (9)$$
$R^2 = 0.901$

$$Y_{(GIB)} = 2E\text{-}05x^6 - 0.001x^5 + 0.025x^4 - 0.261x^3 + 1.309x^2 - 2.959x + 9.124 \quad (10)$$
$R^2 = 0.678$

4. Conclusions

In bio-degradation of elephant grass as prospective substitute for cow dung in biogas production, the basic factors controlled aside temperature were the availability and sustainability of the necessary microorganism, especially the methanogens used in conversion acetones to methane and other constituent gas. The optimal environmental conditions for the thriving of these methanogenes were found to be pH of 6.5 to 8.5 and mesophilic temperature range. The study found that grass in its raw form (pH and microorganism count) cannot produce biogas, but through the use of additive and inoculation, the digested grass was able to produce substantive volume of gas with methane content of about 64%. Although the pH of the grass can be improved by partial biological decomposition of the grass, the reported method (use of native potash) reduces processing time and preserves the natural nutrients in the grass.

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