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Original Article

EVALUATION OF BIOGAS POTENTIALS OF *Cymbopogon citratus* AS ALTERNATIVE ENERGY IN NIGERIA

I.M. Alfa,*[1] C.A. Okuofu,[1] D.B. Adie,[1] S.O. Dahunsi[2], U.S. Oranusi[2] and S.A Idowu[2]

[1]Department of Water Resources & Environmental Engineering, Ahmadu Bello University, Zaria, Nigeria.

[2]Department of Biological Sciences, Covenant University, Ota, Nigeria.

*Corresponding E-mail Address: dahunsi_olatunde@yahoo.com

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Abstract

This research explored the potentials of *Cymbopogon citratus* (Lemon Grass) for biogas production as a cost effective alternative energy source in Nigeria. The *Cymbopogon citratus* was crushed to small sizes between 20 to 50mm and pre-fermented for 40 days in a PVC drum. Six (6) kg of the pre-fermented *Cymbopogon citratus* was mixed with water in ratio 1:1 w/v to form slurry and digested for 30 days. The floating drum gas collection system was used to collect the gas after it was passed through water and lime respectively for scrubbing. A total of 0.125m^3 (6.95x10^{-4} m^3/kg/day) and 0.0897m^3 (4.98x10^{-4} m^3/kg/day) of biogas was produced from the *Cymbopogon citratus* before and after scrubbing respectively. The gas produced was used for cooking test. The scrubbed gas had higher cooking rates for both water and rice respectively (0.12L/min and 0.0052L/min) while the cooking rates for unscrubbed gas were 0.079L/min and 0.0036L/min respectively. During this period, daily ambient temperatures of the research environment varied from 31^{0}C to 42^{0}C while the digester temperature fluctuated between 28^{o}C and 36.7^{0}C. The pH of the medium fluctuated optimally between 6.5 and 7.8. The research demonstrated that Biogas could be produced from *Cymbopogon citratus* in quantity and quality comparative with those in literatures.

Keywords: Anaerobic Digestion, Biogas, Cooking Rate, *Cymbopogon citratus*, Methane content.

1. INTRODUCTION

Biogas technology can serve as a means of reducing energy poverty, which has been a serious barrier to economic development in Africa [1]. Due to the fact that fossil resources are diminishing and non-renewable, oil price has been subjected to being on the increase [2]. Biogas is a renewable, high quality fuel, which can be utilized for various energy services including automobile engine fuel. The recent sharp increase in the price of fossil fuel globally and the attendant climate change issue is a cause for concern. There is currently a movement toward reduced use of fuels from fossil origin; thus, fuel production from renewable biomass is becoming increasingly acceptable [3]. Bioethanol and biodiesel are commercially produced as alternative fuels in the world market and bio-based production of butanol and alkane is also attracting the attention of many researchers the world over. It's therefore obvious that the usage of biofuels will be increasing in order to replace some of fossil fuels for our sustainable future [4,5]. Methane generation from organic wastes through anaerobic digestion processes has been applied to the on-site, co-generation of electrical power and heat in wastewater treatment plants [6], and it's recorded that this technology is potent enough as to significantly lower the operating costs at wastewater treatment facilities and stabilize the organic residues coupled with reduction in greenhouse gas emissions. The methane and energy content of the gas generated usually varies and is dependent on the physical and chemical properties of the substrate used [7].

The major challenge of biogas generation via digestion is the limited solid hydrolysis step [8,9]. Many methods have been developed to achieve this feat, including acid treatment [10,11], ultrasonic treatment [12,9], ozone oxidation [13,14], alkaline treatment [15], and the heating process [10]. Anaerobic digestion is the most efficient because of its ability to convert organic residues into biogas [16]. Anaerobic digestion of corn-ethanol thin stillage and its biogas generation potential have been considered in laboratory studies [17]. Also, biogas yield for molasses distillery slops [18] and poultry litter [19] have been reported.

Cymbopogon citratus popularly known as Lemon grass is an aromatic plant belonging to the family Grami-neae and the genus *Cymbopogon* [20]. It is a clumped perennial grass growing to a height of about 1m. The leaf-blade is linear, tapered at both ends and can grow to a length of 50 cm and width of 1.5cm [21]. The leaf-sheath is tubular in shape and acts as a pseudostem. It is native of the warm temperate and tropical regions of the old world. Lemon grass can tolerate a wide range of soils and climatic conditions. However, vigorous growth is obtained on well-drained sandy loam soil with high fertility and exposure to sunlight [21].

Tajidin et al [22] identified various uses of lemon grass. The uses include medical applications and industrial applications due to its essential oil and citral content. There is no record of any research on the potential of *Cymbopogon citratus* (Lemon grass) for biogas production. The objective of this study therefore is to explore the biogas potentials of *Cymbopogon citratus* (Lemon grass) in terms of quantity and quality of gas.

2. MATERIALS AND METHODS

2.1 Materials: Fabrication of Biodigester and gas Collection Facilities

The primary structure of the cylindrical anaerobic digester plant consists of a 1mm Galvanized steel digestion reactor of height 0.5m and diameter 0.25m. The gas holder tank was fabricated from thin sheet metal and used to temporarily store the biogas until it was used to produce heat or used to replace or supplement the supply of cooking gas. A plastic hose was used to connect the digester to the gas collection system and the biogas stove burner while plastic valves were installed to control the gas flow. Other materials used in this study include pH meter model pHS-2S, (SHANGHAI JINYKE REX, CHINA) for measuring the pH of slurry every week day throughout the retention period and 2/1°C thermometers used to obtain daily temperature of the digester as well as the ambient temperatures for Samaru, Zaria.

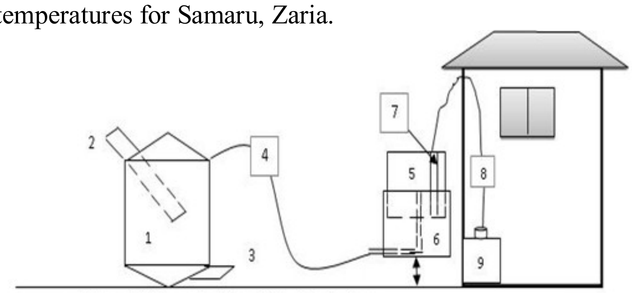

Figure 1: Schematic View of the Plant set up

Key

1. Digester Body 2. Feedstock Inlet pipe 3. Effluent Outlet pipe
4. Hose from digester to gas holder 5. Gas holder 6. Water Jacket 7. Rule
8. Hose to Cooking Stove 9. Cooking Stove in the kitchen

2.2 Methods: Development of Digester, Biomass collection, Slurry Preparation and Digester Loading

The design volume of the 25 litre anaerobic digester was sized according to the amount of volatile solids that must be treated daily and the period of time the material would remain in each of the digesters (Retention time). The design theory adopted for this study is a combination of the Karki's Biogas model [23] and the separate floating gas holder system. The cylindrical shape was adopted to enhance better mixing. The separate gas holder system was incorporated into this design to allow for ease of measurement of gas volume. The digester is a separate component, with the gas holder in a separate water jacket.

The gas collection was done by downward delivery and upward displacement over water. The gas displaces the gas holder (upward) and gets trapped between the gas holder and the water seal. The displacement of the gas holder is dependent on the pressure and volume of the gas produced. The setup is as shown in fig. 1.

Cymbopogon citratus (Lemon grass) were harvested, crushed to small sizes (between 20 to 50mm) using the hammer-mill after which it was pre-fermented in a PVC drum for 40 days according to the method of [24]. Six (6) kg of the pre-fermented *Cymbopogon citratus* was measured out and mixed thoroughly with water in the ratio 1:1 w/v to form slurry.

Partly decomposed slaughter house waste was introduced into the digester as seed material after which the slurry was introduced into the digester through the 50mm inlet pipe at the top of the reactor. The slurry occupied three quarter of the digester leaving one quarter of the digester height as clear space for gas production. The inflow was directed downward to break scum as the new substrate drops and to cause the solids to accumulate at the bottom of the tank where after digestion they were easily removed. The gas was collected from the digester through a 10mm diameter flexible hose connected from the digester to the bottom of the gas collection system. The collected gas was allowed to pass through water and slaked lime respectively as scrubbers using the method of (Chen *et al* [25].

The volume of gas collected before and after scrubbing were taken and recorded. The gases were both used to boil water and rice respectively using Ahmadu Bello University (ABU) biogas stove burner [26] to estimate and compare their cooking rates. The experiment was monitored for 30days from 21st February, 2012 to 21st March, 2012. During this period, daily ambient temperature of research environment measured using the 2/1°C thermometer varied from 31°C to 42°C which is within the mesophilic temperature range.

2.2.1 Measurement of gas production

A calibrated gas holder was used to measure the reading of the daily gas production from the Lemon grass digested. The volume of biogas produced was measured each day shortly before sunset, by computing the volume of the gas holder floating over water level in the water jacket.

The base area of the gas holder is expressed by equation (1)

$$A = \frac{\pi d^2}{4} = \frac{\pi \times 0.25^2}{4} = 0.0491m^2$$

The height of cylinder above water level was read off on the rule attached to the gas holder for calibration.

This height (h) = x, which varies.

Volume of biogas is obtained as the volume of cylinder above water level, given by equation (2)

Volume,

$$V = \left(\frac{\pi d^2}{4}\right) h$$

Where h = x

Substituting for A in equation (1),

$$V = 0.0491x \text{ m}^3$$

Where V= Volume of biogas

3. RESULTS

The quantity of biogas produced from the *Cymbopogon citratus* (Lemon grass) over a period of 30 days is summarized in Fig. 2. Biogas production started on the

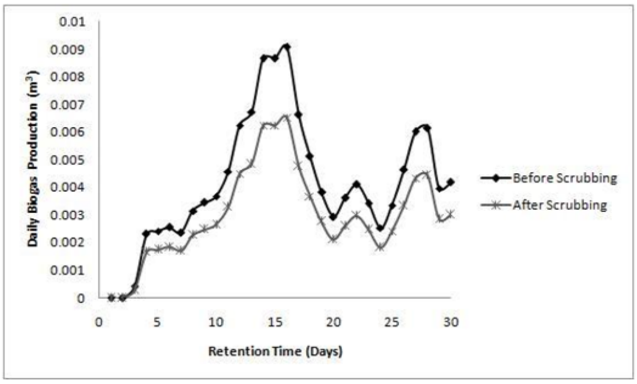

Figure 2: Daily Biogas production from C*ymbopogon citratus* (Lemon grass).

third day of loading the digester and increased gradually until the maximum recorded on the 14th day. Apart from the 22nd and 28th day where sudden increase was observed, biogas production dropped progressively after the 14th day. A total of $0.125m^3$ ($6.95x10^{-4}$ m^3/kg/day) and $0.0897m^3$ ($4.98x10^{-4}$ m^3/kg/day) of biogas was produced from the *Cymbopogon citratus* (Lemon grass) before and after scrubbing respectively.

It was observed that the digester temperature fluctuated between 28^0C and 36.7^0C. Therefore, both the digester and ambient temperature remained within the mesophilic range (20^0C-40^0C) throughout the period of observation. The pH of the medium changed progressively from acidic to slightly alkaline fluctuating optimally between 6.5 and 7.8 (fig. 3).

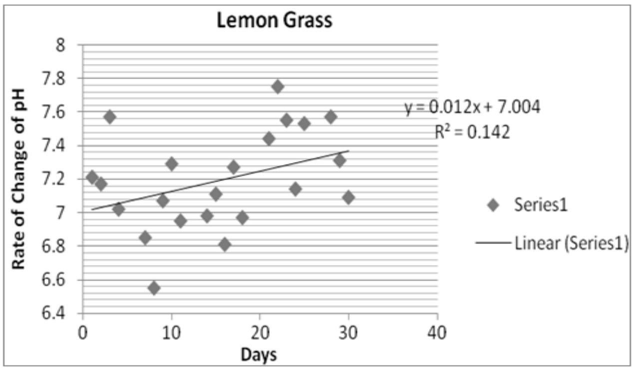

Figure 3: Rate of change in pH of the Lemon Grass at various time intervals

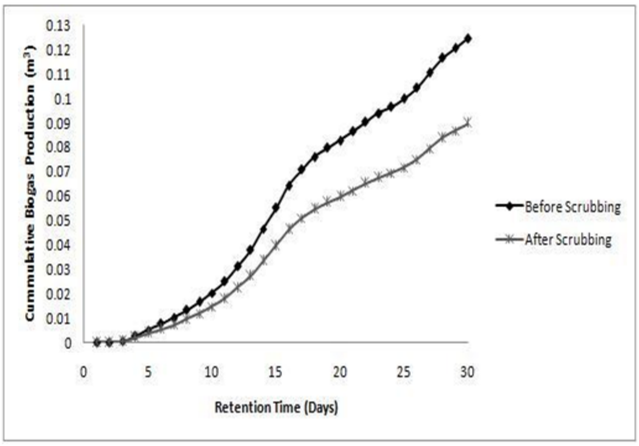

Figure 4: Cummulative Biogas production from C*ymbopogon citratus*(Lemon grass)

Fig. 4 shows a comparative analysis of the cumulative biogas production before and after scrubbing with slaked lime to remove carbon dioxide. The difference in total volume of biogas before and after scrubbing accounts for the estimated volume of carbon dioxide and other gaseous impurities present in the produced gas.

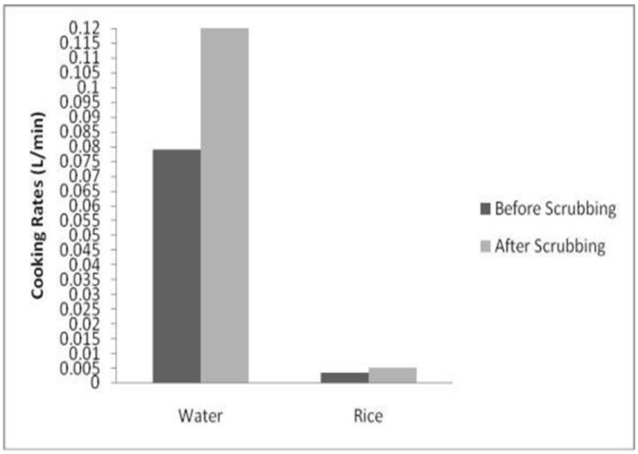

Figure 5: Comparative Biogas cooking rates before and after Scrubbing

Fig. 5 gives the result of the cooking test conducted with the biogas before and after scrubbing. The result shows that the scrubbed gas had higher cooking rates for both water and rice respectively (0.12L/min and 0.0052L/min respectively) while the cooking rates for unscrubbed gas were 0.079L/min and 0.0036L/min respectively.

Table 1: Biogas Yield from Chicken Droppings and Its co-digestion with *Cymbopogon citratus* (lemon grass

	Volume of Biogas produced (m^3)	Average Biogas yield per day (m^3/day)	Average of Biogas per kg Slurry (m^3/kg)	Average daily yield of Biogas per kg Slurry (m^3/kg/day)
Before Scrubbing	1.25×10^{-1}	4.17×10^{-3}	2.08×10^{-2}	6.95×10^{-4}
After Scrubbing	8.97×10^{-2}	2.99×10^{-3}	1.49×10^{-2}	4.98×10^{-4}
Estimated Methane Content	71.76%			

Table 1 shows the total biogas produced, the biogas yield per day, biogas yield per kg of slurry as well as the daily biogas yield per kg slurry. The table also shows the estimate of the methane content of the biogas produced on the basis of the decrease in volume after removal of carbon dioxide. The table reveals that the biogas produced from lemon grass contained about 71.76% methane.

4. DICCUSSION

The fluctuations observed in the volume of biogas produced may be attributed to the change in metabolism of the bacteria in response to the fluctuations in the temperature and pH of the digestion medium. The initial drop in pH was due to the activities of aerobes and facultative aerobes in the production of acidic metabolites on which methane producing bacteria produce methane. Methane generation occur best within a pH range of about 6 and 7.8. This corresponds to the findings of [27, 28]. Thus the drop in temperature observed after the 23rd day (except day 28) could be attributed to the progressive fall in both the digester and ambient temperatures observed from the 25th day towards the end of the digestion period. Temperature is an important factor for anaerobic digestion since methane – producing bacteria operate most efficiently at temperatures 30 – 40^{0}C or 50 – 60^{0}C [29].

The result of the cooking test conducted with the biogas after scrubbing was found to have higher cooking rates for both water and rice respectively than the unscrubbed gas. The values obtained for the gas used after scrubbing are better than those obtained for cow dung and chicken droppings by Ahmadu et al.[30]

The biogas produced from lemon grass contained about 71.76% methane on the basis of the decrease in volume after removal of carbon dioxide. This result corresponds with the values reported by Sasse [31] for succulent grass.

5. CONCLUSION

The research has shown that Biogas could be produced from *Cymbopogon citratus* (Lemon Grass). The total biogas yield observed in this research is comparable with those from other substrates such as cow dung, chicken droppings among others. The methane content recorded is comparable with those obtainable in literature. Although the energy outputs of the gases were not determined, the gases were able to boil potable water and rice in a period of time comparable with those of kerosene, electrical and butane stoves. Scrubbing of the produced gas for removal of impurities such as but not restricted to hydrogen sulphide and carbon dioxide will improve the heating efficiency of the gas.

Furthermore, since lemon grass is a well-recognized medicinal plant in Nigeria as a result of its citral content, the leaves remaining after boiling could be used as feedstock for biogas production. The boiling for medicinal purpose would therefore be a form of pre-fermentation for optimum gas production. Thus, the leaves which would have been disposed as wastes (after medicinal use) can be adapted for energy production. A further study to evaluate the biogas potential of boiled lemon grass compared with that of the fresh lemon grass is therefore recommended.

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