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Comparative evaluation of biogas production from Poultry droppings, Cow dung and Lemon grass

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HIGHLIGHTS

- Biogas was generated efficiently from Poultry droppings, Cow dung and Lemon grass.
- Lemon grass produced less volume but better quality gas than other two substrates.
- Lemon grass also showed highest cooking rate in the cooking test conducted.
- Anaerobic digestion was efficient in pathogen and some parameters reduction.

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ABSTRACT

The study explored the production of biogas from Lemon grass, Cow dung and Poultry droppings. The three substrates were pre-fermented according to standard methods. Six (6) kg of each pre-fermented substrate was mixed with water in ratio 1:1 v/v to form slurry and digested for 30 days. A total of 0.125 m^3, 0.191 m^3 and 0.211 m^3 of biogas were respectively produced from the Lemon grass, Cow dung and Poultry droppings with deviations of 0.00234 m^3, 0.00289 m^3 and 0.00484 m^3 respectively. The cooking test carried out revealed that the scrubbed gas had higher cooking rates for water (0.12 L/min, 0.085 L/min and 0.079 L/min for Lemon grass, Cow dung and Poultry droppings respectively) while the cooking rates for unscrubbed gas were 0.079 L/min, 0.064 L/min and 0.06 L/min respectively. The pH of the medium fluctuated optimally between 6.5 and 7.8. The research demonstrated that Lemon grass produced less volume but better quality biogas compared to Cow dung and Poultry droppings.

1. Introduction

Energy has been identified as a very important factor in the economic, social and political development of any nation (Ojolo et al., 2012). Although the abundant hydrocarbon natural resource (crude oil and natural gas) in Nigeria has been identified as the mainstay of over 80% of revenues to the nation, it has not served as a catalyst for economic growth neither has it served as the major source of energy in the mix of energy supplies (Machunga-Disu and Machunga-Disu, 2012). The annual statistical bulletin of the Organization of Petroleum Exporting Countries (OPEC) 2009 revealed that Nigeria's proven crude oil reserves and natural gas are 37.2 billion barrels and 5292 trillion standard cubic meters, respectively.

In addition, the estimated reserve of tar sands and proven reserves of coals are about 30 billion barrels of oil equivalent and 639 million tonnes (with inferred reserves of about 2.75 billion tonnes), respectively (Adaramola and Oyewola, 2011). On the assumption that new oil and gas reserves are not discovered, it is estimated that the crude oil reserves should run out within the next 50 years and the proven natural gas reserves should run out in about 115 years (Ojolo et al., 2012). This inadequacy of energy supply limits economic growth, restricts socio-economic activities and adversely affects the quality of life. The need for increased energy especially in Sub-Saharan Africa where only 58% of the population is served with safe and clean water supply (WHO, 2005) has made biogas technology a welcomed development. The development of biogas technology will facilitate the achievement of the

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Millennium Development Goals (MDGs) of the United Nations (Alfa et al., 2014).

Furthermore, rising crude oil prices has forced nations of the world to think about alternative energy sources. Of the different available energy options, solar energy is considered the most effective, and can even afford the environmental protection of plants. Plants are known to convert and store enormous solar energy in biomass, harnessing these energy stores will best replace all fossil energy resources in the future (Deublein and Steinhauser, 2008). Unfortunately the new alternative energy sources like the solar, hydro, wind etc. require huge economic investment and technical power to operate, which seem to be very difficult for the developing countries like Nigeria.

Moreover, economic growth and heavy consumption of fossil natural resources are responsible for pollution leading to global warming and the production of acid rain (Thakur, 2006). Biogas technology can serve as a means of reducing energy poverty, which has been a serious barrier to economic development in Africa (Alfa et al., 2012).

Biogas is a renewable, high quality fuel, which can be utilized for various energy services such as heating, combined heat and power, or a vehicle fuel instead of the current practice of using fossil fuels (Machunga-Disu and Machunga-Disu, 2012). Biogas technology can serve as a means of reducing energy poverty, which has been a serious clog in the wheel of economic development in Africa (Adaramola and Oyewola, 2011). The methane and energy content of the gas generated usually varies and is dependent on the physical and chemical properties of the substrate used (Chenxi and Bruce, 2011).

Animal excreta especially Poultry droppings contains more easily degradable organic materials, than other agricultural waste products, but is also known to have a high content of lignin and lignocellulose biofibers (40–50% of the total solids) (Triolo et al., 2011). Besides, a high concentration of poultry manure (PM) with solids content of more than 20%, makes this substrate difficult to digest, therefore, dilution of Poultry droppings to 3–6% total solids provides good mixing conditions in anaerobic digesters (Callaghan et al., 2002). Another option for improving biogas yields is co-digestion of poultry manure with other organic wastes which offers several benefits including increasing biogas production, increased loading of readily biodegradable organics, improved balance of nutrients and C/N ratio, dilution of toxic substances, a better quality gas, and cost reduction due to the ability to process several substrates in one installation (Wang et al., 2012, 2013). Digestion of Poultry droppings have been carried out by many researches in combination with other organic wastes including whey, rice and wheat straws, municipal solid wastes, hog manure, buffalo manure, dairy manure and sewage sludge with different results obtained (Callaghan et al., 2002; Gelegenis et al., 2007; Borowski and Weatherley, 2013).

Past biogas researches in Nigeria utilized animal dung, kitchen wastes and human excreta as feedstocks while the use of succulent plants have been limited to water lettuce, water hyacinth, cassava leaves, *Eupatorium odoratum* and *Cymbopogon citratus* (Ubalua, 2008; Alfa et al., 2012; Dahunsi and Oranusi 2013). Although high quality biogas was recorded from the digestion of these plants, their utilization is bedeviled with the challenge of limited distribution across the nation. These plants are mostly found in the riverine regions of the country which makes them regional substrates. In other parts of the world, powdered leaves of some plants and legumes like *Gulmohar*, *Leucacena leucocephala*, *Acacia auriculiformis*, *Dalbergia sisoo* and *Eucalyptus tereticornis* have been found to increase biogas generation by (Santosh et al., 2004). Although Lemon grass (*C. citratus*) is more widely distributed in Nigeria than the other plants previously tested, its exploration for biogas production is limited. Lemon grass can tolerate a wide range of soils and climatic conditions but its optimal growth is achieved on well-drained, fertile and sunlight exposure sandy loam soil (Sugumaran et al., 2005).

The objective of this study therefore is to compare the production of biogas from Lemon grass (*C. citratus*) with that from well familiar substrates (Cow dung and Poultry droppings) and we hope that the outcome will make a good case for further research and investment into Lemon grass cultivation and utilization in Nigeria.

2. Methods

2.1. Materials

Three (3) identical 25 Litre-biogas digester tanks each of height 0.5 m and diameter 0.25 m were fabricated from Galvanized steel which is strong enough to withstand the weight and pressures of the contained slurry. The cylindrical shape was adopted to enhance better mixing. The tank is air tight and is clearly placed above the ground level and outside the shed where it is exposed to the sunlight for partial heating. The three identical 12.1 L gas holder tanks each of height 0.25 m and diameter 0.25 m were 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. Plastic hose was used to connect each digester to its gas collection system and the biogas stove burner while plastic valves were installed to control the gas flow.

2.2. Fabrication of digesters, biomass collection, slurry preparation and digester loading

The design volume of the three identical batch flow anaerobic digesters was sized according to the amount of volatile solids that must be treated and the period of time the material will remain in each of the digester (retention time). The design of the digesters was based on Ajoy Karki's Biogas model (Karki, 2002) incorporating the separate floating gas holder system for ease of daily measurement of gas volume. The cylindrical shape was adopted to enhance better mixing. The digester is a separate component, with the gas holder in a separate water jacket.

The theory behind the design is simply "downward delivery and upward displacement" following the example of Uludag-Demirer et al. (2008). The slurry on fermenting in the digester produces gas. This gas is delivered to the bottom of the water jacket via a pipe; the pipe extends above the surface of the water level (water seal) in the water jacket. 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.

The Lemon grass (*C. citratus*) was harvested from gardens around some houses within Area BZ Staff Quarters, Ahmadu Bello University, Zaria and crushed to smaller particles using the Hammer mill before they were transported to the research field for further pre-treatment. Cow dung, on the other hand, was collected in sacks fresh and free from impurities from the Zango abattoir and transported to the research ground while Poultry droppings were obtained (fresh and free from impurities such as wood filings) from the Poultry Department (Deep Litter section) of the National Animal Production Research Institute, Shika-Zaria and transported to the research site.

Partly decomposed slaughter house waste was used as seed material for the substrates digested in this study. The Lemon grass (*C. citratus*) was pre-fermented for a period of 40 days while Cow dung and Poultry droppings were pre-fermented for a period of 15 days each in respective plastic drums (Karki et al., 2005). The longer period of pre-fermentation for the Lemon grass was as a