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Energy production from biogas: A conceptual review for use in Nigeria

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ABSTRACT

The authors reviewed the global methods of biogas production, enrichment, compression and storage for energy generation and highlighted its potential application in meeting energy needs in developing countries, with emphasis on Nigeria. Biogas is becoming an increasingly important source of clean energy for rural and urban areas in developing countries, as can be seen by the increased construction of biodigesters. Biogas digester technology has been domesticated in Nigeria and a number of pilot biogas plants have been built with majority (over 75%) of operational Nigerian manure digesters on piggery, cattle farms or abattoirs. A trend is now seen among academic institutions in Nigeria in the design and construction of biogas digesters, for instance, the Usman Danfodio University Biogas Plant, the Obafemi Awolowo University plant, the University of Ibadan prototype (with a patent), Non-Governmental Organisations (NGOs) and Private sector involvement, which shows increasing interest and availability of biogas technology. Biogas is a renewable fuel that is 60–70% methane and can be used to power household appliances and generate electricity using appropriate technologies. These technologies include Biogas digesters which are being used to collect farm animal waste and convert it to biogas through anaerobic bacterial processes. The biogas generated is enriched through a process of scrubbing to obtain at least 95% purity. The current research focus of the authors towards improving biogas yield, enrichment, compression and storage for use in Nigeria is discussed. The current findings indicate that there are economic advantages for the utilisation of biogas in developing countries like Nigeria.

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1. Introduction

Biogas is the name of the mixture of carbon dioxide, CO_2 and inflammable gas Methane, CH_4 which is produced by bacterial conversion of organic matter under anaerobic (oxygen-free) conditions [18]. It originates from Methanogens (methane producing bacteria) in the process of bio-degradation of organic material under anaerobic (without air) conditions. Biogas is a source of renewable energy. It has the advantages of being an eco-friendly source of energy in that the calorific value of biogas is equal to that of half litre of diesel oil (6 kWh/m^3). Biogas is fully capable of replacing other rural energy sources like wood, hard coal, kerosene, plant residues, and propane. Hard coal possesses a calorific value of 8.5 kWh/kg per 0.7 kg. In a developing country like Nigeria where more than 60% of the rural dwellers rely on wood and hard coal for energy, over 50 million metric tonnes of fuel wood is consumed annually, a rate, which exceeds the replenishment rate through various afforestation programmes [19]. Local capability exists in Nigeria for building both floating dome and fixed dome biodigesters using a variety of bio-resources. Biogas digester technology has been domesticated in Nigeria and a number of pilot biogas plants have been built with majority (over 75%) of operational Nigerian manure digesters on piggery, cattle farms [19] or abattoirs [1]. A trend is now seen among academic institutions in Nigeria in the design and construction of biogas digesters, for instance, the Usman Danfodio University Biogas Plant, the Obafemi Awolowo University plant [2], the University of Ibadan prototype (with a patent) [24], Non-Governmental Organisations (NGOs) and Private sector involvement [1], which shows increasing interest and availability of biogas technology. Increasing interest in producing renewable energy has led to a renewed interest in the anaerobic digestion of manure [1] and Nigeria has the capacity of producing an estimate of 15.319 milion tonnes of agro waste and municipal solid waste which can be used for generating biogas [16,19]. However, biogas has not been commercialised in Nigeria, most of the biogas plants are situated on farms and are used as it is produced, mainly for cooking. The main problems associated with the commercialisation of biogas are:

- Its low energy content per unit volume.
- It is difficult to liquefy.
- Small scale production of biogas.

For the commercialisation of the biogas, it is important to make it portable and compatible for various commercial purposes. For that, the energy content for a particular volume must also be increased. This requires the compression of the gas to as higher pressures as possible [3]. For a successful commercialisation of biogas in Nigeria, it is necessary to increase its energy content through the purification of the gas to remove the incombustible gases and compress it in order to make it portable.

2. Biogas digesters

For the production of biogas, organic material, such as animal and plant waste is placed along with water into an oxygen free tank, or in some cases plastic membrane for digestion which is known as the digester. The organic matter is fed into the vessel and the resulting gas is outlet through a pipe that inlets above the waste liquid levels in the tank. Similar mechanisms are achieved using plastic membranes, which are contained in secure enclosures in the ground. Various digester designs exist.

2.1. Types of biogas plants

The three main types of simple biogas plants are:

balloon plants,
fixed-dome plants, and
floating-drum plants [14].

2.1.1. Balloon plants

The balloon plant consists of a digester bag (e.g. PVC) in the upper part of which the gas is stored. The inlet and outlet are attached directly to the plastic skin of the balloon. The desired gas pressure is attained through the elasticity of the balloon and by added weights placed on it.

2.1.2. Fixed-dome plants

The fixed-dome plant consists of a digester with a fixed, non-movable gas holder, which sits on top of the digester. When gas production starts, the slurry is displaced into the compensation tank. Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank.

2.1.3. Floating-drum plants

Floating-drum plants consist of an underground digester and a moving gas-holder. The gas holder floats either directly on the fermentation slurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. The gas drum is prevented from tilting by a guiding frame. If the drum floats in a water jacket, it cannot get stuck, even in substrate with high solid content.

3. Biomass for the production of biogas

In principle, all organic materials can ferment or be digested. However, only homogenous and liquid substrates can be considered for simple biogas plants. It is necessary to dilute the organic material (waste, wastewater, excrement etc.) with about the same quantity of liquid.