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ORIGINAL ARTICLE

Comparative study of the optimal ratio of biogas production from various organic wastes and weeds for digester/restarted digester

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Abstract This study carried out a comparative analysis of the rates of production of biogas from various organic wastes and weeds which enabled the determination of optimal ratio of poultry droppings to domestic wastes. Digester was prepared for the anaerobic fermentation of the domestic wastes and weeds. The gas production did not begin until the 7th day and increased steadily at first, and then increased sharply until it reached its peak on the 18th day before declining. The total gas produced within the 22 days of experimentation was 1771 cm^3. The maximum volume of gas amounting to 809 cm^3 was produced by the sample containing 50% poultry dropping and 50% weeds. This indicates that this sample possesses the best C/N ratio of all the samples prepared. For restarted digester, gas production began on the 2nd day as against the 7th day with no restarted digester and the gas production peaked earlier.

1. Introduction

The process of producing biogas by the anaerobic fermentation of organic matter is a technology which is gaining popularity daily and is more widely adopted for use. This development is due to its ability to provide relief to man from two of the problems encountered in the course of living from day to day. They are the problem of how to acquire energy in sufficient amount for purpose of cooking, heating, lighting and running of machinery, on one hand and the problem of proper disposal of waste in a manner that it will not cause harm to man or damage the environment on the other. The source of energy is grouped into two categories namely renewable and non-renewable sources of energy and biogas belongs to the former.

Organic wastes are of plant and animal origin and are biodegradable, i.e. they can be broken down by micro-organism. Example includes crop residue, animal dropping and animal carcasses. Ye et al. (2008) observed that organic wastes are usually treated by composting, stabilisation ponds, aerobic digestion, and anaerobic digestion. The treatment helps to reduce the harmful microbes present in the waste and make them more stable. Anaerobic digestion serves a dual function

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by treating the waste and obtaining biogas by the anaerobic fermentation of organic waste thus serving a dual function of treating organic waste to make them more stable and less harmful to the environment, and providing energy for cooling, lighting, heating, and running of machinery.

1.1. Organic wastes

Organic wastes are materials, which are of plant and animal origin. They include the remains of dead plants and animals such as stem, leaves, twigs, roots, feathers, hair, blood and opals. As well as waste generated by animals e.g. dung. They are said to be biodegradable i.e. they can be broken down by micro-organisms into smaller molecules. Feijoo et al. (1995) observed that the bacteria act on the complex molecules such as proteins, fats and carbohydrates and break them down to simpler molecules like ammonia, carbon dioxide and nitrides. They are considered as nuisance due to their effect on the environment. They are highly unstable due to the gradual degradation (Yañez et al., 2009). This is because as the decomposition occurs, oxygen is used up. They are also considered as nuisance because of their odours, pH, etc. Treatment of organic waste involves the reducing of the odour level, the quantity and stabilising the organic waste before disposal. Methods used for treatment include composting, stabilisation ponds, aerobic digestion, anaerobic digestion, and incineration. There is an increasing use of anaerobic digestion for the treatment of waste. This is due to the ability to obtain energy from the waste as it is being treated. The process produces a gas known as biogas which can be used for heating, cooking, and running of machinery. Vaclar and William (1980) stated that biogas production has been greatly exploited by China and India, most especially in the rural areas thereby reducing dependence on fossil fuels.

1.2. Biogas

Biogas is the gas obtained when organic matter decomposes in the absence of oxygen. According to Hendriks and Zeeman (2009), it is called biogas because it is obtained from biomass (plant and animal remains). It is produced by the action of anaerobic microorganisms on organic matter. They metabolise the organic matter with the aid of enzymes reducing the large molecules e.g. carbohydrate, proteins and fats to smaller molecules e.g. CH_4 and CO_2 to H_2. The process requires the complete absence of oxygen to take place. The gas produced is a mixture of gases such as methane, carbon (IV) oxide, and hydrogen sulphide.

The gas which is also known as marsh gas, sewage gas, and dun gas is colourless and flammable with a characteristic odour. It contains methane (45–80%), carbon (IV) oxide (27–45%), nitrogen (0.5–3%), hydrogen (1–10%), carbon monoxide (0.1%), oxygen (0.1%), and hydrogen sulphide present in trace amounts. It has a calorific value of 5.5–7.5 kwh/m^3. It rises slowly in air and dissipates due to methane which is slightly lighter than air and carbon (IV) oxide which is heavier than air. Himanen and Hänninen (2011) stated that the composition of the gas is dependent on the nature of the material used as plants tend to produce gas with more amount of carbon (IV) oxide. The amount of gas produced per kg of material also varies with the type of material used. The quality of biogas produced depends on the carbon to nitrogen (C/N) of the materials used. The gas is difficult to compress as much as 34,000 KN/m^2 to liquefy it. Biogas can be used for cooking, heating and running of machinery. Most times, special modifications are needed for an efficient use of the gas.

Carbon (IV) oxide and Ammonia are both removed by passing the gas through a solution of calcium hydroxide ($Ca(OH)_2$). They both react with the solution to give calcium carbonate and Ammonium Carbonate respectively. Hydrogen sulphide is removed by passing the gas through a desiccant such as calcium chloride, (Kompogas, 2011). The calcium chloride can be regenerated by heating it to drive off the water. For cooking purposes gas may be used without scrubbing or scrubbing will only involve removal of H_2S and water. This is because methane has a flammability limit between 5% and 15% by volume of air. Thus leaving the carbon (IV) oxide enables it to attain this mixing ratio with air easily. When the gas is used for running machinery, H_2S, H_2O and NH_3 are removed to prevent corrosion of metal parts. Carbon (IV) oxide is removed to increase combustibility of gas. Biogas produced may be used directly from the digesters or it may be stored in tanks which may be fixed roof or float roof type. The floating roof type enables compression of gas.

1.3. Methane

The importance attached to biogas is due entirely to the presence of methane in the gas. It is the major constituent of the gas making up (45–80%) of the biogas produced. It is a member of the alkane or paraffin series of hydrocarbons with a general formula $C_nH_{2n+2.}$ It has a molecular formula of CH_4, with a molecular mass of 16 g. It is also called a marsh gas because it is formed by anaerobic decomposition of vegetable matter in swampy land. Coal miners know it as fire damp because mixtures with air are combustible. It is a major constitute of natural gas and coal gas. It is ubiquitous in soils, fresh water and marine sediments, takes oceans and the atmosphere. Methane is a gas at room temperature with a boiling point of −16 °C and a melting point of −180 °C. It is a colourless, odourless, and tasteless gas, it has a density of 0.65 g/dm^3 at 20 °C, and is therefore less dense than air. It has an upper flammability limit of 15% by volume of air, and a lower flammability limit of 50% by volume of air.

1.4. Anaerobic digesters

Anaerobic digesters are containers or enclosures from which oxygen has been restricted with an outlet for gas. They are artificial oxygen-deprived environment for the decomposition of organic matter. Biogas produced during the anaerobic decomposition of the organic matter leave the gas outlet provided on the digester. They can be constructed from drums, tins, concrete, bottle, etc. The size of the digester depends on the scales of operation. It is basically an air-tight container with an outlet for gas. The gas may be collected with a separated gas collector or used directly from the digester. The digester may be operated as a batch or continuous process, (Dinsdale et al., 2000).

1.5. Anaerobic fermantation

According to Chonker (1983), biomethanation involves the anaerobic fermentation of CO, CO_2, and H_2 to methane,