RESEARCH ARTICLE OPEN ACCESS

Methane Generation from Cow Dung with the Aid of a Termitic Enzyme Using a Locally Fabricated Bio-Digester

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Abstract:

Energy is one of the most fundamental of human needs and it drives human life, and is extremely crucial forcontinued human development. This paper presents the findings of a research that was carried out to determine the generation of biogas from cow dung using a low cost fabricated bio-digester. A cylindrical drum of capacity 100 litres was used as bio-digester and fed with 40 kg of cow dung mixed with warm water in proportions of 2:1. Also, calcium hydroxide (Ca $(OH)_2$) was incorporated into the experiment to remove the carbon(iv)oxide from the biogas produced and termitic enzymes solution to acceleratethe biogas yield. Results from this study shows that the digestion of cow dung resulted in an appreciable biogas yield. Comparing this result with sample of cow dung mixed with warm water in the ratio 1:1 and taking into account the natural state of the waste when collected for experiment, it is of considerable range when compared with the standard values. Ultimately, digestion of cow dung is one way of addressing the problem of insufficient energy supply in developing countries.

Keywords — **Energy, Biogas, Cow dung, Bio-digester, Digestion, Developing Countries.**

Introduction

The world population continues to increase rapidly, while energy consumption is increasing as well (Sözer and Yaldız, 2006). Also, the use of advanced forms of energy, such as electricity, has improved the quality of public lives around the world. However, majority of the people living in developing countries do not easily access such forms of energy and, therefore, they entirely depend on solid fuel forms like wood to meet their basic needs such as cooking and lighting.According to GTZ (2007), cooking accounts for about 90% of all household energy consumption in developing countries. At the same time Okure (2005) observed that over 60% of the total wood produced in developing countries citing Uganda as an example is used as wood fuel in form of either charcoal, especially in the urban areas, or firewood mostly in the rural areas.The scientific principles of anaerobic digestion with its production of methane gas are well known. It has been employed for many years to stabilize the sludge produced by municipal treatment plants while the methane gas has been used as a source of fuel heating or operating a generator. Until recently, anaerobic digestion has been considered too costly to be economically feasible for treating animal wastes. However, as the costs of energy and fertilizers continue to increase, the economics of anaerobic digestion on the farm will become more attractive. Consequently, anaerobic digestion presents us with the unique method of not only treating the animal waste but also reducing one's dependence on the supply of fossil fuels (James, 2002).

Anaerobic digestion is a process by which environmentally hazardous organic wastes from municipal, agricultural and industrial sources may be stabilised. The treatment has many side benefits, most notably the production of methane-rich biogas which can be used to generate electricity and heat. Anaerobic digestion is performed by a consortium of micro-organisms. In the absence of oxygen the anaerobic bacteria break down organic matter producing methane and carbon dioxide. Several other methods of dealing with organic wastes exist, including aerobicdigestion, direct application to land and combustion. These methods either utilize the available biomass as a fertilizer or a fuel, but not both as is the case with anaerobic digestion.

Biogas is a gas produced by anaerobic digestion (in the absence of oxygen) of organic material, largely comprised of methane (about two-thirds). Biogas is often called "marsh gas" or "swamp gas" because it is produced by the same anaerobic processes that occur during the underwater decomposition of organic material in wetlands (IBA, 2016) Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic (without air) conditions. Biogas is a colourless, flammable gas produced via anaerobic digestion of animal, plant, human, industrial and municipal wastes amongst others, to give mainly methane (50-70%), carbon dioxide (2040%) and traces of other gases such as nitrogen, hydrogen, ammonia, hydrogen sulphide, water vapour etc. It is smokeless, hygienic and more convenient to use than other solid fuels (Maishanu*et al*., 1990).The natural generation of biogas is an important part of the biogeochemical carbon cycle. Methanogens (methane producing bacteria) are the last link in a chain of micro-organisms which degrade organic material and return the decomposition products to the environment. In this process biogas is generated, a source of renewable energy (Energypedia, 2016).

Raw materials for biogas fermentation such as cow dung, poultry waste, water hyacinth, straw, weeds, leaf, human and animal excrement, domestic rubbish and industrial solid and liquid wastes are easily available. Biogas production systems have several benefits, such as eliminating greenhouse gas, reduction of odor, betterment of fertilizer and production of heat and power. Usually efficiency of biogas plant varies with the type of digester, the operating conditions, and the type of material loaded into the digester.

Termites are a large and diverse group of insects consisting of over 2600 species worldwide. With over 664 species (Wanyonyi*et al*. 1984), Africa is by far the richest continent in termite diversity (Eggleton 2000). Methane is produced in termites as part of their normal digestive process. Methanogenic (Methane producing) bacteria are found abundant in the guts of termites.They are source of bio-fuel (methane gas) which is a renewable and sustainable source of energy (Akinmusere*et al.,* 2017).

A biogas production system must be specially designed and requires regular attention by someone familiar with the needs and operation of the digester. Associated manure handling equipment and gas utilization components are also required. The digester does not remove significant nutrients and requires environmentally responsible manure storage and handling system. A well designed and operated digester will require modest daily attention and maintenance. The care and feeding of a digester is not unlike feeding a cow or a pig, it responds best to consistent feeding and the appropriate environmental for temperature and anaerobic- oxygen free conditions. The earlier a problem in operation is identified, the easier it is to fix and still maintain productivity (Corral and Argelia, 2007). This paper therefore aims at generating methane gas from cow dung with the aid of a termitic enzyme using a locally fabricated bio-digester.

Justification of the Study

The use of fossil fuels as primary energy source has led to global climate change, environmental degradation and human health problems (Adeniran*et al.,* 2014). In developing countries like Nigeria, Libya, Ghana etc. which rely on fossil fuels as their main energy source, with time the crude oil which was discovered at a particular point in time may eventually come to an end unexpectedly. Therefore, an alternative means of generating energy is imperative so as not to put all one's egg in one basket as a nation as it has been established that renewable energy resourcesappear to be one of the efficient solutions to the problems resulting from theuse of fossil fuels (Hankisham and Sung, 2003). A significant body of research that has been published both formally and recently discussed largely on biogas production from different animal wastes either as a sole waste or as a co-digestion with other wastes among which cow wastes took quite a great portion. Ofoefule *et al.* (2010) in his research on biogas production from paper waste and its blend with cow dung observed that blending the paper waste with cow dung or any other animal waste give sustained gas flammability throughout the digestion period of the waste. Godi*et al.* (2012) who worked on the effect of cow dung variety on biogas production concluded that from the varieties of cow dung used, the White Fulani, a predominant variety in Nigeria and the West-African sub-region has the highest percentage of biogas. He further opined that the methane from this breed can be used to ameliorate the energy crisis, improve standard of living, generate employment and reduce incidences of deforestation in developing countries. It has also been reported that cow dung coming from a rumen animal is known to contain the native microbial flora that aids in faster biogas production and it is a very good starter for poor producing feedstock's (Misiand Forster, 2001, Yadvika*et al*., 2004, Ofoefule *et al*., 2010). All these therefore leaves room for more research to be done on biogas production using cow dung with an accelerated enzymes gotten from termites to improve biogas yield as applied in this research.

Methodology

This research was a laboratory based work; hence, majority of the facilities in the water and environmental laboratory of the Federal University of Technology, Akure, Nigeria were utilized.At the inception of this research, local materials used in fabricating the bio-digester were procured from the Oba's market in Akure. The materials acquired for the bio-digester are 100litres drum, two 2½ inches adaptors, half-length of 2½ inches pipe, one length of ¾inch pipe, control valves of different sizes, a white keg, uPVCAbro gum and a silicon sealant(Doctor fix), gas hose and 45º angle elbows.

Other tools and apparatus used are hacksaw, soldering iron, steel rod, bolts and nuts, grinding disc, washer, thermometer, bowl and bucket, stirrer, motorcycle rubber tyre tube, iron clips, steel tape, measuring cylinder, boiler, spatula, beaker, gas cylinder. Waste and chemical used are Cow dung, Calcium Hydroxide $Ca(OH)_2$, Distilled water and Tap water.

Experimental Procedures

The bio-digester was initially constructed with the following components namely digestion chamber, slurry inlet and outlet, gas outlet and cover and stirrer.

Each of these components as constructed can be seen in Plate 1 to Plate 4.

Plate 1: The Digestion Chamber

Plate 2: The Slurry Inlet and the Outlet

Plate 3: The Gas Outlet with the fixed Cover

Plate 4: The Stirrer Mechanism

The waste (cow dung) used was collected from a private agricultural farm along Igoba- Ado road, Ondo State. In the course of the collection of the waste, necessary health precaution was taken by wearing hand gloves and nose mask.

Preparation of Calcium Hydroxide Solution to Remove Other Gases.

As methane is being produced from the digestion of the waste, other gases such as carbon (iv) oxide and hydrogen sulphide, are also produced. Such gases have to be removed with an appropriate prepared solution of calcium hydroxide thereby leaving only methane gas. 500g of $Ca(OH)_2$ was measured into a conical flask and 1000cm^3 of distilled water added to it, thoroughly mixed. The conical flask was filled to ⅔ of it and the concentration used was calculated as 0.014mol/cm^3.

Extraction of Enzyme from Termites and its Application

From earlier works carried out by Hoda-Rahimi (2015), it was observed that enzymes from termite can serve as a catalyst to hasten and increase methane production. The process of extracting enzyme from termite was then incorporated into this research to aid the production of biogas from cow dung and to increase the yield of the biogas that will be produced. The processes taken to achieve this are as follows.

Live termites were caught from their termitarium and then brought to the laboratory for further work. They were subjected to anaerobic condition for four days to put them to death, after which their heads were then separated from their bodies using a forceps. Their bodies were then sterilized using alcohol (ethanol) and they were crushed inside a mortar and pestle. Warm water was then added to the grinded termites, stirred, and filtered. The filtrate which is the prepared enzymes was then added to the waste in the digester.

Experimental Set-up

The bio-digester that was used for the work was firstly constructed. After, the cow dung was poured into a bucket and 40 kg of it was weighed using a mass weighing balance, the waste was then mixed with warm distilled water. The mixing ratio adopted for this work is 1: ½ (i.e. the waste to water ratio is 40 kg of waste to 20 litres of distilled water). The mixing of the waste and water was done inside a container with a rod to form slurry which was then gently fed into the digester through the inlet. After feeding the digester, gas hose was connected from the bio-digester to the collecting cylinder jar. Firstly, a hose was connected from the pipe of the gas outlet to the inlet of the conical flask which contain the solution of the prepared calcium hydroxide and this was done to remove the carbon (iv) oxide and other minute gases produced alongside with the methane gas. After, another hose which serves as the outlet was connected to the keg from the conical flask, the hose being held fixed with a candle wax to prevent leakages. The calibrated keg was allowed to rest with its side and the gas was collected via the upwarddelivery gas method. Finally, a gas hose was connected to the cylinder gas jar from the calibrated keg (Plates 5 and 6).

Plate 5: The Experimental Set-up (Front view)

Plate 6: The Experimental Set-up (Rear View)

Results and Discussion

The experimental set-up was for 65 days. The temperatures of both the bio-digester placed at the back of the laboratory and the laboratory room were taken everyday and their averages were calculated. Also, noticeable changes in the biogas produced were recorded every 15 days afterthe initial fermentation period of 20 days for three times. The results are presented and discussed in Figures 1 to 5.

During the fermentation period (i.e. when the dung was allowed to decompose) after feeding the bio-digester, no biogas was produced. The fermentation period takes twenty days which seems long. This definitely can be explained by the feeding composition of cow because cows feed mainly on fibrous material which takes a longer time to break down by micro-organisms. This finding is in conformity to that, from the works of Babatola (2008) in Akure, and Ukpai and Nnabuchi (2012) in Abakaliki, both in Nigeria. Also, Ozor*et al.* (2014) agreed to their observations.

The plots of the cumulative change in methane produced against the number of days and the biogas produced for each day against the number of days are presented in Figures 1, 2 and 3.

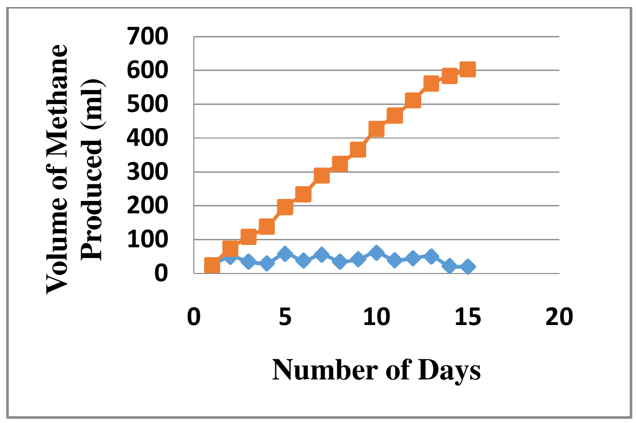

Figure 1: Plot of Methane Gas Generated for the First 15 Days after Fermentation

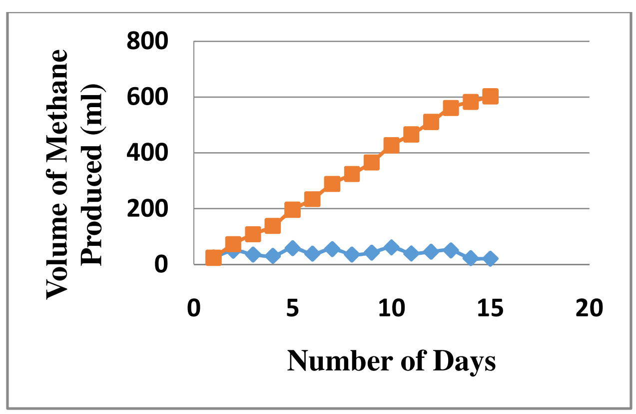

Figure 2: Plot of Methane Gas Generated for the Second 15 Days after Fermentation

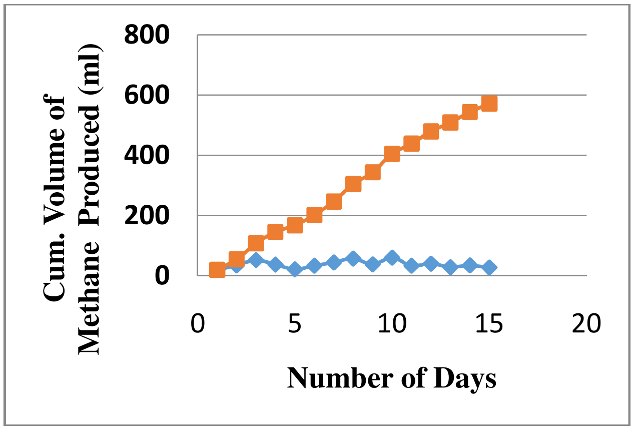

Figure 3: Plot of Methane Gas Generated for the Last 15 Days

It could be observed that there was an increment in the methane generated for the first four days, two days, and three days as shown in Figures 1, 2, and 3 respectively which later decreases and again increases over a considerable range which was achieved by the introduction of the enzyme into the waste after the fermentation period to accelerate the rate of production of the methane gas. This observation is similar to that of Hoda-Rahimi (2015). Therefore, we can infer that the enzyme usedaffects the rate of biogas yield.

Effect of Temperature on Methane Gas Yield

Figures 4 and 5 present the plots of the cumulative volume of methane gas produced against average temperature. Figure 4 presents the plot of the cumulative volume of methane gas produced against average temperature for the fermentation stage while Figure 5 shows for the methane production stage.

From Figures 4 and 5, it was observedthat temperature directly affects the digestion process by controlling microbial growth rates in Figure 4. This observation is similar to that of Otun*et al.* (2015).This shows the rate differences for the reduction of organic matter for temperatures ranging between 20°C and 30°C while for Figure 5, the temperature change are characterised by three thermal zones of microbial activity, namely, psychrophilic, mesophilic, and the thermophilic. Reactions rates are slowest in the psychrophilic zone and turn out to be the highest in the thermophiliczone. Conversely, digestion stability is least stable in the thermophilic zone; sudden changes will cause the digestion process to be upset more quickly and the recovery to be more rapid than in the mesophilic or psychrophilic zones. The converse is true for the other two zones. Also, methanogenic bacteria are very sensitive to sudden temperature changes and therefore digestion temperature should be maintained at a constant level to ensure operational stability.

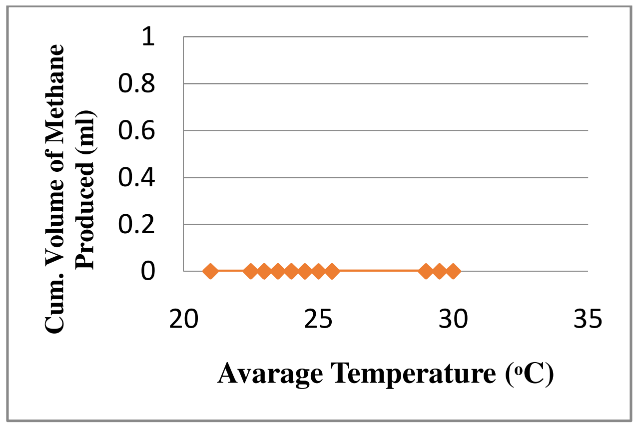

Figure 4: Plot of the Cumulative Volume of Methane Produced against Average Temperature during Fermentation.

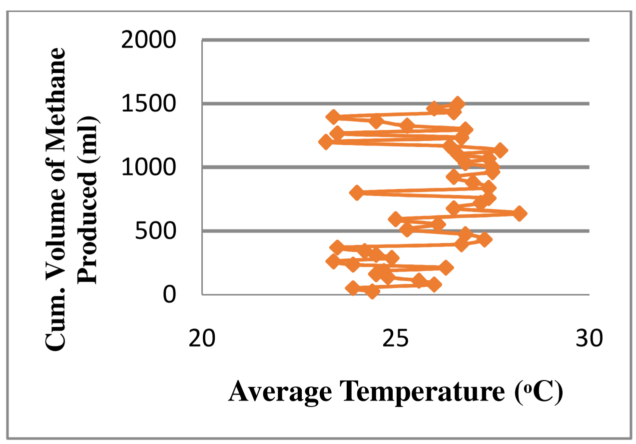

Figure 5: Plot of Cumulative Volume of Methane Gas Produced against Average Temperature

Conclusion

From the experiment, the total methane yielded is 1570 ml and the total biogas yield is 2300 ml. From this result, it could be said that methane is 68% of the total composition of biogas generated from cow dung. The standard percentage range of methane permitted for cow dung is 40 - 70% as recommended by the United State Environmental Protection Agency.

Recommendations

Based on the research, the following recommendations are hereby made;

- Bio-digesters that are not too expensive to construct should be made for household usage to improve the standard of living of families that can't afford buying fossil fuel e.g. kerosene.
- Deep and further research should be done on getting alternative ways of extracting enzymes from termites to aid and facilities maximum biogas production.
- Further researchshould also beconducted to evaluate the effects of input materials on the characteristics of biogas because it may uncover new trends related to biogasproduction efficiency and constituent quality.

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