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Research Paper

Fabrication of a Bio-Digester and Generation of Biogas from Blends of Cow Dungs and Chicken Droppings.

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ABSTRACT
Nigeria is a big agrarian country blessed with rich agricultural resources (agricultural residues and animal wastes) that can be used for biogas production. This study therefore focussed on the fabrication of a bio-digester and generation of biogas using cow dungs and chicken droppings as substrates.A biogas digester with a capacity of 6.8litres was designed and fabricated with a capacity of 880 ml. The substrate (cow dungs and poultry droppings) was mixed with water in the ratio 1:1.The retention time used for this experiment was 14 days during which the daily internal temperature reading was taken in order to determine temperature variation and the influence of sunlight on the production rate. At the end of the first 7 days of the experiment, a total of 506.8ml of biogas was produced and at the end of another round of period of 7 days, 448ml of biogas was actualized.Upon critical analysis, it was observed that the biogas produced has 58.79% of methane (CH_4), 36.92% of carbon dioxide (CO_2), 2.41% of oxygen (O_2), 0.01% of hydrogen sulphide (H_2S) and 1.87% of water vapour. The methane has the highest percentage which represents the main source of energy and indicates that the experiment was carried out under anaerobic condition

***Key Words**: Energy, Biogas, Methane, Temperature variation, and agrarian.*

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I. INTRODUCTION

Energy is one of the most important factors to global prosperity of which its importance cannot be over emphasized ranging from domestic purposes (heat energy for cooking food and heating water), industrial use (for heating furnaces and running electric motors) and transport use which run on fuel. It is also important because it is the cornerstone of economic and social development [1].

There is energy shortage worldwide including Nigeria as a result of less potential energy to harness, making hydro-power a less desirable energy source [2]. The projected refining capacity only supports 445,000 barrels per day, and the actual output of these refineries is far below installed capacity [3]. Additionally, the refineries do not capture the gas that is given off in the refining process and it is instead burned as flares [4].

Fossil fuel is one of the principal sources of energy. 86% of all the energy consumed comes from fossil fuels [5]. There are many problems associated with fossil fuels, which include high costs and fluctuation of prices, increase in demand, disruption in supply, and environmental pollution. This is because they give off carbon dioxide when burned thereby causing a greenhouse effect. The environmental pollution is the main contributory factor to the global warming experienced by the earth today [5].

Agricultural residues and animal wastes are increasingly being diverted for use as domestic fuel to displace fossils fuel and reduce environmental pollution and emission of greenhouse gases. Cassava solid wastes, amongst other plant wastes have been widely used [6]. Agricultural residues in their natural forms will not bring a desired result because they are mostly loose and of low density materials in addition to the fact that their combustion cannot be effectively controlled [7].

Nigeria hosts more than 45% of the poultry in the West African sub region and its poultry population is estimated at 140 – 160 million comprising of 72.4 million chicken, 11.8 million ducks, 4.7million guinea fowl, 15.2 million pigeon and 0.2 million turkeys [8]. This figure accounts for 71.38% of the total livestock kept in the country and supplies 17% of animal protein need of the population [9]. Therefore; poultry manureis agood feedstock for biogas processes.

Biogas produced from animal waste is widely used as a renewable energy source; this source of energy is regarded as cheap and cleans [10]. Chicken waste is being used as feedstock for biogas digesters; chicken manure is consisting not only from bird extract, but may also have feathers, and wood chips or saw dust. Through the anaerobic fermentation these complex organic chicken manure are converted to organic acid which transformed finally to a biogas by microorganisms. The slurry which is remaining after this process is rich in nutrients and could be used as bio-fertilizers and soil amendment.

Biogas is a mixture of methane and carbon dioxide, produced by the breakdown of organic waste by bacteria without oxygen (anaerobic digestion). It contains methane and carbon (IV) oxide with traces of hydrogen sulphide and water vapour. It burns with pale blue flame and has a calorific value of between 25.9-30J/m3 depending on the percentage of methane in the gas. Biogas production is a profitable means of reducing or even eliminating the menace and nuisance of urban wastes in many cities in Nigeria [11]. Consequently, biogas can be utilized in all energy consuming applications designed for natural gas.

Biogas is commercially produced from energy crops and waste materials such as manure, wastewater sludge, and municipal solid waste. However, the biodegradability of different waste streams differs depending on their composition. Sugars and starch are easy degradable, lipids and proteins are intermediately degraded, while cellulose is not easily degradable during anaerobic conditions.

Buffiere et al [12] found a direct correlation between the absolute biodegradability and the sum of the lignin and cellulose content of different waste streams. The higher the lignin and cellulose content was the lower biodegradability was obtained. Therefore, in order to improve the biodegradability of lignocellulosic materials a pre-treatment is needed to open up their compact structure [10]. There are several methods that have been investigated for the pre-treatment [10] including mechanical, physical, thermal, and chemical (i.e., alkali, acidic, oxidative) as well as biological methods. These different pre-treatment methods are well investigated for ethanol processes, however, only a few studies exist regarding the enhancement of biogas production.

Mechanical pre-treatments result in no inhibitors and by reducing the particle size of the substrates usually lead to increased methane production. However, these methods have high energy demands and are not economically attractive [13]. Among the chemical pre-treatment methods, treatments with alkaline have been proved to effectively improve the biological conversion of lignocelluloses. The method was shown to be a promising pre-treatment for improvement of anaerobic digestion of newspaper, corn stalk, hardwoods, softwood, and paper tubes [14].

II. LITERATURE REVIEW

Concept of Anaerobic Digestion

Anaerobic digestion is the controlled degradation of organic waste in the absence of oxygen and in the presence of anaerobic micro-organisms [16]. The digestion process is carried out using an airtight reactor and other equipment used for waste pre-treatment and gas retrieval. The process generates a product called "biogas" that is primarily composed of methane, carbon dioxide, and compost products suitable as soil conditioners on farmlands [17].

Monnet, [18] noted that anaerobic digestion can be used either to treat biodegradable wastes or produce saleable products such as heat/electricity, soil amendment etc. the most valuable use of anaerobic digestion is to combine both waste management and the use of the bi-products. It is unlikely that anaerobic digestion will be a viable treatment without using the biogas and the digestate[18]. The qualities of the biogas and digestate will vary depending on the feedstock and its contamination. Furthermore, the use of biogas and digestate can also involve further treatments, such as composting of digestate.

Monnet, [18] further stated that the process of anaerobic digestion can be further divided into four stages: pre-treatment, digestion, gas upgrading and digestate treatment. He noted that the level of pre-treatment depends on the type of feedstock, for example, manures need to be mixed whereas municipal solid wastes (MSW) are sorted and shredded. The digestion stage takes place in the digester. There are different types of digesters with different temperature, mixing devices, etc. the digestion can be either dry or wet depending on the solid content. This implies that the feedstock can be mixed with water and other appropriate liquid wastes such as sludge or re-circulated liquid from digester effluent [18].

The final stage which is the upgrading of the biogas is necessary because it may contain impurities that can damage boilers or engines depending on what the gas is used for. Hydrogen sulphide and water vapour need to be removed for boilers and combined heat and power units. Removal of carbon dioxide will be required if the gas is to be used as natural gas or vehicle fuel [18].

Biochemical Processes in Anaerobic Digestion

Anaerobic digestion is a naturally occurring process of decomposition and decay, by which organic matter is broken down into its simpler chemicals components under anaerobic conditions. Anaerobic microorganisms digest the organic materials, in the absence of oxygen to produce methane and carbon dioxide as end products under ideal conditions. The biogas produced in anaerobic digestion plant usually contains small amount of hydrogen sulphide (H_2S) and ammonia (NH_3), as well as trace amount of other gases [18].

The science underlying anaerobic digestion can be complex. Thus the process is best understood if split into four main stages. The full process of anaerobic digestion occurs in the following four stages [19]; i. hydrolysis, in which complex molecules are broken down to constituent monomers; ii. acidogenesis, in which acids are formed; iii. acetogenesis, or the production of acetate; and iv. methanogenesis, the stage in which methane is produced from either acetate or hydrogen. [20]noted, that digestion is not complete until the substrate has undergone all of these stages, each of which has a physiologically unique bacteria population responsible that requires disparate environmental conditions.

Concept of Biogas

Biogas is a renewable fuel provided by anaerobic digestion of organic material as substrate for biomethanation. The gas is flammable, and obtained through the action of methanogenic bacteria, which work in the absence of oxygen through a process of anaerobic digestion [21]. It contains 50-75% methane, carbon dioxide, hydrogen sulphide and hydrogen. It can be used as fuel in boilers and dual fuel engines. It is made by fermenting organic wastes in biogas digesters.

The wastes are fed into the digesters via the inlet pipe and undergo digestion in the digestion chamber. The temperature of the process is quite important because methane producing bacteria do their work best at temperatures between 30-40^oC and 50-60^oC. It takes 2-8 weeks to digest a load of wastes.

The Renewable Source for Obtaining Biogas

Biomass is the only renewable energy source that can be transformed into gas, liquid or solid fuel by special conversion technologies [22]. This universal renewable energy carrier can be used in a wide range of applications, in the energy sector, for small scale but also larger applications. Presently it is possible to provide this renewable resource for the whole range of applications that require energy input, starting from heating stations until providing electricity to mobile applications for transport.

On average, the industrialized countries contribute to the total biomass energy sources used in a proportion of 9- 13 %, while in developing countries it contributes in a percentage ranging from 5 % to 30 % [24]. Typically, after the biomass was treated, it is transformed into one of the major energy forms: (i) Electricity or (ii) Heat. Range of application and disposal of biomass form the two, very important advantages of biomass. Another major argument for using the energy resources originated in bio–resources is the possibility of protecting the environment and climate. When stored in biomass energy use, greenhouse gases like carbon dioxide are emitted, but this amount is not a supplementary generated product, as it is result from a natural decay processes. Thus bio-energy carriers can be considered neutral in terms of climate damage, particular CO_2 emission.

Solid Bio-Energy Sources

The largest group of solid bio-energy sources includes products made from wood. They are derived from industrial processing of wood waste. In many areas of agricultural by-products such as straw, are also used to generate energy from biomass.

On one hectare of straw cereals is approximately equivalent to 200 litres of oil [23]. However, straw and other products in this category have different combustion characteristics from those of woody fuels. Point transformation in ash and emission behaviour of biomass type straw means that different technical approaches are needed. Another important category of waste, which is not necessarily part of the old wood sector, represents the wood residues from environmental management. These occurred during maintenance work on roads and canals, parks and care. Wood residues from environmental management are usually a mixture of wood, leaves and straw type products. Only very rarely it is possible to consider these mixtures for a new final product, thus utilization of its energy content is a very good strategy.

Liquid Bio-energy Sources

Mobility is essential in industrialized society. With few exceptions, passenger transport and freight are based on liquid fuel. Today, there are few alternative bio-fuels for these tasks. Ethanol, the alcoholic fermentation and methanol produced from cellulose can be considered as having a biomass origin.

Biogas Plant

In many countries worldwide, biogas plants are in operation, producing biogas from the digestion of manure or other biomass [23]. In addition, with success small scale biogas plants are utilized to displace woody fuels and dung in many developing countries. For example, the Dutch Development Organization, SNV, implemented with success in Nepal and Vietnam over 220,000 household on site biogas plants [8]. Moreover, in China and India, millions of plants are in operation. In conclusion, biogas plants have proven to be an effective and attractive technology for many households in developing countries.

The problems experienced by the biogas production include the following:
(a) Design faults (b) Construction faults (c) Difficulty of financing
(d) Operational problems due to incorrect feeding or poor maintenance, and
(e) Organizational problems arising from the differences of approaches and lack of coordination.

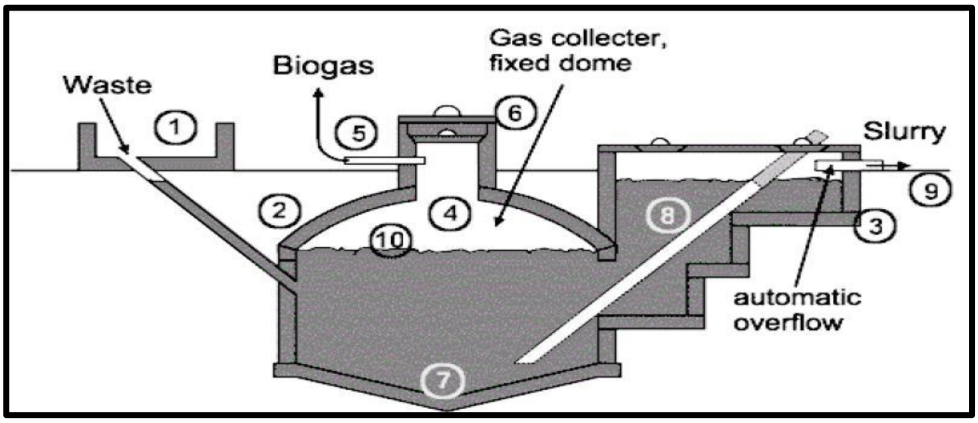

Fig 1: Diagrammatic representation of the experimental set-up

1. Mixing tank with inlet pipe and sand trap.
2. Digester.
3. Compensation and removal tank.
4. Gasholder.
5. Gas pipe.
6. Entry hatch, with gastight seal.
7. Accumulation of thick sludge.
8. Outlet pipe.
9. Reference level.
10. Supernatant scum, broken up by varying level.

The Benefits of Biogas Technology

Well-functioning biogas systems can yield a whole range of benefits for their users, the society and the environment in general, some of these benefits are:

i. Production of energy (heat, light, electricity)
ii. Transformation of organic waste into high quality fertilizer
iii. Improvement of hygienic conditions through reduction of pathogens, worm eggs and flies
iv. Reduction of workload, mainly for women, in firewood collection and cooking.
v. Environmental advantages through protection of soil, water, air and woody vegetation
vi. Micro-economic benefits through energy and fertilizer substitution, additional income sources and increasing yields of animal husbandry and agriculture
vii. Macro-economic benefits through decentralized energy generation, import substitution and environmental protection.

Conversion Processes in Anaerobic System

Biogas microbes consist of a large group of complex and differently acting microbe species, notable the methane-producing bacteria. The whole biogas-process can be divided into three steps: hydrolysis, acidification and methane formation.

- **Hydrolysis:** Hydrolysis is defined as the chemical breakdown of a compound due to a reaction with water. In the first step (hydrolysis), the organic matter is enzymolyzed externally by extracellular enzymes (cellulose, amylase, protease and lipase) of micro-organisms. Bacteria decompose the long chains of the complex carbohydrates, proteins and lipids into shorter parts. For example, polysaccharides are converted into monosaccharide. Proteins are split into peptides and amino acids.

- **Acidification:** Acidification is defined as the natural process by which the content of a mixture or substance becomes more acidic. Acid-producing bacteria, involved in the second step, convert the intermediates of fermenting bacteria into acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide (CO_2). These bacteria are facultative anaerobic and can grow under acid conditions. To produce acetic acid, they need oxygen and carbon. For this, they use the oxygen solved in the solution or bounded-oxygen. Hereby, the acid-producing bacteria create an anaerobic condition which is essential for the methane producing microorganisms. Moreover, they reduce the compounds with a low molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. From a chemical standpoint, this process is partially endergonic (i.e. only possible with energy input), since bacteria alone are not capable of sustaining that type of reaction.

- **Methane Formation:** Methane-producing bacteria, involved in the third step, decompose compounds with a low molecular weight. For example, they utilize hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide. Under natural conditions, methane producing micro-organisms occur to the extent that anaerobic conditions are provided, e.g. under water (for example in marine sediments), in ruminant stomach and in marshes. They are obligatory anaerobic and very sensitive to environmental changes. In contrast to the acidogenic and acetogenic bacteria, the methanogen bacteria belong to the archaebacter genus, i.e. to a group of bacteria with a very heterogeneous morphology and a number of common biochemical and molecular-biological properties that distinguish them from all other bacterial general. The primary aim of this research is to fabricatea bio-digester to generate biogas using cow dungs and chicken droppings as substrates

III. Choice of Feedstock

The choice of feedstock for this project was cow dung and chicken droppings as co-substrate due to the excess abundance of cattle and poultry in EkitiState and Nigeria in general and its numerous advantages. Cow dung is the ideal substrate for bio-digesters because it is not acidic according to [25].

Material Procurement

The cow dung used in this research was obtained from slaughter house located at Abattoir, Iworoko-Ado Road, Ado-Ekiti, and the chicken droppings from available poultry farms in Ado- Ekiti ,Ekiti State, Nigeria.

Material Preparation

Chicken droppings were prepared by soaking it in a paste form for about 12 hours so as to promote the growth of the necessary bacteria. Solid content was separated from slurry by filter cloth. Before using, all the cow dung and chicken droppings collected was homogenized by mixing.

Table 1: Materials and their uses

S/N	MATERIALS	USES
1.	9mm diameter rubber hose	Used to connect the digester to the gas collector
2.	Masking tape	To seal the hose during the experimental procedure
3.	Graduated transparent flask	To measure the quantity of gas produced
4.	Weighing scale	Used for weighing of material needed
5.	Cow dung & Chicken drops	Used as feedstock into the digester
6.	Rubber seal	Used to ensure the digester is airtight
7.	Poly filler	Used for sealing welded joint to avoid leakages
8.	Water	Used for preparing the slurry
9.	Thermometer	Used for measuring the ambient temperature of the slurry
10.	Arc-welding machine	Used for joining the galvanized steel sheet together
11.	Sheet metal cutter	Used for cutting of the sheet metal into size and shape
12.	Hand drilling machine	Used to create bolt and nut holes on the digester
13.	Meter rule	Used for making measurements

Fabrication Process of the Digester

I. Opening was cut at the top of the cylinder for the entry hatch.
II. A hole was drilled for the outlet pipe which was then welded to it.
III. The conjunctions for the regulator valve were welded to the outlet pipe and the nozzle
IV. The digester cover and its component thread were welded to the opening on top of the cylinder
V. All welded joints were grinded and tested for leaks

Figure 2: Fabrication process of the digester

The Experimental Procedures

Cow dung to chicken droppings with ratio 1:1 and water to the feedstock (cow dung and chicken droppings) mixing ratio was 1:1 as research variables was fed to digester and homogenized with manual stirrer. The inlet of the digester was covered tightly and it was padded with rubber seal to ensure the anaerobic condition was maintained. For the extraction process one end of the rubber hose was connected to the digester gas outlet located at the top of the digester and the other end of the rubber hose was connected to a graduated flask for gas collection.

An experiment was conducted for 14 days and reading taken for this retention period. The temperature of the biogas products was measured once daily. The daily reading was taken every day for 2 weeks and the average daily temperature was recorded.

The resultant biogas was collected over water using water displacement method and as such the volume was subsequently calculated from the dimensions of the graduated transparent flask provided. The temperature reading was taken once daily between12:00 – 3:00p.m of the day. This was done in order to determine the temperature changes during the day and also the effect of sunlight on the digester.

Figure 3: Experimental process

IV. Results

The table below shows the quantity composition of the substrate (cow dung and chicken droppings).

Table 2: Quantity Composition of Substrate

S/N	Composition	Quantity
1.	Semi Dry Matter	3.0kg
2.	Water (H_20)	3.0 liters
3.	Slurry	6.0 kg

Production of Biogas from Cow Dung and Chicken droppings

The peaks in Figure 4 indicate the fluctuation in the volume of gas produced from the substrate. The fluctuation signifies possible variation in environmental conditions which affects the microbial activities in the system. Figure 4 shows that gas production in the substrate started within the first week of set-up. On the 8th day, the gases produced were burnt but a conspicuous flame was not achieved indicating the presence of excess carbon dioxide (CO_2).

Table 3: Temperature and volume of gas as retention rate increases

Retention Rate	Temperature	Volume of gas (ml)
1	34.4	0
2	30.2	71.0
3	29.9	69.5
4	30.8	70.3
5	32.7	69.9
6	31.8	71.3
7	33.4	72.4
8	29.3	64.2
9	28.9	63.2
10	30.3	59.9
11	30.4	58.6
12	29.6	60.0
13	26.6	63.2
14	24.4	50.3

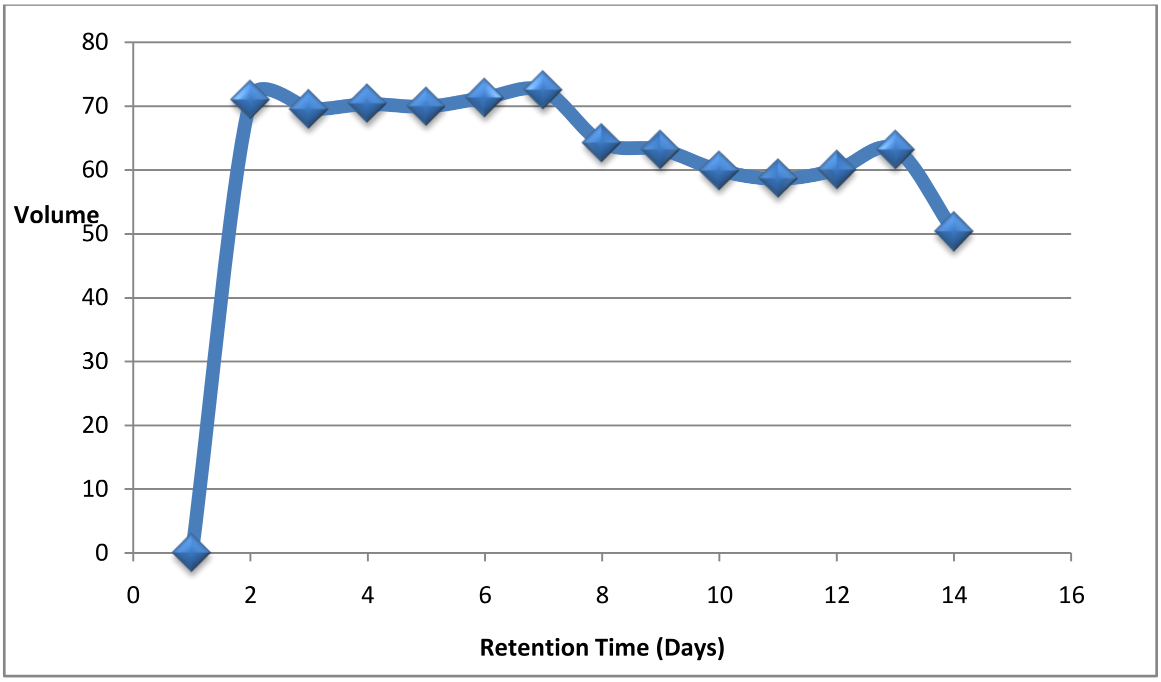

Figure 4: Daily gas production from cow dung and chicken droppings

Observation shows from figure 4 that as the retention time (HRT) in weeks increases, the temperature (^{0}C) increases to a maximum point (33.5^{0}C) which shows increase in the rate of biogas production and the temperature later falls which shows decrease in the volume of biogas production, that is; decrease in the production rate of the substrate (cow dung and chicken droppings) leads to decrease in temperature, though not below the room temperature (20^0C). The decrease in the 2^{nd} week of the biogas temperature shows distinctively that the substrate has reached the maximum biogas yield point.

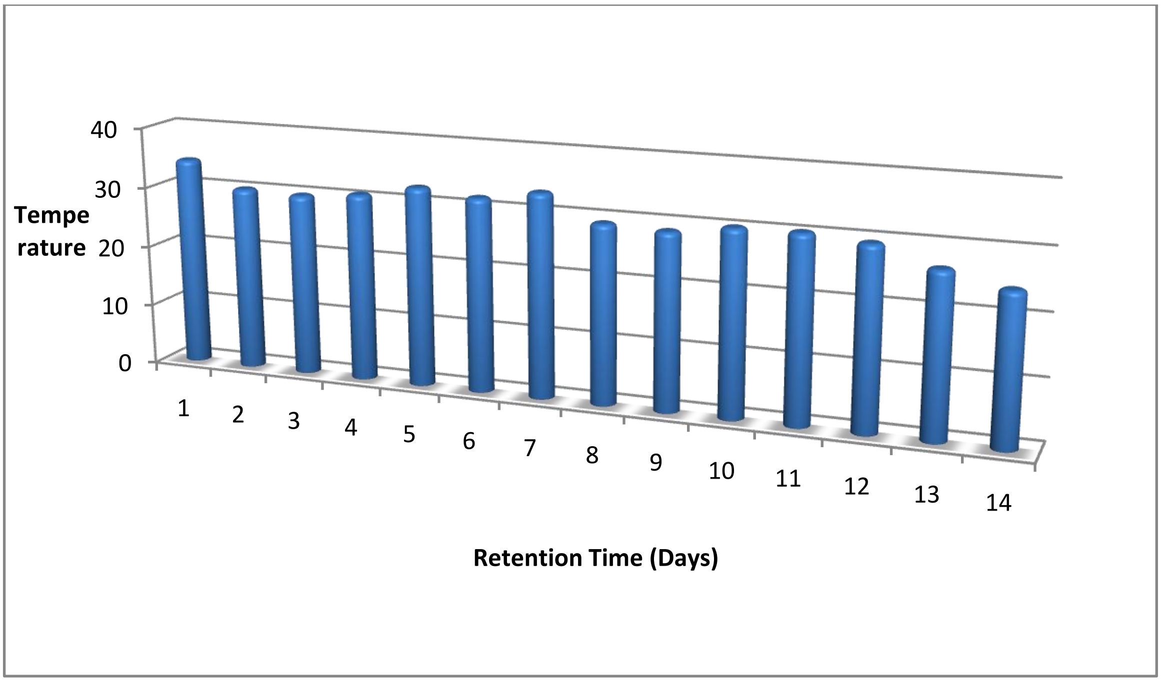

Figure5: Daily temperature reading for Biogas production

V. Conclusion

Based on the findings of this study, the following conclusions were drawn:

i. Biogas can be produced by the microbial digestion of organic matter in the absence of air. Various wastes, such as municipal wastes, kitchen waste, animal waste and crop residue can also be used in the production of biogas.

ii. Biogas production took place within the retention period of two weeks from microbial digestion of cow dung and chicken droppings in an anaerobic condition.

iii. The percentage yield of products of biogas produced depends on the type of substrate used and its chemical constituents.

iv. The total average retention period for the experiment was 14 days (2 weeks) before gas production and collection was carried out.

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