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PURIFICATION AND MANUAL COMPRESSION OF BIOGAS PRODUCED FROM FARM ANIMAL WASTES FOR DOMESTIC USE IN FCE(T), BICHI AND ITS ENVIRONS

BY

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Abstract

In order to meet society's energy needs and provide an alternative source of energy for cooking, biogas, a renewable energy source, was produced. This research assembled a biogas technology that produced, purified and compressed biogas into Liquefied Petroleum Gas (LPG) cylinder using a fabricated proto type hand compressor. Farm animal wastes from Department of Agricultural Education, Federal College of Education (Technical), Bichi was collected, dissolved in water and used as substrate for the digester, the substrate then undergoes fermentation in the absence of oxygen by process of anaerobic digestion. The biogas produced in the digester was channeled to the purification facility where Hydrogen Sulphide (H2S), carbon dioxide (CO2) and water (H2O) were removed from the biogas, the purified biogas was stored in the storage tank and then compressed into the LPG cylinder by a proto hand compressor. The biogas produced was combustible when subjected to a flame test. This research is the first attempt to provide solution to the problem of manually compressing biogas to LPG cylinder.

Keywords: Biogas Production, Farm Animal Wastes, Purification, Manual Compression, Domestic Use, Biogas Technology

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Introduction

The increasing world population and the need for energy and fuel has become very prevalent as it is required for almost everything the human does or wishes to do. There are many useful forms of energy that have influenced our way of lives and daily activities. Energy is the ability or capacity to do work, without energy, many things would have been difficult to achieve. Nearly all of the energy needed to meet our demands (80 percent of global energy) comes from burning fossil fuels. At the current rate of global energy demands, fossil fuels cannot replenish fast enough to meet these growing needs. The (over) consumption of these non-renewable fuels has been linked to the emission of greenhouse gases and pollutants into the atmosphere, the leading cause of global warming and climate change (Pyke, 2017).

Due to the high cost of oil and natural gas, most people have resorted to the use of renewable energy resources such as biofuels (e.g biogas), wind, solar and animal manure as an alternative source of energy. Renewable energy is becoming more important these days due to its cost effectiveness and availability even though the demand for hydrocarbon energy (energy derived from crude oil, natural gas and coal) continue to rise. Cow manure is another source for clean renewable energy which is a biofuel.

Biogas is only one of the many types of biofuels (Solid, liquid and gaseous) fuels from Biomass. Biofuel is a type of energy derived from renewable plant and animal materials. It is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion rather than a fuel produced by geological processes such as those involved in the formation of fossil fuel such as coal and petroleum, from prehistoric biological matter (Nachana'a, 2019). All biofuels are produced from renewable energy sources that also include energy produced from solar, hydro, wind and geothermal sources. Like natural gas, biogas has a low volumetric energy density compared to liquid biofuels, ethanol and biodiesel. However, biogas may be purified to a natural gas equivalent fuel for pipeline injection and further compressed for use as a transportation fuel. Methane, the principal component in biogas, has four times the volumetric energy density of hydrogen (H_2) and is suitable for use in many types of fuel cell generators (Wilkie, 2019).

Physically, methane is a colorless and odorless gas, lighter than air [Ogden et al. 1999]. Methane is very poorly soluble in water (23 mg l^{-1} at 20°C) and acetone, but is well soluble in alcohols (methanol, ethanol), ether and aromatic hydrocarbons (benzene and toluene) [Antonopoulou et al., 2008].

The continuous rise in price of oil and gas and the dwindling natural resources with its attendant effects on the world populations, has focused the world on renewable energy, so also the ongoing crisis in Ukraine have also increased uncertainty in global oil and gas markets, putting renewed pressure on net importers in the developed countries and encouraging the need for sourcing for an alternative to the natural gas for cooking.

The problem of rising cost of cooking gas and environmental hazards caused from deforestation can be minimized by the biogas technology, which will produce gas that will serve as an alternative to the natural (cooking) gas.

Statement of the Problem

No meaningful development can take place in a society without energy. However, the amount of energy required by any society depends on the state of development, the available local resources and the economic capacities of the country. Most countries rely on locally produced or imported fossil fuel which over time have greatly reduced. Nigeria has substantial biomass potential of about 144 million tons per year (Shaaban et al., 2014). According to the U.S.

Energy Information Administration (EIA) most Nigerians, especially rural dwellers, use biomass and waste from wood, charcoal, and animal dung, to meet their energy needs (EIA, 2015). Biomass (comprising crop residues, manure, charcoal, and wood) accounts for about 80% of the total primary energy consumed in Nigeria; oil (13%), natural gas (6%) and hydro (1%) (EIA, 2015). This large percentage represents biomass used to meet off-grid heating and cooking needs in the rural areas.

This has serious environmental implications as it results in deforestation, poor health of households particularly women and children and heavy work burden (Alemayehu, 2014). The heavy burden on women and children is indirectly responsible for poor literacy. Therefore, there is urgent need to provide a cheap and viable alternative source of energy to cut down high cost of natural gas, minimize deforestation, improve standard of living and literacy of rural masses.

There are several ways that waste, with its locked-in energy, can be used as a fuel source, through a process called Anaerobic Digestion (EPA, 2021). The advantage of anaerobic digestion is that, its produce (biogas) will not only provide a fuel for domestic use, but can also be converted into biofuel for automotive industry (Khalid, 2016).

The need for biogas as an alternative for natural gas is due to the rising cost of cooking gas and to reduce overdependence on firewood and charcoal by rural communities which has adverse effect on the ecosystem.

Justification of the Study

Biogas technology can be viewed as a means to reduce rural poverty and bring about rural development. Biogas can be an energy substitute for animal waste, fire wood, agricultural residues, diesel, paraffin, petrol and electricity. In addition, eutrophication and air pollution are minimized (Lantz et al., 2007). Additionally, it does away with the necessity of gathering firewood every day. Biogas is a renewable, as well as a clean source of energy. Gas generated through biodigestion is non-polluting; it actually reduces greenhouse emissions (i.e. reduces the greenhouse effect). No combustion takes place in the process, meaning there is zero emission of greenhouse gasses into the atmosphere; therefore, using gas from waste as a form of energy is a great way to combat global warming. Biogas plants significantly curb the greenhouse effect: the plants lower methane emissions by capturing this harmful gas and using it as fuel.

The by-product of the biogas generation process is enriched organic digestate, which is a perfect supplement to, or substitute for, chemical fertilizers. The fertilizer discharge from the digester can accelerate plant growth and resilience to diseases, whereas commercial fertilizers contain chemicals that have toxic effects and can cause food poisoning, among other things.

Biogas technology saves women and children from the daunting task of firewood collection. As a result, more time is left for cooking and cleaning. More importantly, cooking on a gas stove, instead of over an open fire, prevents the family from being exposed to smoke in the kitchen. This helps prevent deadly respiratory diseases.

Objectives of the Study

The principal aim of this research project is to locally assemble a biogas technology that would compress biogas to LPG cylinder for domestic use in FCE(T), Bichi and its environs.

Specifically, the study sought

1. To use water plastic drum as a biodigester
2. To use farm animal wastes as feedstock in biodigester for biogas production.
3. To remove impurities from the biogas obtained
4. To locally fabricate gas compressor to compress biogas to LPG cylinder

Literature Review

Conceptual Framework

Biogas is an environmentally friendly, renewable energy (fuel) source produced when organic matter, such as food or animal waste, is breakdown by microorganisms in the absence of oxygen, in a process called anaerobic digestion. Biogas mainly consists of 50 – 70% methane (CH_4) and 25 – 50% carbon dioxide (CO_2). Other components of biogas are water (H_2O), Oxygen (O_2), Sulphur (S_2) and Hydrogen Sulphide (H_2S) (Wellinger et al., 2013).

Different organic materials can be used as substrate (inputs) for the biogas production process. Common substrates are food waste from households and restaurants, industrial waste from the food processing industry and slaughterhouses, sludge from wastewater treatment plants, manure and other residues from the agriculture sector (Wellinger et al., 2013). Depending on the composition of the substrate used, different pre-treatment technologies are needed, to prepare the substrate for digestion in the digesters at the biogas plants. Pre-treatment can include crushing or grinding to reduce the size of the material, diluting to make the substrate more volatile, and removal of unwanted material such as plastics, textile, metals or gravel (Wellinger et al., 2013).

Components	**Symbol**	**Concentration (vol %)**
Methane	CH_4	55 – 70
Cabondioxide	CO_2	33 – 40
Water	H_2O	$2(20^0C) – 7(40^0C)$
Hydrogen Sulphide	H_2S	20 – 20000 ppm (2%)
Nitrogen	N_2	< 2
Oxygen	O_2	< 2
Hydrogen	H_2	< 1
Ammonia	NH_3	< 0.05

Table 1: shows the typical makeup of biogas produced from biowaste (Eawag, et al., 2014)

Process of Producing Biogas

An anaerobic process, the creation of biogas occurs in two stages, which are as follows:

i. Acid generation stage: During this phase, a group of bacteria that create acids in the feedstock interact with biodegradable complex organic compounds in the waste materials. This stage is known as the acid producing stage since the organic acids are the primary product.
ii. Methane formation stage: Methane generation process occurs when a group of methanogenic bacteria interact with the organic acids to produce methane gas.

Materials Needed to Produce Biogas

The primary resource for producing biogas is cattle dung, but other materials can also be used, including food scraps, plant wastes, bird droppings, and industrial agricultural waste.

Existence of Raw Materials
The availability of raw materials determines the biogas plant's size. An average cow produces 10 kilogram of manure per day. 1 kg of cow dung slurry at a ratio of 1:1 with water produces 0.04 m^3 or 40 litres of biogas under anaerobic condition.

The total amount of dung needed to produce $3m^3$ of kg is 3/0.04 = 75kg. Therefore, it takes a minimum of 4 animals to produce the necessary amount of cow dung.

Time Required to Produce Biogas
The feedstock (raw material) utilized determines how long it takes for biogas to be produced in a biogas plant. Several types of feedstock include:

i. Organic material, such as organic landfill materials
ii. Food and drinks, such as waste water and dairy plant waste and meat packing
iii. Sludge from wastewater treatment

Any biodegradable organic substance, whether it derives from plants or animals, has the potential to release gas. Depending on the make-up of the feedstock and kind of anaerobic digester, the time it takes for the gas plant to start generating biogas ranges from 5 to 90 days generally, more often 10 to 30 days. It will take less time for a feedstock with a simple composition of carbon and nitrogen to begin producing gas than it takes for one with a complicated composition (such as cellulose and lignin).

Here are a few typical biogas production times:

1. Cow manure is treated in a complete mix, 37°C anaerobic digester. Typically, biogas production takes 30 days.
2. Anaerobic sludge blanket reactor treating beverage waste at high rates of upflow. One to two days will be needed for biogas generation.
3. Piggery waste is being treated in a covered anaerobic lagoon. Production of biogas will take 45 days.

A reliable conservative estimate of how long it takes to produce biogas is a complete mix style anaerobic digester working at 37^0 C and treating the wastes for 30 days.

Factors Affecting the Production of Biogas
Numerous factors affect the formation of methane and the anaerobic breakdown process. Anaerobic digestion is carried out by a variety of bacteria that need specific environmental factors in order to function. The following are some of the elements that affect anaerobic digestion:

Temperature: During the biodegradation process, particularly the methanogenesis stage, temperature is one of the key parameters to take into account. The temperature range for this stage is divided into three categories: mesophilic (between 25 and 42^0C), thermophilic (between 43 and 44^0C), and psychrophic (below 20^0C). Anaerobic digestion is not advised at temperatures below 20^0C since the reaction rate is slow at this temperature. The mesophilic temperature range is thought to be faster, more energy-efficient, and more stable for the system than the thermophilic range (Ghaindelli, 2017). However, reaction rates and gas production are faster at the thermophilic temperature range. Additionally, at this higher temperature, the digestate is more thoroughly hygienized, solid substrates degrade more effectively, substrate availability and digestibility are improved, and the possibility of separating liquid and solid fractions is increased (Al Saedi et al., 2008).

Temperature has a significant impact on anaerobic digestion efficiency; as a result, variations in temperature can disrupt the effectiveness of the microorganisms, cause gas losses, and cause the process to stop. As a result, maintaining a steady temperature will increase efficiency and reliability (Jarvis et al., 2009).

At higher temperatures than at lower temperatures, methane generation takes longer. Low temperatures cause a significant reduction in methane generation at temperatures below 35^0C. In comparison to a biodigester that operates at mesophilic temperatures, a thermophilic biodigester has a higher gas production and better conversion rates (Angelidaki, 2004).

pH: When determining the acidity or alkalinity of a solution (or substrate combination, in the case of anaerobic digestion), the pH value is utilized. It is represented in parts per million (ppm). pH has an impact on methanogenic microbial development (Bahira, Baki, & Bello, 2018). It affects the dissociation of various substances, such as ammonia, sulfide, and organic acid, which are crucial to the anaerobic digestion process. The methanogenesis phase occurs over a relatively small pH range, ranging from above 5.5 to 8.5, with an ideal range between 7.0 and 8.0 (Ghiandelli, 2017). With rising temperatures, carbon dioxide becomes less soluble in water.

The pH level in anaerobic reactors is managed via the bicarbonate buffer system. In fact, the partial pressure of CO_2 and the amount of alkaline and acidic components in the liquid have an impact on the pH inside the biodigester.

Carbon to Nitrogen Ratio: For the biogas plant to operate smoothly, it is important to maintain the right composition of the feedstock in order to retain the ratio of carbon to nitrogen in the feed within desired range. The necessary nutrients for anaerobic bacteria to function effectively are provided by both nitrogen and carbon. While nitrogen aids in the development of their cell structures, carbon supplies the energy they require for survival.

Depending on their relative richness in carbon or nitrogen content, feed ingredients can be categorized as nitrogen- or carbon-rich. It is typically observed that microbes use carbon 25 to 30 times more frequently during digestion than nitrogen. In order to comply with this criteria, feedstock components are maintained in such a way as to guarantee a C:N ratio of 25 to 30 and a concentration of dry matter of 7 to 10%. However, in some substrates, a low C:N ratio and a higher dry matter concentration can result in some gas yield.

Table 2: Carbon to Nitrogen Ratio in Different Organic Wastes

Organic material	**C: N**
Organic materials C/N ratios	8
Duck dung	8
Human excreta	10
Chicken dung	12
Goat dung	18
Pig dung	19
Sheep dung	24
Cow dung	24
Buffalo dung	25
Water hyacinth	43
Elephant dung	60
Maize straw	70
Rice straw	90
Wheat straw	200
Saw dust	

Source: Karki and Dixit (1984) in Adelekan (2009)

Volatile Fat Acid: The ability of the anerobic process depends on the amount of an intermediate chemical called volatile fat acids (VFA). Although the buffer capacity of the biodigester due to the presence of CO_2 gives to the pH variation a significant margin before the accumulation of VFA may lead to several problems such as stop the degradation process even before that a change in pH occurs, the accumulation of VFA during the acidogenesis phase leads to an accumulation of VFA and subsequently an accumulation of VFA, which leads to an accumulation of VFA and a drastic decrease in pH. The allowable concentration of VFA is influenced by the alkalinity of the manure, therefore it is possible that a particular concentration is acceptable for one system while being inhibitory for another. VFA concentration cannot, therefore, be employed as a monitoring metric for the anaerobic degradation process (Jarvis et al., 2009).

Toxic Compounds: One of the factors influencing the activity of the anaerobic bacteria in the biodigester is the presence of toxic compounds there. They may be produced mechanically during the degrading process or added to the feedstock (Ghaindelli, 2017). Certain pH and substrate conditions can cause some hazardous compounds to be released during anaerobic digestion, which can prevent bacterial growth and methane generation (Al Seadi et al., 2008). As an illustration, consider how a high concentration of lipids and carbohydrates results in a high concentration of ammonia and sulfides. On the other side, the feedstock could be contaminated by external chemical substances that interfere with the ability of the bacteria to function. However, the latter's concentration is typically too low to have a significant impact on the system (Terfera, 2009).

Biodigester types

i. Small Scale Biodigester
  - Fixed Dome Biogas Plants
  - Floating drum plants
  - Low-cost polyethylene tube digester
  - Ballon plants

- Horizontal plants
- Earth-pit plants
- Ferro-cement plants

ii. Types of Industrial Digesters
- Batch Plants
- Continuous plants
- Semi-batch basis

Useful Resources

Table 3: Average Dung Yield

S/No.	Living Beings	Quantity of Dung / Night Soil produced (kg/day)
1.	Cow, Heifer	10.0
2.	Bullock	14.0
3.	Buffalo	15.0
4.	Young bovine	5.0
5.	Horse	14.0
6.	Horse, young	6.0
7.	Pigs, over 8 score	2.5
8.	Pigs, under 8 score	1.0
9.	Ewes, rams and goats	1.0
11.	Lambs	0.5
12.	Duck	0.1
13.	10 hens	0.4
14.	Human beings	0.4

Sources: Rajendran et al (2012); Fulford (2015); SEAI (2012).

Empirical Review

Numerous studies have been conducted to determine the output of biogas. Adamu (2014) used the water displacement approach in a laboratory scale experiment to study the impact of substrate on biogas yield while keeping track of the amount of gas produced. Chicken manure, sheep manure, cow dung, waste from tomatoes, and fluted pumpkin leaves are the substrates. Over the course of 22 days, the cumulative biogas produced by each substrate was observed and recorded; the results showed that sheep dung had the highest cumulative volume of biogas per 100g of substrate (240ml), followed by cow dung (200ml), and waste tomatoes and chicken manure (each with a cumulative volume of 170ml). Methane has an average composition of 65.34 mol% of the biogas generated, followed by carbon dioxide at 22.81 mol%, hydrogen at 7.49 mol%, oxygen at 0.95 mol%, nitrogen at 3.39 mol%, and very small amounts of carbon monoxide and water vapor.

Begum, Gangagni, Nicky, Sridhar & Veeriah(2017), provides an example of the function of decentralized biogas facilities set up in India by big corporations that could support the country's circular and bio-based economy. Characterizing and analyzing the direct and indirect consequences of current and planned biogas plants is a valuable way to address the idea of a circular economy and a bio-based economy.

Dankawu, Usman, Musa, Safana, Ndikilar., Shuaibu, Yakubu, Uzair, Lariski, Silikwa, & Ahmadu (2022), uses co-digestion of cow dung and chicken dung to make biogas from animal waste and poultry waste for alternative cooking fuel. Utilizing resources that were readily available locally, a four-liter digester and gas collection system were built and constructed. The digesters were utilized to co-digest the cow dung and poultry manure as well as to digest them separately as a single substrate. According to the digester results, the amount of gas produced ranges from 222cm^3 (20g of cow dung plus 60g of poultry waste) to 258 cm^3 (80g of cow dung plus 0g of poultry waste), proving that cow dung produces more gas than poultry waste.

Ray, Mohanty & Mohanty (2015), designed and established a facility at College of Engineering Bhubaneswar, Odisha, India, for the production of biogas from kitchen wastes in the on-campus dormitory. This facility would be used for purification, compression, and bottling.

Sulaiman, Mahadi, Khalid, Anas A, Nabil, Zaharaddeen, (2016), created a biogas digester with a 0.14 m^3 capacity using food waste from the school hall as the feedstock. The test was conducted at ambient temperatures between 35 and 50^{0}C within a retention time of three days, and the flammability of the gas produced was tested with a gas burner. The food waste sample was crushed and combined with water in a ratio of 1:2 to form slurry.

Ray et al., (2016), conducted research on systems for the production, purification, compression, and storage of biogas that are appropriate for use as a cooking gas in rural communities. An elastic balloon is used to collect the biogas, which is created in a floating drum-style digester by the anaerobic digestion of kitchen waste. A foot lever compressor was created that enables people to stand while applying pressure to the biogas through a valve system. Along with the compressor, a container filled with silica gel is used to remove water vapor from biogas, and a fiber container filled with steel wool serves as a scrubber for hydrogen sulfide at the biogas entrance to the compression system. The outcome demonstrated that the system was capable of compressing biogas into a container at 4 bar pressure for a duration of 30 minutes.

Ephron (2020) created a biogas digester using materials that were readily available in Malawi and evaluated its effectiveness there. Pig dung, goat stomach waste, and kitchen waste were fed to three pairs of locally built tabular polyethylene digesters of the same design. The gas production was fastest in the digesters containing pig dung (1 day), then went on to those containing goat stomach wastes (3–4 days), and finally those containing kitchen wastes. Each pair of digesters had one digester enclosed in a greenhouse made of transparent polyethylene. The average amount of methane in the biogas was 62.1%, and the average daily gas production from digesters was 35.7 L/day. the study therefore concluded that the overall performance of the tabular polyethylene digesters that were fed with goat stomach waste and pig dung was superior compared to other studies done at similar ambient temperatures.

Dzene (2015) developed a conceptual framework of waste-to-biomethane concept application in an urban energy system. Techno-economic evaluation of biogas production and consumption is described with particular interest in biomethane application in the transport sector.

Materials and Method

Research design

The design and establishment of a biogas production, purification, compression, and bottling unit are among the steps that were taken in this research experiment. The biogas system for this project was based on continuous plants technology, where the biodigester will be continuously fed and emptied as it is suitable for rural households and laboratories requirements and fits well into daily routines as gas production is constant.

Materials

The materials that were used for the research are:

- Water drum (Biodigester)
- Mixing tank
- Cow dungs
- Connecting Hoses
- Proto hand pump
- Gas Storage Container
- LPG Cylinder
- Purification unit

Experimental Design

The biogas system comprises the production, purification and storage facility. The production, purification and storage unit are schematically represented in Figure 1 below.

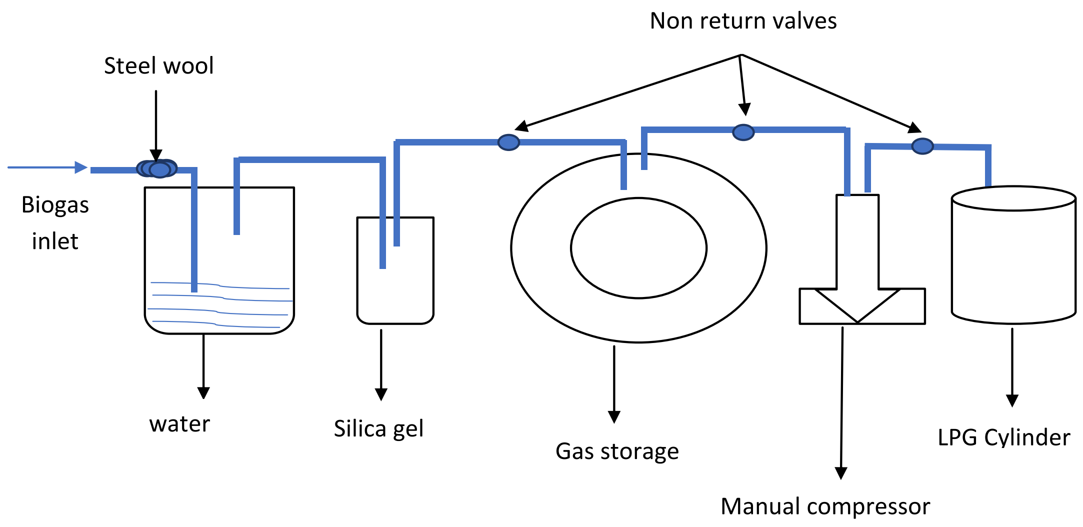

Fig 1. Schematic Diagram of Biogas production unit
Source: author's own development

Production of Biogas

Cow dung was collected from the Federal College of Education (Technical), Bichidiary farm. Maize and millet stalks were carefully removed from the dung and the dung thoroughly mixed with water to form a homogenous slurry in a mixing tank, the ratio of cow dung to water is 1:1 (i.e 1kg of dung to 1 liter of water). The slurry was thereafter discharged into the digester (a suitable plastic container) through a 3" pipe which serves as the inlet pipe. The digestate formed was left to ferment in the digester in the absence of oxygen by the process of anaerobic digestion.

The biodigester has a volume of 220 liters and was filled with feedstock of 180 Kg. The gas pipe from the digester was left open and gas production started after 14days and continued for 4days. A gas outlet pipe fitted with a pressure gauge (the pressure gauge measures the pressure build up in the digester) was fixed to the top of the digester tank, from which the biogas was conveyed from the digester through a ¾ inch hose fitted with a non-return valve to the purification unit to undergo purification and thereafter transferred to the storage tank. The water purification chamber was seen giving out bubbles, an indication that a gas was given off and the gas storage tube was inflated confirming the production of biogas from the digester since the gas tube was left opened.

Fig 2: Experimental Setup
Source: author's own development

Purification of Biogas

The biogas purification system consists of three units:

i. The hydrogen sulfide (H_2S) removing unit,
ii. Carbon dioxide (CO_2) removing unit, and
iii. Moisture trapping unit.

The three units are interconnected with plastic hoses. Steel wool, pure water and an adsorbent material (silica gel) are used in the purification of the biogas. The steel wool is to react with the hydrogen sulphide, the water is to reduce the percentage of carbon dioxide and the silica gel is to reduce the presence of water vapour in the purified biogas. The experiment involves passing the raw biogas with the pressure build up in the digester through the steel wool to remove the hydrogen sulphide, after the hydrogen sulphide is removed by the steel wool, the raw biogas will be sent onto the water scrubbing unit to remove carbon dioxide. Carbon dioxides dissolves in water to form carbonic acid (H_2CO_3) and thereby removes carbon dioxide from the biogas produced. The acid is weak.

$$H_2O + CO_2 \longrightarrow H_2CO_3$$

Compression and Storage of Biogas

The biogas storage system consists of three units:

i. a proto hand pump compressor,
ii. a pressure gauge and
iii. an LPG cylinder.

The compressor that was used in the experiment is a proto hand pump compressor type that was fabricated by the researchers and work by the repetition of the pulling and pushing activities of the piston which sucks in biogas from the biogas storage and compressed it into the LPG cylinder. The proto hand pump compressor works at a pressure of 30psi (206843 N/m^2) to compress the biogas into the LPG cylinder.

Combustion Test

The biogas produced was subjected to a flame test and it was confirmed that it supports combustion as it burns with a blue flame (see fig. 3), an indication of high methane content of the biogas. The biogas is then compressed with the proto hand compressor pump into the

LPG cylinder. It was successfully compressed into the LPG cylinder but when the cylinder is opened and lit it doesn't support combustion which could have resulted from excessive intake of carbon dioxide and other gases by the hand compressor pump from the environment which reduces the high combustion rate of the methane gas in the biogas.

Fig 3: biogas burning with blue flame
Source: author's own development

Result and Discussion

Table 4 shows the day the biodigester start producing biogas, the highest and lowest temperature recorded those days and the volume of biogas produced. Biogas production as starts on the 14^{th} day of the experiment as the improvised biogas storage bag fitted with a non-return valve was observed to have been inflated with biogas which has undergone purification in the purification chamber. It was discovered that methane forming bacteria works best in the pressure of *about*110,000 to 120,000 N/m^2 as that was the pressure in the biodigester when the production started.

Table 3: Temperature and volume of biogas obtained

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Temp ^{0}C	39 26	35 22	39 27	39 26	39 26	40 22	34 24	37 26	37 22	36 23	38 26	35 23	34 24	37 27	36 23	30 23	34 23	36 23	36 26	36 24	37 23	36 25
Biogas obtained (m^3/kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.5	7.7	7.7	7.6	7.2	6.3	5.0	0.4	0.04

Source: author's own development

Conclusion

This research successfully constructed a biodigester using a 220 liters plastic drum. Biogas was produced from the biodigester, purified and stored in an improvised gas storage bag fitted with non-return valve for one way movement of the biogas. The purified biogas was manually compressed into LPG cylinder with the proto manual hand compressor but was not able to support combustion.

Suggestion for further Research

More research should be carried out to ascertain the reasons why biogas compressed manually into LPG cylinder by a fabricated hand pump does not support combustion and to find a way to solve the problem.

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