**Non-Peer Reviewed*

# Biodigester and Biogas Technology as Veritable Tool for Poultry Waste Management in the Federal Capital Territory, Abuja, Nigeria

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## Abstract

Poultry waste management is multidimensional and involves public health, waste management, utilization of fertilizing value, and fuel and energy production issues. The poultry industry in FCT Abuja, Nigeria, faces significant challenges in managing the large quantities of organic waste generated, which can have detrimental effects on the environment and public health if not properly handled. This thesis explores the potential of biodigester and biogas production as a sustainable and efficient technology for poultry waste management in FCT Abuja, Nigeria. The study aims to assess the feasibility, economic viability, benefits, and limitations of biodigester and biogas technology in managing poultry waste, providing valuable insights for policymakers, poultry farmers, and environmental stakeholders.

The intent of the study is also to show that the chicken waste used as feed material to produce biogas can tap additional energy from the otherwise wasted energy and make the poultry industry co-exist with the environment of the neighbours. This research will identify and evaluate the economic feasibility of producing biogas from poultry waste. The research is of particular interest to the poultry farmers and to Waru community of Federal Capital Territory, Abuja, Nigeria, as the people are becoming very conscious of the environmental impact due to pollution. This will also solve the crisis of offensive smell emanating from the poultry farm, causing disputes between the poultry farmer and the host Waru Community.

**Keywords:** Bio-digestion, Biomass, Biogas, Poultry Waste, Renewable Energy, Slurry

## 1.1 Background

Poultry is an important subsector of the livestock industry and the fastest-growing agricultural enterprise in Bangladesh (Rahman M, Chowdhury E, Parvin R. 2021). Rahman M, Chowdhury E, Parvin R. 2021, It contributes significantly to the economy of Bangladesh by providing employment opportunities in rural and semiurban areas, as well as accessible protein sources for the growing population. According to Jabbar MA, Rahman M, Talukder RK, Raha S 2021; Poultry production has grown from 91 million in 1,990 to 365.85 million in the fiscal year of 2020–2021, owing to the huge demand for poultry meat and eggs.

This research embarks on a mission to delve into an innovative paradigm of poultry waste management, one that revolves around the creation of a cutting-edge digester system employing locally sourced materials. At its core, this transformative digester system aspires to revolutionize the conventional waste management landscape by ingeniously harnessing poultry waste as its primary feedstock. This resourceful approach promises a dual benefit – the generation of biogas to satiate the voracious energy appetite and the production of nutrient-rich digestate, a potent organic fertilizer poised to breathe life into the earth. This dual-pronged approach epitomizes the synergistic relationship between sustainable energy generation and eco-friendly waste management.

As the world grapples with the necessity of embracing renewable energy, biomass stands out as a formidable contender, reigning as the predominant source of renewable energy in the contemporary milieu. Astonishingly, despite its colossal potential, a significant chunk of this resource remains untapped, holding untold possibilities. Against this backdrop, amplifying bioenergy's contribution, whether through electricity generation or as fuel for transportation, emerges as a tangible strategy for not only curbing the ominous specter of global warming but also bolstering energy security. Additionally, this pursuit unfolds pathways to unlock latent waste management potentials, particularly in rural and peri-urban settings, consequently orchestrating a harmonious symphony of employment creation and sustainable growth (Yue et al., 2014).

Yet, the journey towards seamlessly integrating bioenergy into the energy matrix is not devoid of challenges. Robust supply chain networks assume paramount significance as they constitute the bedrock on which the sustainable incorporation of bioenergy hinges. In essence, this expedition underscores the intricate interplay between innovative technologies, localized resource utilization, and the imperative of a resilient supply chain to realize the promise of a greener, more energy-abundant future.

## Research objectives

The specific objectives of the research are the following:

1 To determine the quality of the produced Biogas in terms of physical, mechanical and thermal properties.
2 To evaluate the performance of Biogas in domestic cooking applications by determination of fuel properties and combustion behaviour.
3 To assess the economic feasibility of a household scale Biogas production based on the estimation of production cost and revenues.

## Research Questions

This research addresses six closely linked objectives and will focus on answering the

following questions.

1. What are the conventional poultry waste disposal system in the FCT, Abuja
2. Can poultry waste be converted into biogas?
3. What is the quality of the biogas in terms of physical, mechanical, and thermal properties?
4. How will the developed biogas perform in a domestic cooking application? How long will it take for the biogas to ignite and boil water?
5. How much will it cost to produce the biogas using poultry waste bio-digestive technique?
6. How economically viable will this technology be for application in rural communities of the study area?

## 2.1 Waste Generation:

Waste generation is made up of activities in which materials are identified as not being useful and are either disposed or not of value. According to a World Bank Report in 2018, global annual waste generation is expected to jump to 3.4 billion tones over the next 30 years, up from 2.01 billion tones in 2016. The volume and range of solid waste generated daily in Nigeria has been increasing within the last few years and this is due to high population growth, urbanization, industrialization and general economic growth.

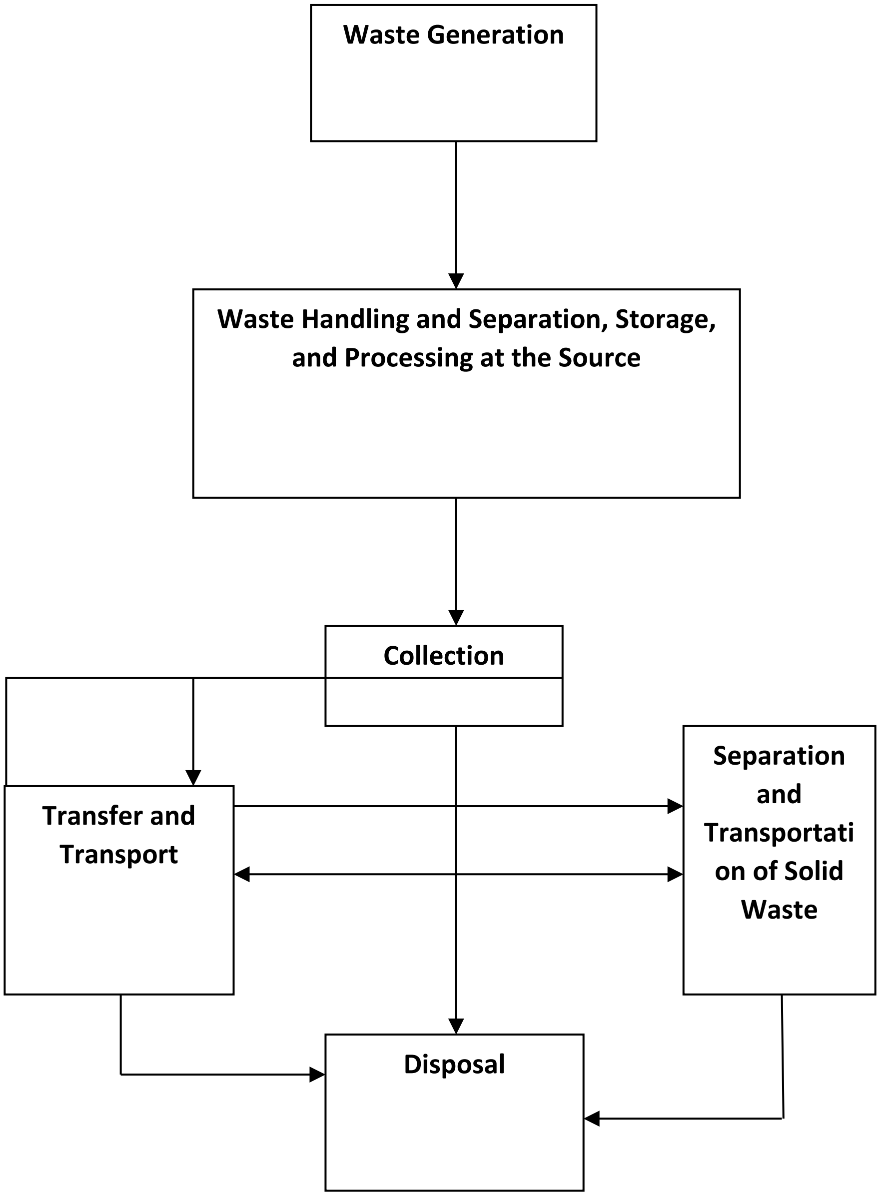


**Figure 1: Interrelationship of Functional Elements of Solid Waste Management**

Source: Tchobanoglous, G., Theisen, H. and Vigil, S. (1993). Integrated Solid Waste: Engineering principles and management issues. McGraw-Hill Publishing company, USA.

### 2.1.1 Waste Storage:

According to Kreith, F. (1994), it is widely explained to mean where solid waste is stored before it is collected. It is usually in dustbins and not supposed to be thrown away indiscriminately. Storage is of primary importance since it adds to aesthetic consideration.

### 2.1.2 Waste Collection:

Collection of the stored waste is another important element in solid waste management processes. The waste stored is collected and hauled to the location where the collection vehicle/vector is emptied. According to Thakur, Dr Rjendra Singh. 2019; in developed climes like America, the most common type of residential collection services include “backyard carry” and “setout-setback” Individual bins/containers are also placed alongside shops and residential areas, which are emptied directly into the trucks/tippers. This method prevents people from dumping waste indiscriminately. On the flip side, the procurement and provision of waste bins and containers may seem expensive to implement in Nigeria and Bwari for that matter. This cannot be unconnected with the poor maintenance culture of Nigeria as a whole.

### 2.1.3 Transfer and Transport:

DEVEX, 2019 stated that transfer and transport often involves two steps. The first concerns itself with the transfer of wastes from the smaller collection vehicles to the larger transport equipment while the second concerns itself with the subsequent transport of the wastes, usually over long distances to the final disposal site.

### 2.1.4 Processing and Recovery:

Waste processing and recovery includes all technology, equipment and facilities deployed to improve the efficiency of other stages in recovering usable materials, conversion of products or energy. In recovery, separation operations have been devised to ensure that valuable resources are recovered from the mixed solid wastes delivered to solid waste processing plants or transfer stations.

### 2.1.5 Disposal:

This is the ultimate fate of all solid wastes including residential waste collected and transported directly to landfill site. Several methods of solid waste management have evolved over the years. These methods according to the Centre for Environment and Development in 2003 vary greatly with type of wastes and local conditions. This is divided into early solid waste management practices and contemporary methods of solid waste management.

## 2.2 Concept of Biogas and Bio-digestion

At the end of 2019, the global amount of biogas plant capacity was about 19.5 GW with growth in capacity being fueled by among others, high fossil fuel prices, cheap and easy access to biomass feedstock, and concerns over emissions and global warming (S. T. Chen, H. I. Kuo, and C. C. Chen, 2007). The most common feedstock used to produce biogas are wastes, like domestic wastes, i.e., food, vegetables, fruits, and animal wastes like dung, poultry dropping, or public moist wastes from food cafes and restaurants, markets, and biological waste from industries having high moisture content and high degradability (M. J. B. Kabeyi and A. O. Oludapo, 2020). Biogas production by anaerobic digestion enhances the country's energy basket status and significantly contributes to natural resource conservation and environmental protection (F. Scholwin and M. Nellas, 2012; M. J. B. Kabeyi and O. A. Olarewaju, 2022; S. Achinas, V. Ahinas and G. J. W. Wuverink, 2017; and B. Afework, J. Hanannia, J. Jenden, K. Stenhouse, and J. Donev, 2022).

Biogas is produced by the anaerobic action of a class of bacteria under suitable conditions. Gas is an environmentally friendly energy resource with a calorific value between 21 and 24 MJ/m3 [30]. Natural anaerobic biodegrading of organic matter releases 590–800 million tons of methane into the atmosphere due to uncontrolled natural biodegradation. Biogas recovery systems apply controlled conditions in the biodegradation of biomass for the production of biogas for energy application (P. C. Joale, P. F. Ricardo, and T. G. I. Medina, 2011). Biogas generally contains 50–70% methane and 30–50% carbon dioxide, based on the type of substrate used and process control and management. Other constituents are hydrogen sulfide and nitrogen, among others. With larger plants, biogas can be supplied into gas networks upon enrichment. Anaerobic digesters are generally designed to operate in the mesophilic (20–40°C) or thermophilic (above 40°C) temperature zones (M. J. B. Kabeyi and A. O. Oludapo, 2020).

Anaerobic digestion of wastes for sanitation and use of biogas as an energy carrier has existed for long worldwide. Digested wastes from biogas plants are also used widely as a valuable fertilizer in farming. In Germany, the share of biogas in electricity generation was about 4.5% in 2013 because of favorable pricing of electricity generated from renewable sources which saw biogas plants increase from about 140 in 1992 to about 7,720 by the end of 2013. As a midterm strategy, biogas has a potential to fill up the residual load from electricity generation based on wind and photovoltaic (M. Lebuhn, B. Munk, and M. Effenberger, 2014).

Biogas generally contains 30–70% methane and 30–50% CO2, which depends on the substrate fed to the digester. Other constituents of biogas are small volumes of hydrogen. The typical heating value of 21–24 MJ/m3 or 6 kWh/m3 is suitable for cooking, heating, lighting, or electricity production while a large plant with biomethanation can supply enrichedbiogas into gas supply networks or mains (S. Kabasci, 2009). Biogas production technologies used to recover biogas from biomass harness anaerobic degradation pathways by the action of a suite of bacteria which exist in form of at least three bacterial communities needed by the biochemical chain that finally produce methane alongside other gases (P. C. Joale, P. F. Ricardo, and T. G. I. Medina, 2011).

## 2.3 Production of Biogas

Typically, it has following parts –

- Mixing tank
- Inlet chamber
- Digester
- Outlet chamber
- Overflow tank

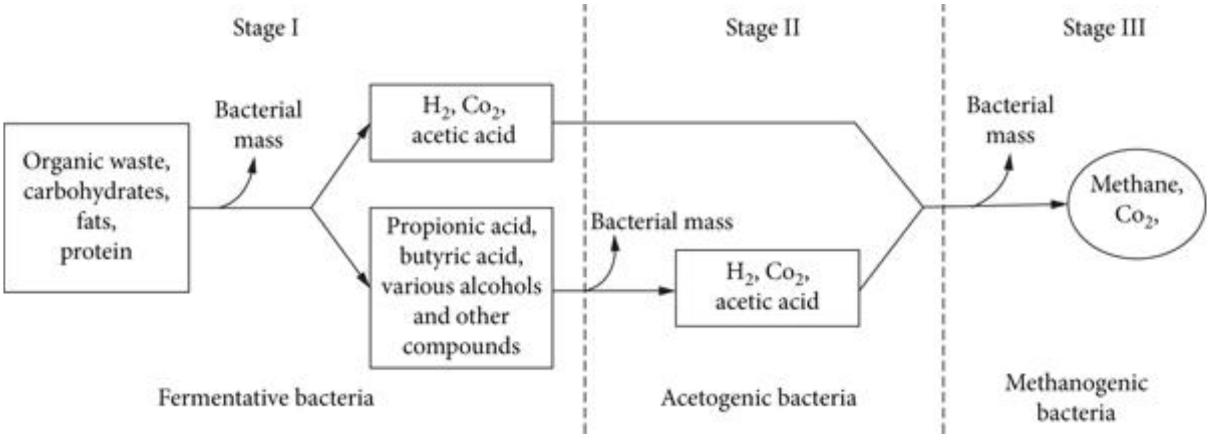


Figure 2 Summary of the biogas formation process

Figure 2 summarizes the process into three stages with hydrolysis and acidogenesis combined.

From Figure 2, it is noted that biogas production is divided into three main stages, i.e., stage I which involves the action of fermentative bacteria, stage II which involves the action of acetogenic bacteria, and stage III which involves action by methanogenic bacteria. Proper management of the three stages ensures optimum production of biogas.

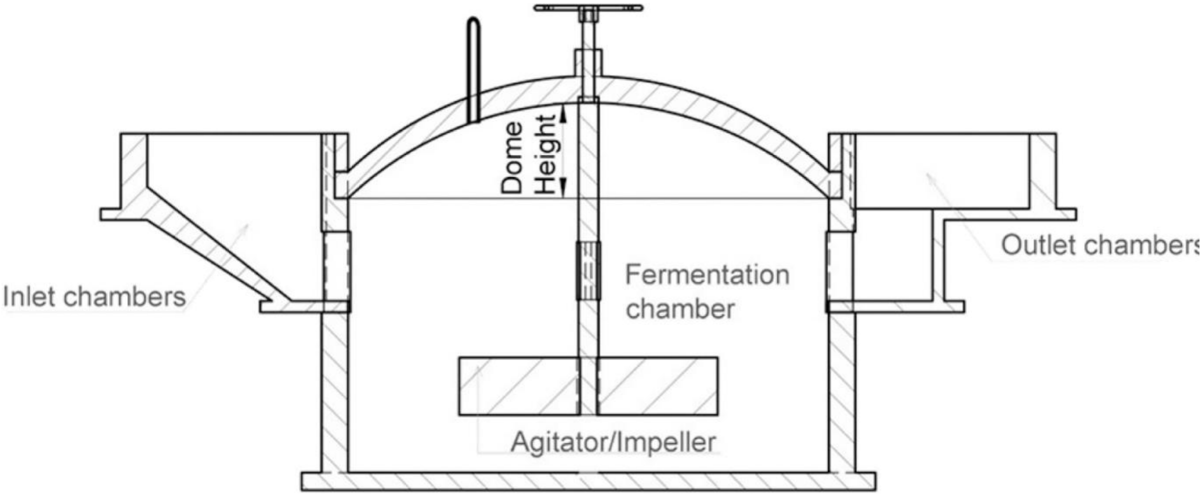


**Fig. 1: Conventional Digester design**

A digester is a specialized vessel used in various industrial processes, such as wastewater treatment and biogas production, to facilitate the decomposition of organic materials. The digester typically consists of distinct components, each serving a crucial role.

The inlet is the point through which organic material, such as sewage or biomass, is introduced into the digester. This input serves as the substrate for the biological reactions taking place within the system.

The outlet is the exit point where the processed materials, such as treated wastewater or digested slurry, are discharged from the digester. This output is significantly transformed compared to the influent, with reduced organic content and improved environmental compatibility.

The gas chamber is a separate section within the digester designed to capture and store the biogas produced during the anaerobic digestion process. Biogas is composed mainly of methane and carbon dioxide and can be used as a renewable energy source for heating or electricity generation.

An agitator is a mechanical device placed within the digester to ensure proper mixing of the substrate, microorganisms, and nutrients. This mixing promotes uniform microbial activity and optimal digestion conditions, enhancing the breakdown of organic matter and the generation of biogas.

The combination of these components within the digester structure allows for efficient conversion of organic materials into valuable byproducts, such as biogas and stabilized solids. This process is not only environmentally beneficial but also offers the potential for resource recovery and energy generation, contributing to sustainable waste management and energy production practices.

### 3.1.0 Introduction

The materials used to produce the Biogas and the methodology employed in the production and determination of their quality, performance and cost are described in this chapter. Additionally, the statistical analysis used to obtain results from the data generated was explained.

### 3.2.0 Description of the Study Area

The study was conducted in Phreta Farm located at Waru Village in Abuja Municipal Area Council of the Federal Capital Territory, Abuja, Nigeria. Phreta Farm is located about 15km to the south of the city of Abuja and the capital city of Nigeria. And situated at 9°26' N latitude and 42°03'E longitude with an altitude of 1980 meters above sea level (Mishiraet al., 2004). However, the experiment is being conducted from July to August, 2023 at the laboratory of Animal Care in Karu, FCT, Abuja, Nigeria or the Laboratory of National Biotechnology Development Agency, Abuja, Nigeria.

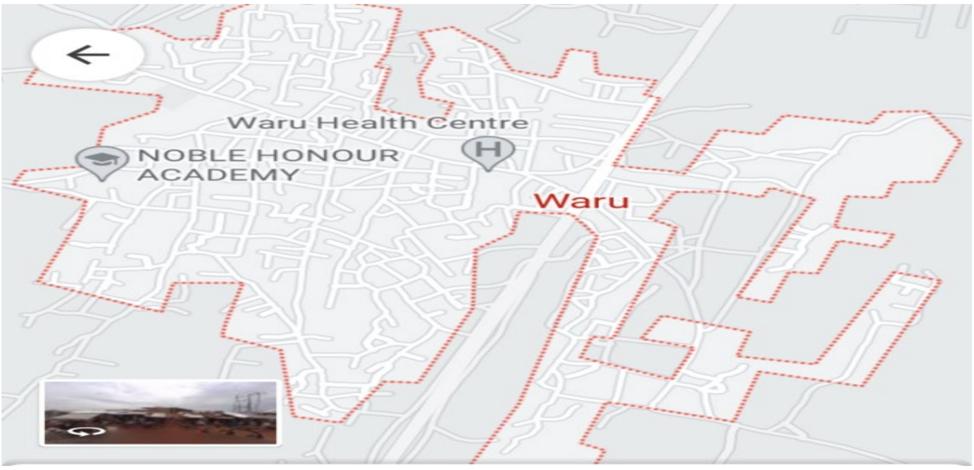


**Fig. 3.2.0: Location of the Study area**

### Research Design Framework

A mixed method approach was used in this research: experimental and survey design method. In the experimental design, being an attempt to establish cause-effect relationships among variables, an independent variable (biomass combination) was manipulated to determine the effects on the dependent variables (physical, mechanical and thermal properties) of Biogas developed from Poultry Waste and Bio-Digestive Processes. The variables were measured numerically and analysed by statistical techniques using software. The survey method required generating information from primary and secondary sources. The primary source involved market survey of the prices of commodities while the secondary information was sourced from literature and web pages of specific government agencies in Nigeria. Figure 3.1 summarizes the design of the research methodology.

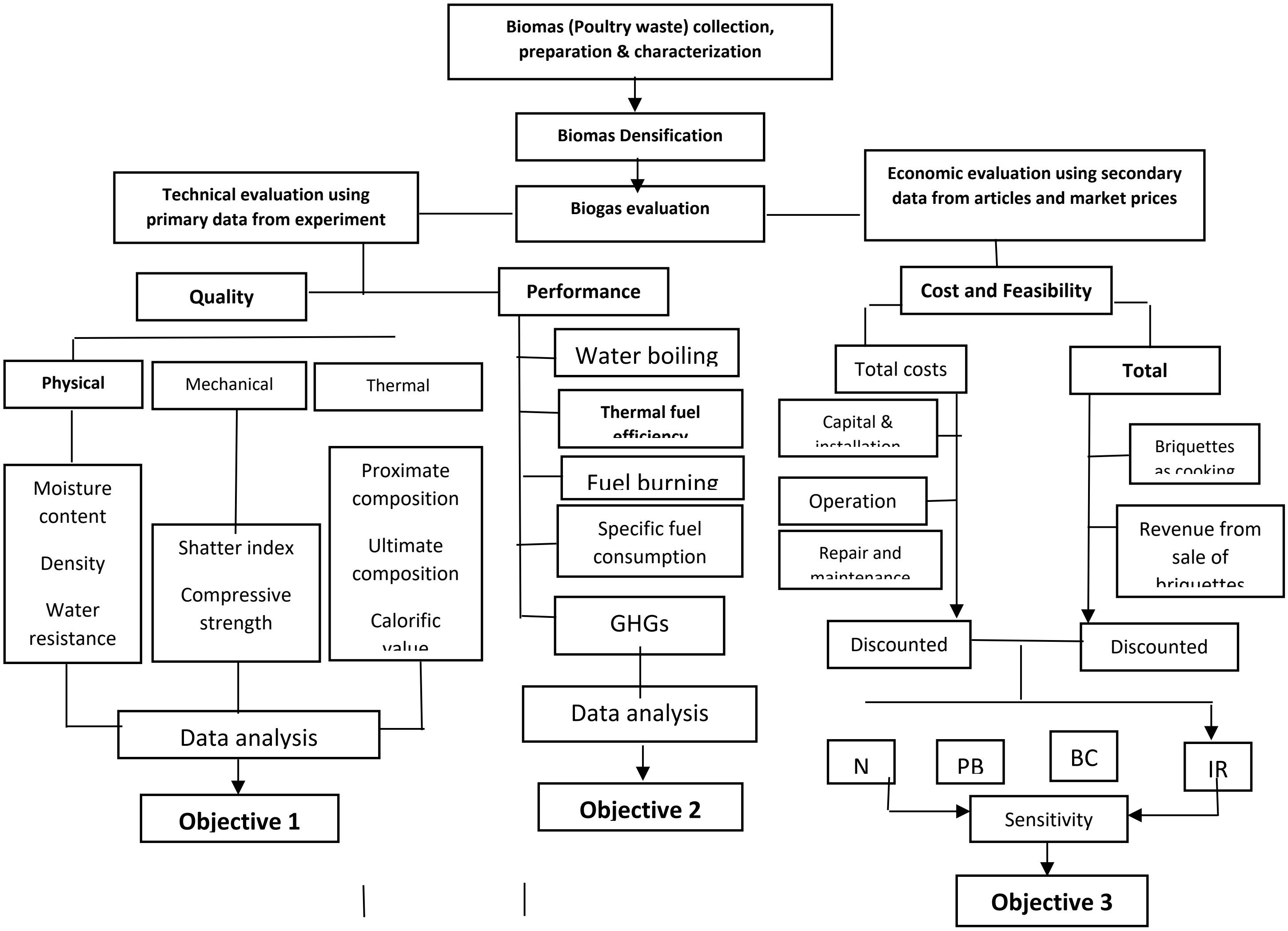


**Figure 3.1: Framework for evaluation of technical and economic viability of biogas in Nigeria.**

### 3.3.2 Calculations for Proposed Digester Volume

The research conducted by Alfa et al. (2014) focused on investigating the potential for biogas production from poultry droppings through the process of anaerobic digestion. In their study, the researchers were able to produce a total of 211 liters of biogas from an initial substrate of 6 kilograms of poultry droppings. The recorded standard deviation of 4.84 liters signifies the variation in biogas production results among different experimental runs, indicating the degree of uncertainty associated with the measurements.

To facilitate the anaerobic digestion process, the researchers adopted a specific approach. They first subjected the substrate to a pre-fermentation step, during which the poultry droppings were mixed with water in a 1:1 volume-to-volume (v/v) ratio. This mixture formed a slurry, which is a homogeneous blend of solid and liquid components. The primary objective of this pre-fermentation stage was likely to initiate the breakdown of organic matter and prepare the substrate for efficient digestion.

The anaerobic digestion phase spanned a period of 30 days. Throughout this duration, the pre-fermented substrate was kept in an oxygen-free environment to encourage the growth and activity of anaerobic microorganisms. These microorganisms are responsible for breaking down the organic components of the poultry droppings, resulting in the production of biogas. The composition of biogas typically comprises methane (CH4) and carbon dioxide (CO2), with trace amounts of other gases like hydrogen sulfide (H2S).

In the context of this thesis, the aim is to build upon the insights gained from the research by Alfa et al. (2014). The thesis seeks to explore the potential for biogas production from poultry droppings in a manner that optimizes the process based on previous findings. Specifically, the research conducted by Adelekan and Bamgboye (2009) indicated that a water-to-feedstock ratio of 3:1 led to increased biogas yield from poultry waste. In this context, the Ph.D. thesis aims to digest a larger quantity of poultry droppings, approximately 10 kilograms, with a water-to-feedstock ratio of 3:1.

The decision to use a higher water-to-feedstock ratio is grounded in the findings of Adelekan and Bamgboye (2009), which suggested that such a ratio led to enhanced biogas production. By replicating and building upon their findings, the Ph.D. thesis aims to contribute to the understanding of optimal conditions for biogas generation from poultry droppings. This research has the potential to offer valuable insights into sustainable waste management practices and renewable energy generation.

Based on the Finding, a vessel to digest 10kg of Poultry dropping leaving a total of 30% head space will have a volume which is minimum:

= 3:1 i.e x:10kg

if x=3*10 therefore 30L:10kg = total of 40L space

30% head space = 40*0.3= 12L

This implies the vessel must at least be up to 40+12(L) =52L to ensure appropriate digestions, however since these materials are being sourced from local market not specifically fabricated, a vessel with a higher volume can be adopted

### 3.3.3. Material selection

The selection of construction materials for the biodigester hinges upon a triad of critical factors: availability, cost, and research feasibility, collectively determining the foundation of the biodigester's functionality and longevity. Material availability emphasizes local sourcing to minimize ecological strain, bolstering resource efficiency and community engagement. Cost-effectiveness ensures materials align with the budget while maintaining superior performance, striking a balance for economic viability and extended impact. Research feasibility mandates non-reactive and durable materials, rigorously tested for compatibility with operational parameters and waste types, safeguarding against degradation and ensuring efficacy. This holistic approach harmonizes availability, cost, and research feasibility, with an emphasis on non-reactive and durable attributes that enhance reliability, safety, and ecological significance. The symbiotic relationship between sustainable material choices and the biodigester's overall success is underscored, encapsulating a strategy that optimizes both functionality and sustainability.

| Availability | Cost-effectiveness | Research feasibility |
|---|---|---|

### 3.3.4. List of locally sourced materials

1 70 litre drums with lids
2 63 diameter pipes
3 63 diameters back nuts
4 63 diameters by 1/2 adaptor & plugs
5 63 diameter ball gauge
6 1/2-inch unions
7 1/2-inch reducer
8 1/2-inch pipes
9 1/2-inch clips
10 5/16-inch hose and clips
11 Brass nozzles
12 Brass ballgames
13 3/8 steal valves
14 Iron fillings
15 Activated lints/activated carbon/silica gel
16 Adhesives in ranges / rubber Adhesives / lubricants
17 Tefflons
18 Suitable Neoprene
19 Spray Paint

20. Retrofitted Tyre Tubes (size 16)

Note: all the materials were bought in triplicates, because the experiment will be conducted in triplicate to ensure accuracy of results

**Fig 3.3: Materials Used**

### 3.4.0. Tools used

1. Measuring Tools: Including tape measures, rulers, and levels for accurate dimensions and leveling.
2. Cutting Tools: Such as saws, angle grinders, or cutting torches for shaping and cutting materials like steel or pipes.t
3. Drilling Equipment: Including drills and bits for creating holes in various materials.
4. Screwdrivers and Wrenches: For assembly and fastening of different components.
5. Piping and Plumbing Tools: Including pipe cutters, pipe wrenches, and plumbing sealants for setting up inlet and outlet pipes.
6. Safety Gear: Such as gloves, safety goggles, helmets, and protective clothing to ensure the safety of workers.

### 3.5.0 Fabrication

### 3.5.1 Digester Tank

The process of constructing the biodigester involves several meticulous steps to ensure its functionality and integrity. A 70L container serves as the basis for the biodigester, initially inspected for potential leakages and thoroughly cleaned. The container, measuring 30x30x77cm and featuring a round lid, forms the core structure.

To facilitate the anaerobic digestion process, two holes are meticulously created in the top of the digester. These holes, designed as feedstock inlets, are generated by boring into the digester's top using a 63cm drill bit. Subsequently, a 63-diameter pipe, measuring 45cm in length, is prepared to serve as the inlet pipe. This pipe is attached to a connectable segment of a 63-diameter back nut. The back nut, when affixed to the front side of the lid, is securely connected and sealed using appropriate adhesives. This establishes a reliable connection between the inlet pipe and the biodigester lid.

Conversely, the outlet for generated gas comprises a smaller orifice with a diameter of 3/8. A 13.3/8 steel valve is threaded into the drilled hole, and a plastic union secures the outlet to the lid. To ensure a hermetic seal, the connection is sealed using adhesive materials.

Mirroring the methodology applied for the feedstock inlet, a corresponding outlet for the digestate is established. This entails utilizing a 63-diameter ball gauge, which is connected and integrated following a similar principle. However, the outlet is located 12cm above the base of the digester.

**Fig 3.4.1: Digester Tank**

### 3.5.2. Scrubber

The scrubber system comprises a 1-inch pipe with a height of 40cm. Within this system, a combination of iron fillings and cotton materials is employed. The iron fillings play a crucial role in eliminating hydrogen sulfide ($H2S$) through a chemical reaction with the biogas. This reaction is represented as follows:

$Fe + H2S \rightarrow FeS + H2$

In this reaction, iron (Fe) reacts with hydrogen sulfide (H2S) to produce iron sulfide (FeS) and hydrogen gas (H2).

Concurrently, the cotton materials within the scrubber system are utilized to extract moisture from the biogas. By absorbing moisture, the cotton aids in rendering the biogas flammable and suitable for use as fuel. This dual-action scrubber system contributes significantly to the purification and optimization of the biogas for safe and efficient utilization.

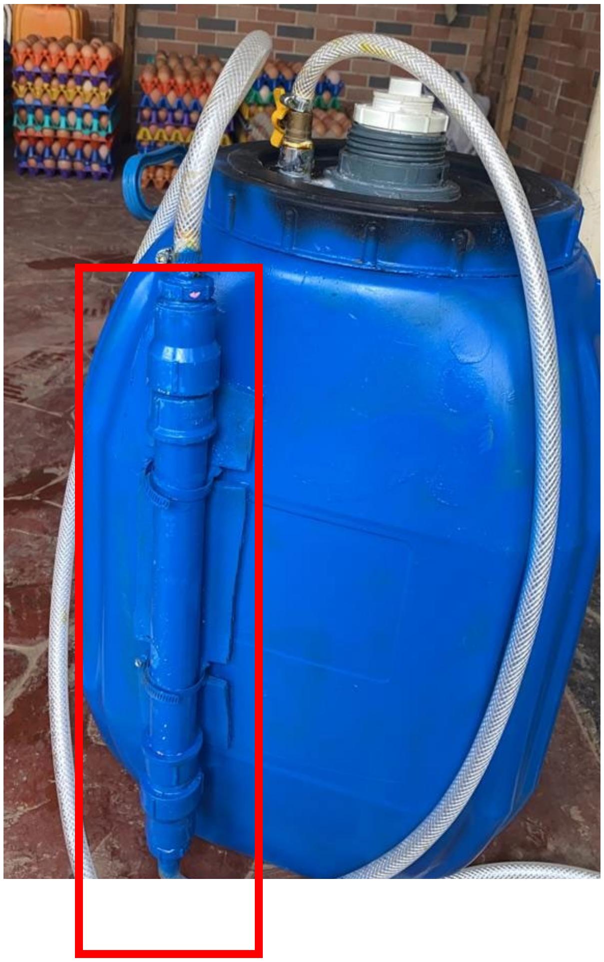


**Fig 3.5.2: Scrubber system**

### 3.5.3 Gas collection System

The fundamental principle underpinning the gas collection process involves the retrofitting of a conventional glass test tube with a size of 16. This retrofitting entails incorporating a two-way free-flowing mechanism comprising an inlet and an outlet. The inlet is seamlessly connected to the scrubber system, which serves the purpose of gas purification. On the other hand, the outlet acts as the designated point for igniting the gas generated within the digester.

**Fig 3.4.3: Gas collection systems**

### Pressure Testing

The process of pressurization was achieved by inflating the designated tube within the system. Following successful pressurization, a meticulous verification process ensued. The entire system was securely locked, maintaining the applied pressure. A solution of soap was then employed as an effective means to identify any potential leakages throughout the system.

By systematically applying the soap solution, the research team closely monitored the system's components, connections, and joints for any visible signs of gas escaping. The formation of bubbles, prompted by gas leakage, was vigilantly observed and recorded. This step served as a crucial quality control measure, ensuring the integrity of the gas handling system by promptly identifying and addressing any leaks that could compromise system efficiency or safety.

## 3.6. Digester Feeding

### 3.6.1. Sample collection

samples were procured within thoroughly cleaned 20-liter paint buckets. The objective was to accumulate samples amounting to 30 liters. Consequently, two buckets, totaling 40 liters in volume, were transported to the abattoir. The specimens were gathered from a poultry farm situated in the village of WARU within the AMAC region.

8.927088608379329,

**Fig 3.5.1: sample collection location**

### 3.5.2. Sample Processing

Sample processing involved the following steps: each collected sample was carefully weighed to ensure a uniform 10kg portion for every one of the three digester units. These samples encompassed a variety of materials including feathers, leather, and plastic. Each 10kg segment was then mixed with 30 liters of water, establishing a well-balanced ratio of 3:1. The resulting mixtures underwent meticulous homogenization to achieve a consistent composition.

**Fig 3.6.2: Sample Processing**

### 3.6.3. Digester Feeding

Following the completion of sample processing, the subsequent phase involved the feeding of three individual digesters with a total of 40 liters. This allocation adhered to a specific ratio of 3:1, denoting the proportion of 30 liters of water to 10 liters of substrate material.

**Fig 3.6.3: Digester feeding**

### 4.1.0 **Introduction**

In this study, we present the results of an investigation aimed at understanding the dynamics of gas production within a biodigester system. The experiment involved a meticulously designed process, where temperature readings were collected at specific intervals to establish a comprehensive understanding of gas generation and its correlation with environmental conditions.

Throughout the experiment, temperature data were meticulously gathered at precise time points – 2 PM and 2 AM – each day. These readings were obtained using a digital thermometer, capturing the subtle fluctuations in temperature that occur within the biodigester environment. By meticulously documenting temperature variations, we aimed to unveil potential patterns or trends that could shed light on the interplay between temperature and gas production.

Following the rigorous temperature monitoring process, the study transitioned into gas production measurement. Gas production was quantified within a 24-hour cycle, capturing the accumulation and release of gases from the biodigester. This involved measuring the volume of gas generated within the system over the specified time frame.

The procedure ensured that each 24-hour cycle's gas production data were systematically recorded. These records included the volume of gas produced and any potential fluctuations observed during the release of gases into the atmosphere. This comprehensive approach aimed to provide a holistic perspective on gas production trends and patterns, uncovering potential relationships between temperature variations and gas generation.

By meticulously gathering temperature readings and quantifying gas production in this manner, the study aimed to offer valuable insights into the complex interplay between environmental conditions and the efficiency of the biodigester system. The results of this investigation have the potential to inform not only our understanding of gas production mechanisms within biodigesters but also broader applications in sustainable energy production and waste management strategies.

### 4.2.0 Profile of Poultry Waste Management Practice in FCT, Abuja, Nigeria

Poultry wastes can be divided into solid wastes, liquid waste and gas wastes. The solid waste consists mainly of bones, undigested ingesta, hairs and occasionally aborted feti, while the liquids comprise of blood, urine, water, dissolved solids and gut contents. Odors and emissions produce gas wastes. Effluent generated from the abattoir is characterized by the presence of a high concentration of whole blood of slaughtered food birds and suspended particles of semi-digested and undigested feeds within the stomach and intestine of slaughtered and dressed food animals. In Abuja, most of the abattoirs visited managed their wastes in either of the following ways, namely

- Burial methods;
- Controlled incineration methods;
- Composting method;
- Rendering method;
- Blood processing method;
- Anaerobic method;
- Washed into flowing streams method; and
- Transportation method.

Table 5: Below gives vividly the various methods of abattoir wastes management as

employed by different poultries visited in Abuja, FCT.

Question I: What are the ways poultry waste is currently been managed in FCT, Abuja, Nigeria?

| S/No | ITEM | SA | A | D | SD | MEAN (x) |
|---|---|---|---|---|---|---|
| 1 | Burial method is the main way of managing poultry waste. | 107 | 115 | 16 | 2 | 3.36 |
| 2. | Controlled incineration method is the main way of managing poultry waste. | 96 | 113 | 26 | 5. | 3.25 |
| 3. | Composting is the method of poultry waste Management. | 108 | 99 | 23 | 10. | 3.77 |
| 4. | Rendering is the method of poultry waste management. | 72 | 78 | 52 | 38. | 2.77 |
| 5. | The blood of slaughtered animals are processed as a way of poultry waste management. | 80 | 40 | 90 | 30. | 2.71 |
| 6. | Poultry waste are managed through Anaerobic digestion process. | 102 | 92 | 33 | 13. | 3.18 |
| 7. | The wastes from poultry are washed into a flowing stream/river. | 111 | 120 | 8 | 1. | 3.42 |
| 8. | The wastes from poultry are gathered and transported to a designated waste disposal site. | 120 | 101 | 17 | 2. | 3.41 |
| | General Mean | | | | | 3.23 |

Source: Field Survey (January 2023)

Further explanation and quick check are contained in the diagram below

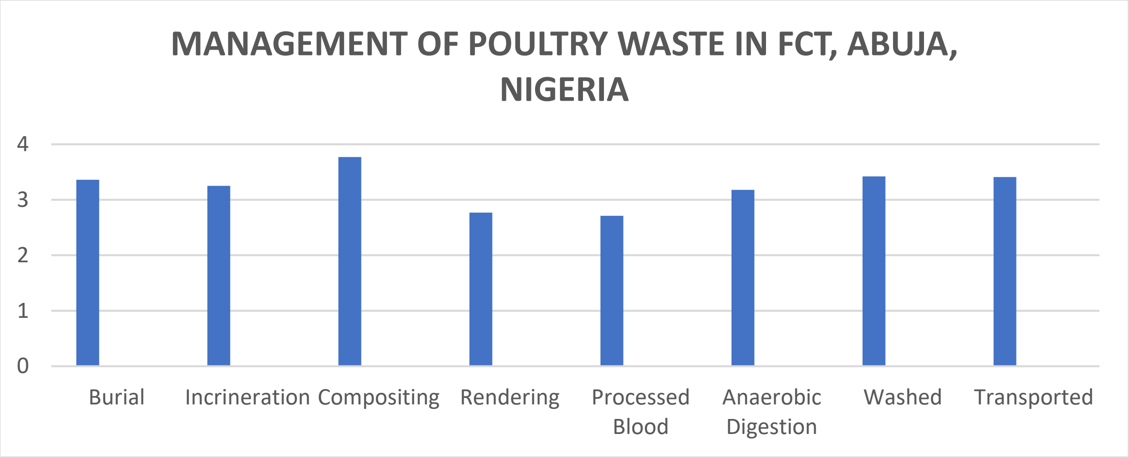


Fig. VI Source: Table 5

On the average and going by Fig. I above; the commonly used method of waste disposal is the Composting Method and closely followed by the Transportation and Washed into a flowing river/stream method. The choice of these methods is not unconnected to the fact that they easy to use, cheap to maintain and readily available. However, for any chosen method, there is the attendant health implication. Data obtained from research question one is presented on Table 5 and Fig. VI which showed that the entire questionnaire items were agreed with. The minimum and maximum rating means (x) to the items were 2.71 and 3.42 respectively, and a general rating mean of 3.23. It therefore implied that the respondents agreed to the itemised current ways of abattoir management in the FCT, Abuja.

### 4.3. Gas Measurement

The "16/8-7 inch" notation typically refers to the tire size, where "16" is the outer diameter of the tire in inches, "8" is the section width in inches, and "7" is the inner diameter of the rim in inches. However, this notation doesn't provide enough information to accurately calculate the volume of air that the inner tube can hold, as it doesn't specify the length of the tube or the thickness of the rubber.

To calculate the volume of air the inner tube can hold, you would need the following information:

Inner Diameter: This is the diameter of the hole in the center of the tube that fits around the rim. It's usually slightly smaller than the rim diameter.

Length: This is the length of the inner tube when it's fully inflated and installed in the tire.

Thickness: The thickness of the rubber material of the inner tube, typically measured in millimeters or inches.

With these measurements, you can use the formula for the volume of a cylinder:

Volume = $\pi \times (\text{Inner Diameter} / 2)^2 \times \text{Length}$

### 4.4. Biogas Data

**Table 4.4: Data for 30 days Digestion**

| DAYS | Temperature (Celsius) | DIGESTER 1 Volume ((L) | DIGESTER 2 Volume ((L) | DIGESTER 3 Volume ((L) |
|---|---|---|---|---|
| JULY | | | | |

| | | | | |
|---|---|---|---|---|
| 1. | 28-23 | 12.9 | 12.9 | 11 |
| 2. | 28-26 | 12.3 | 12.6 | 12 |
| 3. | 28-23 | 12.6 | 12.5 | 12.5 |
| 4. | 28-23 | 12.3 | 12.2 | 12 |
| 5. | 27-23 | 11.1 | 11 | 12 |
| 6. | 27-22 | 10.5 | 10 | 11 |
| 7. | 28-22 | 11.2 | 11.5 | 11.7 |
| 8. | 27-23 | 10.5 | 10.7 | 11 |
| 9. | 27-21 | 11.1 | 11 | 11.3 |
| 10. | 27-22 | 11.6 | 11 | 11 |
| 11. | 28-23 | 11.3 | 11.6 | 11 |
| 12. | 28-22 | 11.3 | 11.6 | 11.6 |
| 13. | 27-22 | 11 | 11 | 11 |
| 14. | 28-23 | 11.3 | 11.3 | 11.9 |
| 15. | 27-22 | 10 | 10 | 9 |
| 16. | 27-22 | 9.5 | 9.9 | 9.9 |
| 17. | 27-22 | 10.1 | 10 | 10 |

| | | | | |
|---|---|---|---|---|
| 18. | 28-24 | 10.6 | 10.5 | 10.9 |
| 19. | 28-23 | 10.5 | 10.4 | 10.4 |
| 20. | 28-23 | 9.3 | 9.2 | 10 |
| 21. | 27-22 | 8 | 8 | 8 |
| 22. | 28-23 | 8.5 | 8.5 | 8 |
| 23. | 27-22 | 8 | 8 | 8 |
| 24. | 28-23 | 7.5 | 7.9 | 7.9 |
| 25. | 29-21 | 9.2 | 8 | 8 |
| 26. | 28-23 | 7.2 | 7 | 7 |
| 27. | 28-22 | 7.9 | 7 | 7 |
| 28. | 27-22 | 6.2 | 6.9 | 7.2 |
| 29. | 28-23 | 7.5 | 7 | 7.5 |
| 30. | 28-23 | 7 | 7 | 7.7 |
| 31. | **TOTAL** | **298** | **300.7** | **315.5** |

1.83083
6229

Standard Deviation

**Fig 4.4: Daily Production Chart**

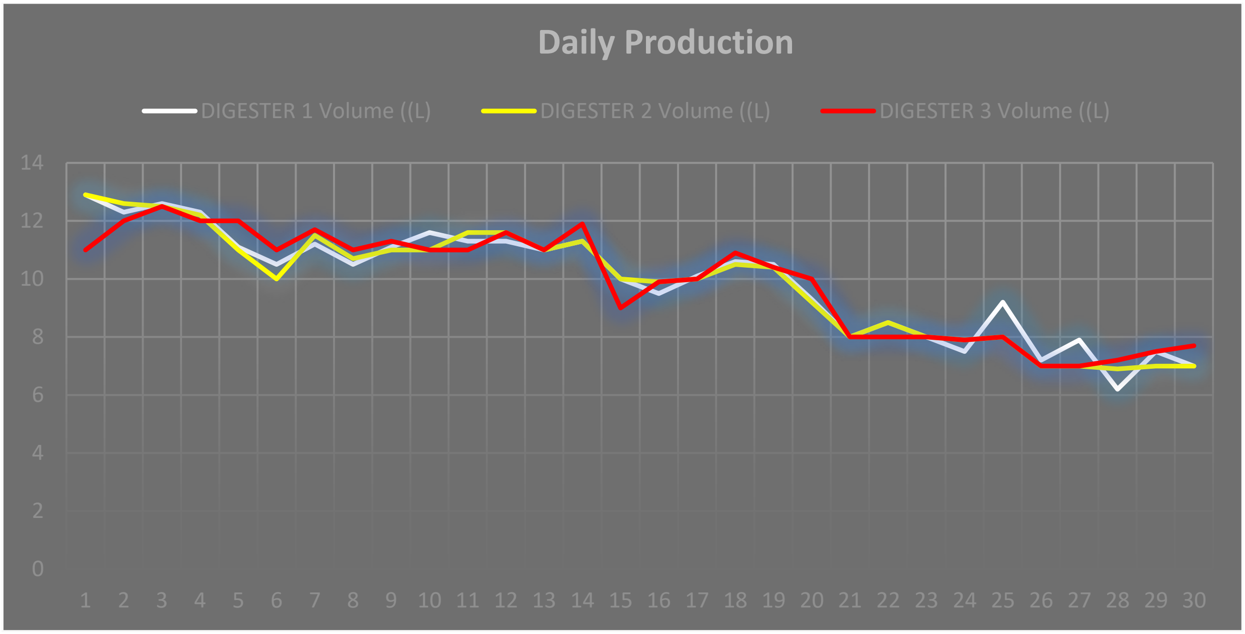


**Fig 4.4: Total Gas Production Chart**

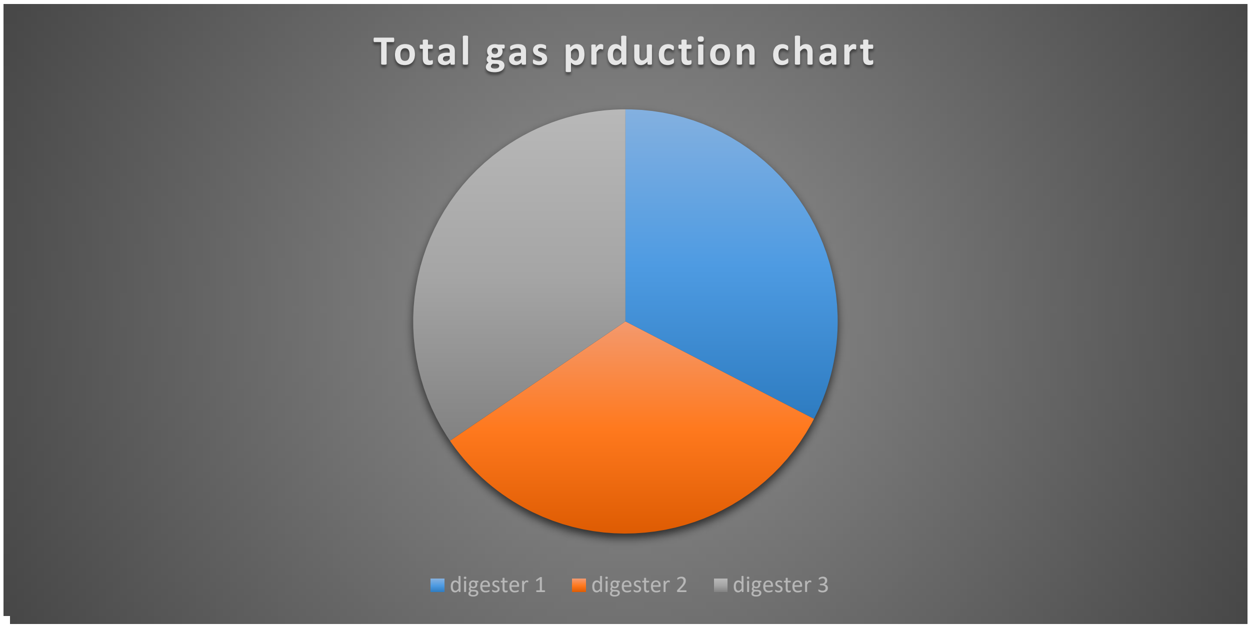


**Table 4.4 Average Daily Production over 30 days with Daily Temp Max.**

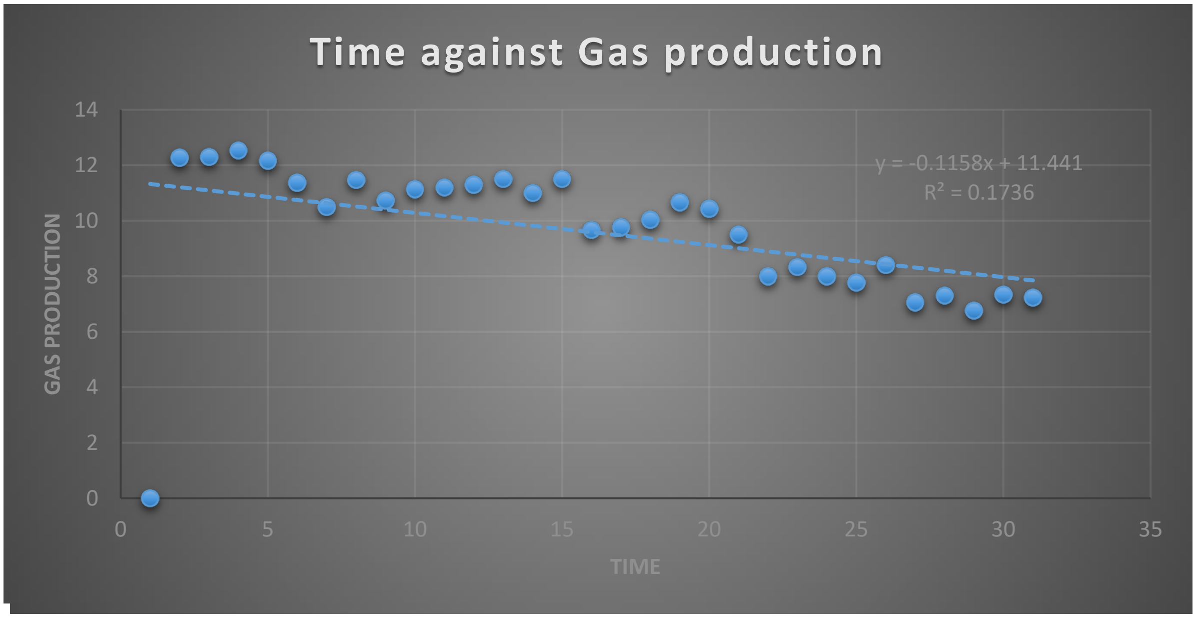
| DAYS | Temperature (Celsius) | Gas Volume Average |
|---|---|---|
| 1. | 28 | 12.3 |
| 2. | 28 | 12.3 |
| 3. | 28 | 12.5 |
| 4. | 28 | 12.2 |
| 5. | 27 | 11.4 |
| 6. | 27 | 10.5 |
| 7. | 28 | 11.5 |
| 8. | 27 | 10.7 |

| | | |
|---|---|---|
| 9. | 27 | 11.1 |
| 10. | 27 | 11.2 |
| 11. | 28 | 11.3 |
| 12. | 28 | 11.5 |
| 13. | 27 | 11.0 |
| 14. | 28 | 11.5 |
| 15. | 27 | 9.7 |
| 16. | 27 | 9.8 |
| 17. | 27 | 10.0 |
| 18. | 28 | 10.7 |
| 19. | 28 | 10.4 |
| 20. | 28 | 9.5 |
| 21. | 27 | 8.0 |
| 22. | 28 | 8.3 |
| 23. | 27 | 8.0 |
| 24. | 28 | 7.8 |
| 25. | 29 | 8.4 |
| 26. | 28 | 7.1 |
| 27. | 28 | 7.3 |

| | | |
|---|---|---|
| 28. | 27 | 6.8 |
| 29. | 28 | 7.3 |
| 30. | 28 | 7.2 |

## 5.1 Findings

### Fig 4.5: Scatter Plot Time against Gas Volume



### 4.5.1. Regression analysis

| | |
|---|---|
| SUMMARY OUTPUT | |
| *Regression Statistics* | |
| Multiple R | 0.93569751 |
| R Square | 0.87552983 |

|  |  |
|---|---|
| Adjusted R Square | 0.871084467 |
| Standard Error | 0.654946307 |
| Observations | 30 |

Multiple R (0.9357): The value of 0.9357 indicates a strong positive correlation between the predicted gas production values (based on your regression equation) and the actual observed gas production values. This suggests that as the number of days increases, the gas production in the biodigester tends to decrease because of the spent organic matter.

R Square (0.8755): The R Square value of 0.8755 means that approximately 87.55% of the variability in gas production over the 30-day period can be explained by the number of days. This indicates that your regression model captures a substantial portion of the variability in gas production using the number of days as the independent variable.

Adjusted R Square (0.8711): The Adjusted R Square value of 0.8711 takes into account the complexity of the model and suggests that even after considering the potential inclusion of unnecessary variables, your model still explains a significant portion of the variability in gas production.

Standard Error (0.6549): The standard error of 0.6549 represents the average distance between your predicted gas production values and the actual observed gas production values. Lower values of standard error indicate that your model's predictions are closer to the actual values, indicating a better fit of the model to the data.

In summary, your regression analysis suggests that there is a strong positive correlation between the number of days and gas production in the biodigester. The model you've built explains a substantial amount of the variability in gas production, and this relationship holds even when considering the model's complexity. The relatively low standard error indicates that your model's predictions are close to the actual observations.

### 4.5.2. Combustion capacity

Upon igniting the biogas, distinct flame characteristics were observed, presenting a vivid interplay of colors. Notably, the flame exhibited shades of red and blue, which are indicative of specific combustion properties. While the blue flame might appear faint or barely noticeable in still camera pictures, its presence was strikingly evident during the actual physical combustion of the gas.

The presence of a blue flame is a significant indicator of efficient and complete combustion. Blue flames are associated with higher temperatures and indicate that the combustion process is effectively breaking down the hydrocarbon molecules within the gas. This results in a cleaner and more energy-efficient burn compared to flames dominated by yellow or orange hues.

Despite the challenge of capturing the true intensity of the blue flame through photography, the tests conclusively demonstrated the presence of this characteristic blue flame during the combustion of the natural biogas. The interplay between the red and blue hues in the flame highlights the composition and quality of the biogas, showcasing its potential as a viable energy source.

In practical applications, the presence of a distinct blue flame reinforces the viability of using the natural biogas for various purposes, such as cooking, heating, or generating energy. The visual cues provided by the flame's coloration give valuable insights into the combustion efficiency and the potential energy release from the biogas, further emphasizing its suitability for sustainable energy applications.

### 4.5.4. Methane content

The gas evolution from the biodigester aligns with Kalsum et al.'s (2020) study on anaerobic digestion of cow dung in a fixed dome biodigester. Their research focused on methane gas quality in this process. They noted a gradual change in gas color, shifting to a deeper blue hue over time.

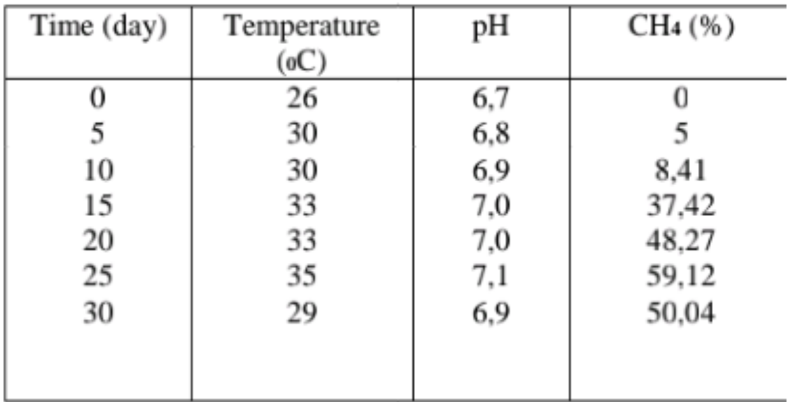
The bluish gas color arises from changes within the biodigester during anaerobic digestion. Methane, a major biogas component, exhibits this color under specific conditions. While naturally colorless and odorless, methane can appear bluish in larger volumes or concentrations due to its interaction with light.

Kalsum et al. likely linked the deepening blue color to rising methane concentration as anaerobic digestion progresses. Methane's lower density and lightness make it appear bluish in larger volumes. As methane content increases, the blue color intensifies.

This correlation between methane concentration and gas color, seen in Kalsum et al.'s study, provides insights into anaerobic digestion dynamics and biogas composition changes. The bluish transformation indicates methane-rich gas, validating efficient methane extraction through digestion.

In our biodigester system, increasing gas blueness daily signifies enriched methane content. This reaffirms digestion effectiveness, reflecting prior research trends. The visual cue highlights the potential for methane-rich biogas use in renewable energy, aligning with sustainable waste management and energy goals.

**Figure 4.5: Methane Increase with time (Kalsum et al, 2020)**



| Time (day) | Temperature ($_{o}$C) | pH | $CH_4$ (%) |
|---|---|---|---|
| 0 | 26 | 6,7 | 0 |
| 5 | 30 | 6,8 | 5 |
| 10 | 30 | 6,9 | 8,41 |
| 15 | 33 | 7,0 | 37,42 |
| 20 | 33 | 7,0 | 48,27 |
| 25 | 35 | 7,1 | 59,12 |
| 30 | 29 | 6,9 | 50,04 |

**Fig 4.5: Gas flaming**

### Limitations

However, it is important to acknowledge a limitation of this study, which lies in the absence of utilizing a bioanalyzer to directly determine the absolute ratios of methane, carbon dioxide, nitrogen gas, and hydrogen sulfide within the produced biogas. While the visual observations and flammability tests provided valuable insights into the characteristics of the gas, a bioanalyzer could have offered a more precise and quantitative analysis of the gas composition. Incorporating such advanced analytical tools could have enhanced the accuracy and comprehensiveness of our understanding of biogas composition dynamics and its potential applications. Future studies could consider integrating bioanalyzers to provide a more detailed assessment of the gas composition in biodigester systems.

### 5.2. Conclusion

In conclusion, this study aimed to investigate the dynamics of gas production within a biodigester system, shedding light on the intricate interplay between environmental conditions and the efficiency of gas generation. Through meticulous data collection and analysis, we examined temperature fluctuations and their potential correlation with gas production.

The experiment involved collecting temperature readings at specific intervals, revealing nuanced temperature changes occurring within the biodigester environment. These variations were documented with precision, allowing us to uncover potential patterns that might influence gas production trends.

Transitioning into the gas production measurement phase, we meticulously quantified gas production over 30-day cycles. The data captured the accumulation and release of gases, contributing to a holistic understanding of gas production patterns. Notably, the flammability tests further illustrated the gas's characteristics, showcasing distinct red and blue flames during combustion.

The regression analysis provided valuable insights into the relationship between the number of days and gas production. The high multiple R-value indicated a strong positive correlation between predicted and observed values, while the R Square value of 0.8755 highlighted that approximately 87.55% of gas production variability could be explained by the number of days. The adjusted R Square value reinforced the model's robustness, considering its complexity.

With a relatively low standard error, the model's predictions closely aligned with actual observations, underscoring the validity of the findings. This comprehensive approach contributes to our understanding of gas production mechanisms within biodigesters, potentially informing broader applications in sustainable energy production and waste management strategies.

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