

DESIGN AND PRODUCTION OF A HOUSEHOLD BIOGAS DIGESTER

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CERTIFICATION

This is to certify that this project is original and was carried out by the students as mentioned earlier, of the Department of Mechanical Engineering, Faculty of Engineering, University of Benin, Edo state, Nigeria under the supervision of Prof. D. I. Igbinomwanhia.

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DEDICATION

This project is dedicated to the almighty God, the giver of insight, wisdom, knowledge, and understanding. For granting us the wisdom strength, provision, and perseverance to complete this project

ACKNOWLEDGEMENTS

We give the most gratitude to God almighty for giving us his grace and blessings upon us all through our program. We thank our parents and guardians for their unwavering love, encouragement, and support. Our sincere appreciation goes to Prof. D. I. Igbinomwanhia, our esteemed project supervisor whose guidance, and expertise were instrumental in shaping this work. We thank the Department of Mechanical Engineering, University of Benin for providing the enriching academic environment, resources, and opportunities that facilitated our learning and growth. To our friends and colleagues whose camaraderie enriched our experience, we owe immense thanks.

ABSTRACT

The purpose of this project is to design a small-scale biogas digester that uses household food waste as feedstock to address the financial and environmental issues that arise from food waste. The aim is to reduce dependency on fossil fuels by producing biogas from biodegradable waste, which can be used for power generation and cooking. A review of the literature, conceptual design, meticulous manufacturing, and performance testing are among the goals. The study emphasizes how important it is to address rising food waste to improve the environment and provide financial relief. The project's goal is to make it easier for homes to adopt biogas plants by offering ideas that are simple enough for installation. The scope includes designing and building a biogas canister digester as well as producing biogas from home food waste.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND STUDY

Household food waste is a type of municipal waste that is not consumed and is lost or wasted. In a typical household, food is wasted every day either in its cooked state or in its raw state due to spoilage. In Nigeria, most household food wastes are disposed of in landfills where they decay and contribute to the production and emission of greenhouse gases, harming the environment and contributing to the climate change crisis. As the wastes at the bottom of these landfills decay due to the absence of oxygen, biogas is produced and escapes into the atmosphere. This emission causes the depletion of the ozone layer. Biodegradable waste from household food wastes can be converted to biogas and used for different household applications like cooking, power generation, and reduction of the household's need for fossil fuels thus reducing the financial strain involved in acquiring energy. How can one design a small and sustainable biogas-producing facility in such a small niche? Biogas canisters can be considered.

1.2 PROBLEM STATEMENT

The amount of food waste produced by households poses a serious environmental and financial problem, increasing landfill waste and greenhouse gas emissions. To effectively manage household food waste and turn it into renewable energy, looking into alternative and sustainable solutions is important. To find a sustainable and environmentally friendly solution to these problems of managing biodegradable waste (food waste) and producing renewable energy, this project will examine the viability of converting biodegradable waste (food waste) into biogas for cooking and also cover the design and manufacture of biogas digester for household application.

1.3 AIM AND OBJECTIVES

Aim

To design and produce a biogas digester with feedstock from household food waste

Objectives

The aim is achieved by:

1. Carrying out a literature review on biogas and biogas production processes
2. Developing a conceptual design for a biogas digester
3. Carrying out the detailed design of the biogas digester
4. Manufacturing the biogas digester
5. Testing the biogas digester for optimum performance

1.4 SIGNIFICANCE OF STUDY

The improvement of biogas technology will help in the energy sector of Nigeria, and make the environment and atmosphere cleaner and better. In Nigeria, some biogas plants are being used by individuals who can construct them by themselves. The significance of this study is to provide an avenue for anyone to be able to easily purchase the already-made concepts and designs, and be able to install the digester themselves with just basic knowledge of the biogas technology. This study seeks to simplify the adoption and easy incorporation of biogas plants in households.

1.5 SCOPE OF WORK

The scope of this work involves the research of biogas production from food wastes from households, and the design and fabrication of a biogas canister digester.

1.6 METHODOLOGY

The methods adopted for achieving the aim and objectives of this work are as follows:

1. Literature review of the research.
2. Feasibility studies
3. Conceptual design and preliminary testing.
4. Detailed design of the prototype
5. Fabrication of the prototype
6. Testing and review of the performance of the prototype
7. Conclusion and recommendation.

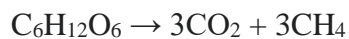
CHAPTER TWO

LITERATURE REVIEW

2.1 ANAEROBIC DIGESTION

A series of processes in which biodegradable substances are broken down through the action of micro-organisms in the absence of oxygen to produce biogas as a byproduct is known as anaerobic digestion. The engineered or controlled environment where anaerobic digestion occurs is called the anaerobic digester. This process of anaerobic digestion is used both industrially and domestically by utilizing waste to produce biogas. Anaerobic digestion occurs naturally in some soils and lake and oceanic basin sediments, where it is usually referred to as "anaerobic activity" (Koyama T. 1963) (Pamatmat et al 1973), it also occurs in the digestive systems of termites and large animals (DOE 2013). In Anaerobic digesters naturally occurring biological events are carried out in a controlled or engineered environment to dispose and treat biodegradable materials and produce biogas and other valuable effluents as by-products. Anaerobic digestion helps in the reduction of biochemical oxygen demand, chemical oxygen demand, and pathogens. It also helps in converting nitrogen into a more plant-available form which can then be used as fertilizers.

Anaerobic digestion is primarily made up of four stages namely; Hydrolysis, Acidogenesis, Acetogenesis, and Methanogenesis, the entire process of anaerobic digestion is summarized by the equation below, where glucose is anaerobically digested into carbon dioxide and methane by bacterial.



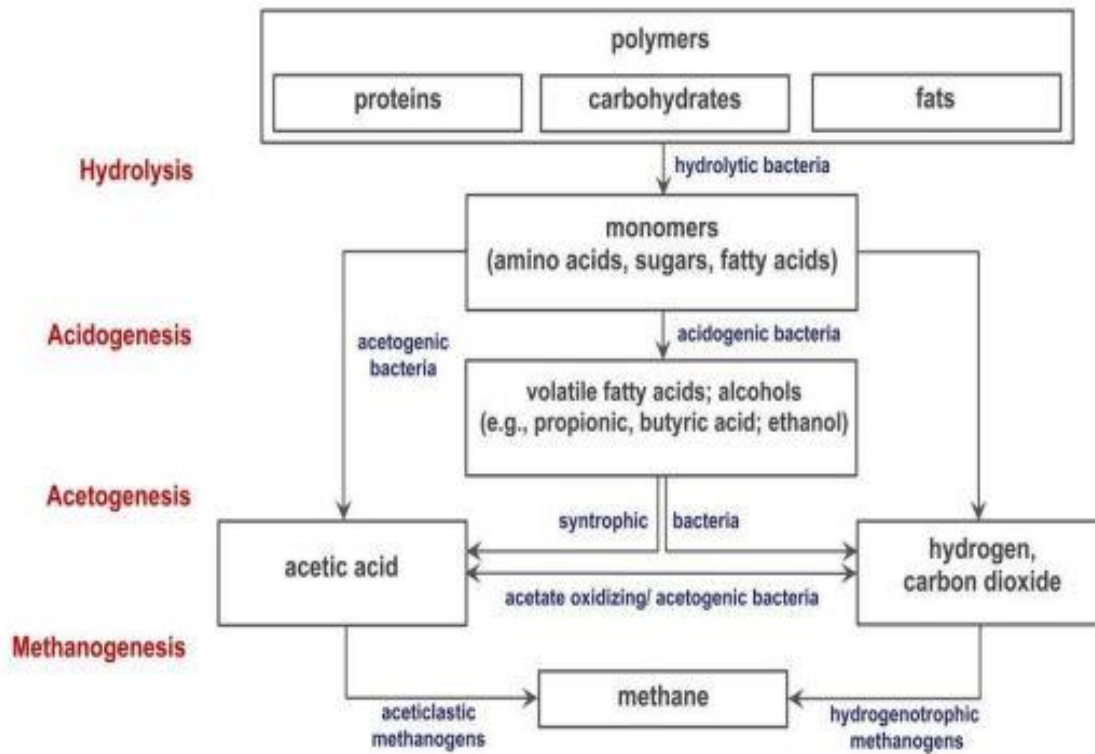


Figure 2.1 - AD Process Flow Chart.

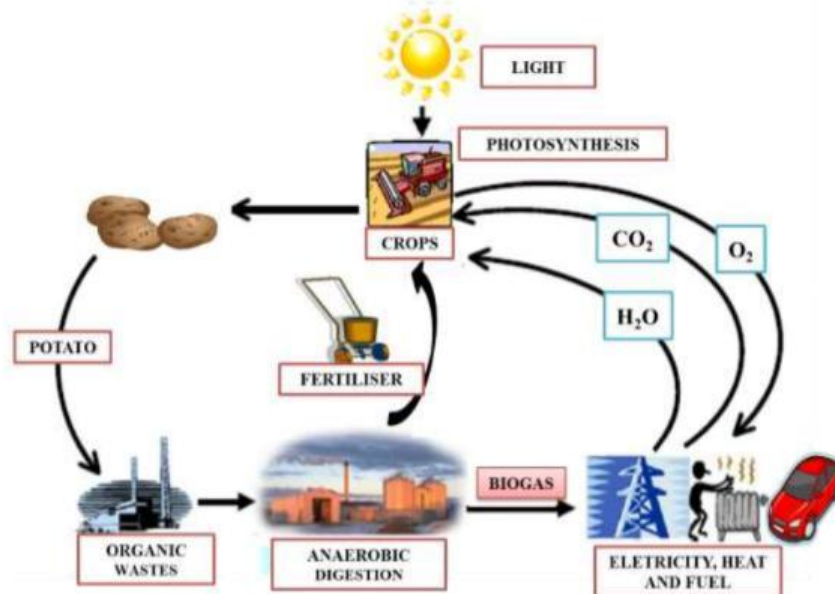


Figure 2.1 - Schematic representation of the sustainable cycle of anaerobic digestion of potato wastes from industry (adapted of Al Seadi, 2002, apud Holm-Nielsen et al., 2009).

AD requires twenty times less energy than an aerobic process. In this latter process, only low-energy compounds CO₂ and H₂O are formed, and a great deal of energy is lost to the air. In the case of AD, high-energy metabolic products are formed instead (e.g. alcohols, organic acids,

Figure 2.2 – schematic representation of the sustainable cycle of anaerobic digestion of potato waste

2.1.1 Hydrolysis

The word hydrolysis is a combination of two separate words “Hydro” which means water and “Lysis” which means to unbind or to split, so hydrolysis at the very basic level is the breaking down of large organic compound through the action of water (H₂O).

The input feedstock is usually made up of large organic polymers, for the micro-organisms present in the digester to be able to act on this large carbon chain molecule they have to be broken down into smaller units or monomers such as simple sugars, fatty acids, and amino acids which are then available for further breakdown by other bacterial, this process is known as hydrolysis, hence the reason for it being the first step in the process of anaerobic digestion (Sleat 2006).

2.1.2 Acidogenesis

In this stage, acidogenic (fermentative) micro-organism converts the products of hydrolysis into volatile fatty acids (VFAs), ketones, CO₂, and alcohols.

2.1.3 Acetogenesis

During this stage, metabolites from acidogenesis that methanogenic bacteria cannot directly convert to methane are further digested into methanogenic substrates. Alcohols and volatile fatty acids are oxidized to produce acetate, hydrogen, and carbon dioxide, which are methanogenic substrates. The hydrogen produced at this stage is often considered a waste product, and it slows down these bacteria's metabolism.

2.1.4 Methanogenesis

The products obtained from the Acetogenesis stage are further acted upon by methanogens (bacteria that create CH₄) to produce mainly carbon dioxide, water, and biomethane in this

last stage of the digestion process. Methanogenesis takes place between pH 6.5 to pH 8, and it is sensitive to both high and low pH. Methanogens can be divided into two classes: those that primarily convert acetic acid to CH₄ and those that combine hydrogen and carbon dioxide to produce CH₄. A few exceptional methanogens can do both.

2.2 BIOGAS

Biogas is a source of renewable energy (Le Mer 2001), it is a mixture of gas produced from anaerobic fermentation of biodegradable materials. Agricultural waste, manure, municipal waste, plant material, sewage, green waste, wastewater, and food waste are some of the raw materials used to produce biogas. Biogas can be produced primarily in two ways, naturally and industrially. It is found naturally in wetland soils, oceans, forest soils, termites, and ruminant animals (Le Mer 2001) and industrially in a biogas digester. The composition of biogas varies according to the nature of the feedstock fed to it and the nature of the conditions of the digester (Temperature, pH, and substrate conditions) (Hafner et al. 2017). It is primarily made up of methane (CH₄), carbon dioxide (CO₂), a small quantity of hydrogen sulfide (H₂S), moisture, and other contaminants (siloxanes, ammonia, and sulphuric compounds). Biogas can find application in various areas of human life such as the by-products of the digestion process can be used by farmers to serve as manure for fertilization of crops, and biogas can be used for generating electricity and cooking in our contemporary homes.

Factors influencing biogas production

Although the production of biogas seems to be a straightforward process, it is not necessarily a simple one. Biogas production is affected by various factors that determine the quantity and quality of the biogas. Enhancing biogas yield and quality to maximize the energy potential and

environmental benefits of biogas production is the main reason for research on biogas technology. Several methods can be used to achieve this goal; while also considering the factors that affect biogas production. Some of these factors and methods are stated below:

2.3.1 Feedstock

In the process of biogas production, feedstock is the first and most crucial concern when applying anaerobic digestion systems. For the production of biogas, known biodegradable feedstocks include solids, slurries, and liquids in both diluted and concentrated forms (Armah et al. 2017). Virtually, all organic materials can be processed using anaerobic digestion, but since the production of biogas is our goal the more digestible (that is the substrate can be easily broken down) the substrate the more it is likely to yield a larger amount of biogas. Agricultural wastes and crop residues, animal waste, marine waste, forest residues, and municipal solid wastes are all included in this feedstock (R. Khoiyangbam 2011) (A. J. Ward 2008). Residues from a variety of agricultural products and practices can be utilized as a feedstock to create biogas.

Agricultural waste and crop residue are abundant sources of biomass that can be used as anaerobic digestion feedstock (N. Ravindranath et al 2005) (M. Macias-Corral et al). As the practice of animal breeding has grown in popularity, animals also produce a substantial amount of waste (V. Skoulou 2007). Most rural areas of India have used cattle dung as a solid waste feedstock since there are 354 million tons of cattle dung available annually (N. Ravindranath et al 2005). Seaweeds, micro- and macroalgae, and water hyacinths are excellent feedstock for the production of bio-energy (H.-W. Yen 2007). The length of time required for anaerobic digestion depends on the chemical complexity of the material. Material rich in easily digestible sugars breaks down quickly, whereas intact lignocellulosic material rich in cellulose and hemicellulose polymers can take much longer to break down.

The initial purpose of anaerobic digesters was to process manures and sewage sludge. However, since the biodegradable material has already had much of the energy content taken out by the animals that produced it, sewage and manure are not materials with the greatest potential for anaerobic digestion. As a result, many digesters use co-digestion, which involves using two or more type of feedstock. For example, in a farm-based digester where the main input is dairy waste, the rate at which gas is produced can be increased by adding to the digester a secondary feedstock, grass, and corn are traditional on-farm feedstock, as are several organic byproducts including organic home trash, restaurant grease, fats, oils, and other restaurant waste.

2.3.2 Retention time / Detention time

It is the amount of time a set amount of feedstock remains in the digester. In a nutshell, it describes the length of time the feedstock undergoes anaerobic digestion. It is calculated as the volume of the digester divided by the feedstock added per day and it is expressed in days. The retention time in a digester is affected by the operating temperature condition of the biogas digester and the type of feedstock used. Because organic materials decompose slowly in anaerobic conditions, it takes a while for the digestion to be completed. In Indian digesters, when the feedstock is diluted with an identical composition, a distinction between solid and liquid predominates, hence giving rise to the term solid retention time and hydraulic retention time

a) Solid Retention Time (SRT)

This is the amount of time the volatile solid content of the feedstock remains in the digester.

b) Hydraulic Retention Time (HRT)

This is the average amount of time the dissolved portion of the waste in the spends in the digester.

SRT is one of the most important parameters taken into account in the design of the anaerobic digester. The rate of methanogen loss in the digester effluent will exceed the rate of growth if a digester SRT is markedly below the design values. VFAs, which are poisonous to methanogens in high concentrations, will build up as a result. An upset or "stuck" digester is the end outcome.

2.3.3 Moisture Content

The mass of water that a material can hold is its moisture content, which is typically expressed as a percentage of weight (Mrosso et al., 2023). In the experiment carried out by (Mrosso et al., 2023), The crucible was carefully cleaned, drained, and heated to 105°C for about 30 minutes before being left in the oven to cool to room temperature. Before use, the dried crucible was weighed (W1). Each substrate's wet sample was added to the crucible, which was then carefully placed in an oven set to under 105°C for about three hours to achieve a constant weight (W2). After allowing the crucible and the feedstock to cool in the oven to room temperature, they were once more weighed using a mass balance (W3) (Mrosso et al., 2023).

2.3.4 Total Solids

The amount of solid remaining in the feedstock after water has evaporated or the amount of organic matter that is still in the crucible after the vaporescence process is the total solid. In the experiment carried out by (Mrosso et al., 2023), the drying procedure was carried out in a 105°C oven.

2.3.5 Total Volatile Content

The residues obtained from the TS calculation were burned for 1 hour at 550°C in a muffle furnace to produce grayish-white ash. The crucible and the ignited sample were given six hours to cool in the kiln.

2.3.6 Nutrients and C: N ratio

Maintaining a balanced C/N ratio of approximately 20–30:1 is necessary to produce high-quality biogas. A measure of the relationship between carbon and nitrogen in organic matter is the carbon to nitrogen (C: N) ratio. This refers to the measurement of the nutritional equilibrium that microorganisms need in order to integrate into their respective cell structures, as stated by Kossman et al. (1997), Monnet (2003), and Korres and Nizami (2013). If this ratio is out of balance, slow decomposition may result from high C/N ratios (found in woody materials, for example), while ammonia inhibition may result from low C/N ratios (found in manure), which lowers the quality of the biogas. It is crucial for the overall success of the anaerobic digestion processes that these nutrients are present in the digester. Carbon (C), nitrogen (N), phosphorus (P), sulfur (S), and nitrogen (N) are the macronutrients that are primarily examined (Monte, 2010; Carrilho, 2012; Azeitona, 2012; Deublein and Steinhauser, 2008; Zupančič and Grilc, 2012). Hydrogen (H₂), a nutrient necessary for methane production by hydrogenotrophic methanogens, is also included (Kossman et al., 1997).

According to research, carbon breaks down 25–30 times more quickly than nitrogen does. The ideal C:N ratio will also depend on the type of substrate, and it will impact the biogas production (Korres and Nizami, 2013; Kossman et al., 1997) (Table 2.1). According to reports, the optimal carbon:nitrogen:phosphorus (C:N:P:S) ratio is roughly 100:10:1:1, but the ratio needed for a high methane yield is 100:3:1 (O'Flaherty et al., 2010). Deublein and Steinhauser (2008) state that the ratio C: N:P:S of 333-167:7-4:2:1 is sufficient for the formation of methane based on research.

Table 2.1 - C:N ratio ranges that are optimum for anaerobic digestion of organic matter gotten from literature:

Optimum C:N ratio	Literature
20-30:1	Monnet (2003) Zupančič and Grilc (2012) Khalid et al. (2011) Herout et al. (2011)
16-25:1	Deublein and Steinhauser (2008)
15-25:1	Korres and Nizami, 2013 (2013)
25-32:1	Bouallagui et al. (2005)

2.4 THE BYPRODUCT FROM THE BIOGAS DIGESTER

The byproduct from biogas production in the digester is referred to as digestate. The digestate is a nutrient-rich substance that comes from the anaerobic digestion process after the microorganisms have broken down organic matter in the feedstock. It comprises several elements, such as solid and liquid fractions, and its composition varies depending on the feedstock and the digestion process. The composition, treatment, and potential applications of digestate as a fertilizer in agriculture are considered below:

2.4.1 Composition of Digestate:

The solid fraction of digestate mainly contains organic matter, which is partially decomposed, and some undigested materials. There may also be some fibrous residues from the feedstock. This has nutrients that are suspended and dissolved, such as potassium, sulfur, ammonium, and different trace components of nitrogen, phosphorus, and nitrogen (both inorganic and organic

forms). The digestate usually has pH levels that vary but are mostly slightly alkaline, depending on the operating conditions of the digester.

2.4.2 Treatment of Digestate:

Digestate can go through a variety of treatments to make it properly fit for use as fertilizer. There can be effective management of the digestate when the solid and liquid portions are separated. Mechanical techniques like settling tanks can be used for this separation. It may be easier to handle and transport the solid portion if the moisture content is reduced through drying procedures. Valuable nutrients (like phosphorus) from the liquid fraction can be recovered using the struvite crystallization method. The digestate can be further stabilized and when it is combined with other organic materials and subjected to composting, the odor can be reduced.

2.4.3 Potential Application in Agriculture as Fertilizer:

Due to its nutrient-rich structure, digestate has a lot of promise for use in agriculture as an organic fertilizer and soil conditioner. Digestate is a rich source of nutrients, such as nitrogen, phosphate, and potassium, that are required for plant growth. It can act as a source of these nutrients when correctly handled, hence lowering the demand for synthetic fertilizers. The soil structure, moisture retention, and microbial activity are all enhanced by the organic matter in digestate. It improves the capacity of the soil to hold nutrients and its fertility. Digestate frequently contains advantageous bacteria from the digestive process, which can increase soil biological activity. By using digestate as fertilizer, the danger of nutrient overflow into water bodies is diminished, which helps prevent environmental damage. By altering the digesting process or blending digestate with other fertilizers, the nutritional content of digestate can be customized to meet the needs of particular crops and soil types. The alkaline composition of the digestate can assist in balancing acidic soils, raising the pH levels of the soil. When applying digestate, take into account the crop's need for nutrients. Digestate applications before or throughout the growing season can make sure that plants get the nutrients they require. For

digestate, there are several application techniques, such as surface broadcasting, injection, or inclusion. Crop kind, soil quality, and equipment accessibility should all be taken into consideration while deciding on a strategy.

However, some challenges may arise when the digestate is used as a fertilizer. The nutrient content of digestate may not always match crop nutrient requirements so, extra nutrient management is required. There is a risk of pathogens and contaminants being in the digestate so, proper treatment and quality control need to be put in place to reduce their harmful effects. Also, The high moisture content and bulkiness of the digestate can give some logistical challenges in transportation and application.

To also properly utilize the digestate for agricultural purposes, some practices can be followed:

Nutrition management strategies that show the nutrient content of the digestate and the nutrient needs of particular crops could be created. There should be regular checks and tests for the pH level, nutritional content, and possible pollutants of the digestate. Quality control procedures should always be used on the digestate and by so doing, it could be efficiently incorporated into agricultural use. To ensure optimum usage of the digestate, crop rotation techniques could be adopted this is because different crops have different nutrient needs, and so, nutrient imbalances can be avoided in the soil by crop rotation. Observation of the environment and how the use of digestate affects it is also very important; especially in terms of nutrient runoff and groundwater contamination. Assessment of the economic feasibility of employing digestate as fertilizer by performing cost-benefit assessments is also a good practice. This helps to prevent losses to both the individual (in terms of finance) and the environment (in terms of pollution). This reviews factors like possible gains in crop production and cost savings on synthetic fertilizers. It is important to comprehend both the advantages and disadvantages of using the digestate to ensure its efficient use.

2.5 SUSTAINABILITY OF BIOGAS PRODUCTION AND THE IMPACT ON THE ENVIRONMENT

The utilization of biogas as an energy source aligns with principles of sustainability and social and environmental responsibility. Biogas, derived from renewable resources that can be replanted or reproduced, ensures sustainability according to Brundtland's 1987 report, which defines sustainability as meeting current needs without compromising future generations. Biogas production from waste has demonstrated effectiveness, offering environmental, societal, and economic benefits. This process impacts agriculture, the environment, and the energy production sector.

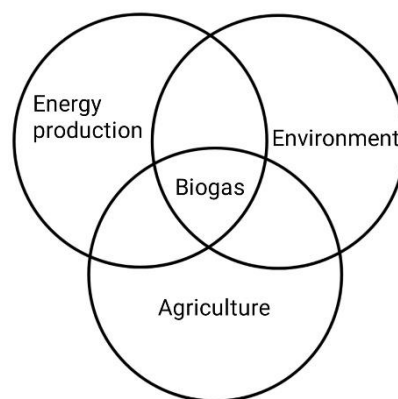


Figure 2.3 – Venn diagram showing the sector's biogas production cuts across

Organic residues have increased significantly in recent years, but their potential for reuse has received little attention. One step toward recycling and reusing these materials is the implementation of selective waste collection. However, burning organic waste is not a sustainable solution, and the buildup of organic wastes still presents a problem in many communities. Thus, biogas production technology presents itself as a useful strategy for reducing food waste, zoo technical waste, and agricultural waste—all of which are significant sources of biodegradable organic matter. This opinion is supported by Klingler (2005) and

Lapik et al. (2011), who show how biogas production is effective in managing a variety of organic wastes and by-products.

The production of biogas is praised as an environmentally friendly energy source that is closely related to the sustainable economy, which recycles resources continuously. As the highest step in the hierarchy of biomass utilization, it produces sanitized biofertilizer and biogas at the same time (Fagerström et al., 2018).

According to Fägerström et al. (2018), organic waste decomposes in landfills and releases gases and leachate, primarily methane, which adds to the greenhouse effect.

Waste storage problems in biogas plants are turned into valuable resources through the process of anaerobic digestion, which creates value from waste (Martin et al., 2012).

By lowering pollution and improving the management of organic materials, biomethanization transforms waste into energy and fertilizers, which is essential for protecting the environment (Ali et al., 2013).

Table 2.2 - Effects of biogas production on the energy sector, agriculture, and the environment (Birkmose T., 2001)

Energy sector	Agriculture	Environment
<ul style="list-style-type: none"> • As CO₂ neutral energy • As renewable energy 	<ul style="list-style-type: none"> • Improvement in the use of nitrogen from manure • Balancing the phosphorus/potassium ratio in the resulting slurry • Reduction of trash transportation • Slurry free of weed seeds and pathogenic germs 	<ul style="list-style-type: none"> • Limitation to nitrogen leaching • Reducing odor problems • Reduction of greenhouse gas emissions • Controlled waste recycling

2.5.1 Impact of biogas production on climate and atmosphere.

a) Contribution to the protection of climate change:

Concerning the sustainability of biogas production, significant issues arise regarding emissions of air pollutants such as formaldehyde, carbon monoxide, sulfur dioxide, nitrogen oxides, suspended particles, aromatic hydrocarbons, and odorous substances like hydrogen sulfide (Janas et al., 2018; Mezzullo et al., 2013).

An illustrative study conducted on a dairy farm in the Pad River Valley by Battini et al. (Paolini et al., 2018) exemplifies this concern. They determined that emissions reductions from anaerobic fermentation ranged between 23.7% and 36.5%, contingent upon digestate management practices. Moreover, Kaparaju et al. estimated annual greenhouse gas (GHG) reductions of 177, 87, and 125t CO₂ equivalent for dairy, sow, and pig farms, respectively (Kaparaju et al., 2011).

b) Methane emissions

The annual increase in atmospheric methane concentration by approximately 1% underscores the urgency of addressing methane emissions, with agriculture, particularly animal digestion and manure, accounting for around half of methane emissions in the European Union (Jorgensen, 2009). However, the anaerobic treatment of animal manure offers a promising solution by yielding a renewable energy source that simultaneously reduces CO₂ emissions and mitigates methane emissions. This dual impact is achieved by replacing fossil fuels with biogas, thereby reducing CO₂ emissions by 2.6 kg for every 0.5 kg of oil replaced. Additionally, the capture and controlled use of methane in biogas plants effectively curtails its release into the atmosphere. Particularly in developing countries, small-scale biogas facilities play a pivotal role in forest conservation efforts by alleviating pressure on forest resources for household energy needs. This not only aids in maintaining soil integrity but also helps prevent natural disasters like floods and desertification, with approximately one hectare of forest conserved per biogas plant (Klingler, 2005).

c) Carbon dioxide emissions

Assuming that biogas is composed of 65% CH₄ and 35% CO₂, methane is converted into CO₂ at a rate of 83.6 kg per gigajoule during combustion. Furthermore, the storage and transportation of digestate and biomass may result in CO₂ emissions. On the other hand, when combustion and transport/storage emissions are taken into account, CO₂ is regarded as biogenic and has no

effect on the climate. By reducing the need for fossil fuels, biogas production helps to reduce greenhouse gas emissions caused by human activity. Research shows that producing biogas from by-products (food waste, pomace, slaughterhouse waste, and manure) is a more sustainable method than producing energy crops. Particularly when dealing with solid municipal waste, efficient digestate management can greatly reduce overall emissions (Paolini et al., 2018). Additionally, studies have demonstrated that anaerobic fermentation of manure can reduce greenhouse gas emissions; estimates for pig and cattle manure vary from roughly 0.3 to 0.6 kg CO₂-equivalent per kilogram of organic matter (Jorgensen, 2009).

d) Nitrous oxide (N₂O) emissions

Nitrous oxide (N₂O), methane (CH₄), and carbon dioxide (CO₂) all have a greater greenhouse potential than N₂O, which makes them significant contributors to the greenhouse effect. Methane and nitrous oxide are frequently compared using their CO₂ equivalents, where 1 kg of CH₄ is equal to about 22 kg of CO₂ and 1 kg of N₂O to about 310 kg of CO₂. Despite being present in small quantities, nitrous oxide greatly reduces the greenhouse effect.

Nitrogen fertilizer conversion that occurs anaerobically accounts for a large amount of N₂O emissions in agriculture. Still, anaerobic digestion in biogas plants can contribute to a decrease in N₂O emissions by lowering the amount of organic matter available for denitrification pathways. According to Jorgensen (2009) and Paolini et al. (2018), this could lessen the release of digestate when it is applied to fields.

As can be seen presently, there is very little detailed information on the reduction of nitrous oxide due to the anaerobic digestion of animal waste. Anaerobic fermentation causes this gas to reduce by:

- i. Careful prevention of emissions while storing manure;
- ii. Mitigation of anaerobic conditions in the soil;
- iii. Very reduced N₂O losses through increased nitrogen availability for plants and a faster nitrogen absorption through crop plants;
- iv. Less use of inorganic nitrogen fertilizer and N₂O avoidance during the production of nitrogen fertilizer.

e) Ammonia emissions

The presence of nitrogen in the form of ammonia (ammoniacal nitrogen) in a solvent tends to rise during anaerobic digestion, particularly under conditions of elevated pH values. This increase in ammoniacal nitrogen levels influences the release of ammonia during the storage of digestate. To mitigate these losses from exposed digesters, it would be beneficial to cover them with various materials, such as chopped straws (Amon T., 2010)

f) Emissions of particulate matter

When compared to other energy sources, biogas combustion must be carefully managed to reduce particulate matter emissions, such as dust, which raises concerns. Estimates of combustion emission factors, which range from 0.232 to 0.238 g/Nm³, are important to take into account, particularly in combined heat and power (CHP) systems. However, the formation of secondary suspended powders can be prevented by storing these materials in enclosed spaces, as the emissions of pollutants like ammonia and NO_x from unfermented and digested substrates can cause this problem.

As a result, using biomethane instead of diesel offers the chance to enhance air quality by lowering emissions of NO_x and suspended particulate matter. Furthermore, methane emissions from biomethane are significantly lower than those from liquid fuels, even after accounting for the benefits to the climate from the reduction of slurry powders, volatile organic compounds

(VOCs), and polycyclic aromatic hydrocarbons (PAHs). According to Paolini et al. (2018), incorporating biogas into national energy networks may also reduce the amount of solid fuel used in residential areas, improving indoor air quality and public health.

2.6 REVIEW OF PAST LITERATURE

Rajendran Karthik et al (2012) gave a review of the household digester designs and their operating parameters such as substrate, pH, loading rate, and temperature, and stated the benefits of a digester in the areas of waste reduction and energy provision. P. Mahanta et al (2005) experimented with the efficiency of anaerobic digestion and discovered that the efficiency is majorly dependent on the concentration of bacteria activity influenced by the parameters stated by Rajendran Karthik et al. (2012). Setyobudi et al. (2021) experimented on a vertical household digester with a total volume of 0.274 m³ and a height of 1.352. This experiment was done by simulating the biogas produced in a digester with the above parameters, being used by two persons living in a house. It was discovered that the biogas produced is sufficient for cooking for a day. Aliyu (2017) experimented with the biogas potential of carbohydrates, proteins, and other classes of food with a pH range of 6.7 - 6.9 and a retention period of 30 days. A conclusion was drawn at the end of the experiment that carbohydrates had the most yield during this retention period. This yield stemmed as a result of its ease of being broken down into simple monomers when compared to other classes of food. Brunn et al (2014) made a tentative study of the need for proper maintenance of the biogas digester to avoid unrecoverable impacts on the environment. One of the major maintenance stated was the need for the biogas consumption to be more than its production to avoid huge losses of methane which is detrimental to the environment. Ojikuto et al (2014) carried out an analysis of the production of biogas from common household food wastes such as yam peels, plantain peels, orange peels, and fish waste in a batch digester for a retention period of 70 days, under a mesophilic temperature condition ranging from 30⁰c - 37⁰c with a total solid concentration of

8%. A conclusion was drawn that food waste in this condition had a significant effect ($p \leq 0.05$) on substrate temperature and pH levels and not much effect ($p > 0.05$) on biogas production. Xu, F et al. (2018) outlined some challenges and opportunities in the process of anaerobic digestion of food waste. Some of the opportunities outlined are curbing environmental pollution in the form of excess waste and reducing the financial cost of dumping waste. Though the anaerobic digester is necessary for these processes, there are some challenges faced in the process and some of these challenges include the accumulation of Volatile Fatty acids (VFA), Process instability, low buffer capacity, and high financial cost. El-Mashad et al (2010) evaluated the effect of manure screening on the biogas yield of dairy manure in a batch digester under mesophilic conditions (35°C). The study determined the biogas production potential of different mixtures of unscreened dairy manure and food waste and compared these results with the yield from manure or food waste alone. This comparison was done using a first-order kinetics model. The model was used to calculate the methane yield from different mixtures of food waste and unscreened dairy manure. A conclusion was then drawn that adding food waste into a manure digester at levels up to 60% of the initial volatile solid greatly increased the methane yield for a retention period of 20 days. Lay et al (1997) experimented and found out the methane production rate can be rapidly increased when the moisture content and pH levels are controlled. It was discovered that a moisture content of 96% and a pH range of 6.8 - 7.8 increase the rate of methanogenic activity which in turn increases the methane yield. Kim et al (2006) examined the effect of temperature and hydraulic retention time on the anaerobic digestion of food waste. A modified three-stage methane fermentation process was adopted and these three stages include: Hydrolysis, acidogenesis, and methanogenesis. The operating temperature of the digester ranged from 30°C - 55°C and the Hydraulic retention time ranged from 8 - 12 days. It was discovered that with liquor food waste thermophilic digesters gave a stable performance when compared to mesophilic digesters at the same retention time.

CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS

The research utilized a blend of different food waste including cooked rice, yam peels, Irish potato peels, plantain peels, and seeding agents primarily consisting of cow dung. The raw materials were sourced from residential houses. Mild steel (low carbon steel) was chosen for the vessel shells, with a maximum allowable stress of 138 MPa at room temperature. Uni-directional valves and pressure gauges were incorporated into the design, with their dimensions and positioning carefully selected through comparison with liquid natural gas cylinders commonly found in households across the country. A manual hand pump was modified for the purpose of directly feeding the digester, as the feed input occurs at the bottom.

A gas hose was employed to transport the gas from the digester to the consumption point, typically a burner. The materials used in the project's design varied depending on the components involved.

3.2 DESIGN OF THE DIGESTER

3.2.1 Design Specifications

Table 3.1 - Design specification of digester

Volume	About $0.15m^3$ or 150Litres
Dimensions	Height – about 1m

	Diameter – about 0.4m
Material	Stainless steel
Feedstock	Biodegradable waste
Maximum Feedstock	About 21.5kg
Head type	Flathead

3.2.2 Design Considerations

- a) The volume of waste to be digested per day
- b) Design for continuous biogas production
- c) The type of waste available
- d) Availability of waste
- e) Design of a method for stirring the feedstock
- f) No extra heating system was used
- g) No additional power sources needed
- h) Design for the minimum cost but optimum performance
- i) The input unit must be at the bottom to avoid loss of gas during feeding

For this research, the digester plant is of a portable size, which makes it very easy to maintain and also based on the amount of food waste available.

3.3 CONCEPTUAL DESIGN

Different concepts were developed, but due to the factors stated above only one of the designs would fit best as would be seen.

3.3.1 Design Concept 1: A Digester with Hexagonal Cross Section and a Hand Pump

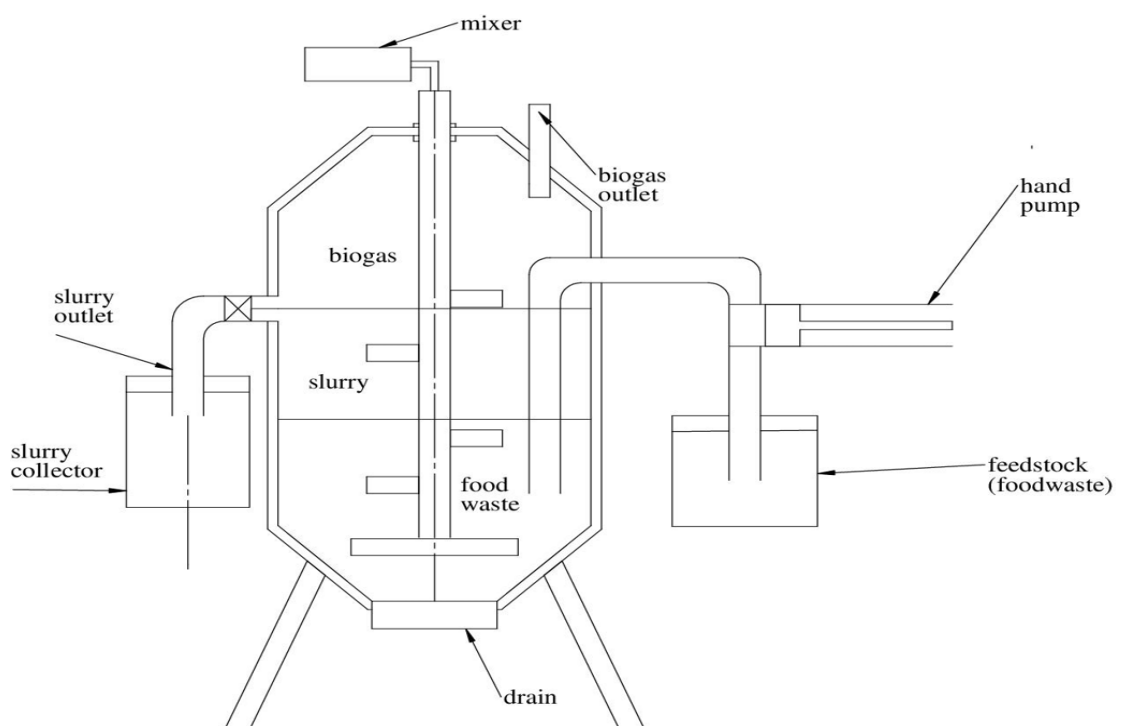


Figure 3.1- A digester with a hexagonal cross-section and a hand pump

Description of Design

The above design makes use of a horizontal hand pump located at the input unit, two separate tanks outside the digester (slurry outlet and the mixing tank), a support stand for which the digester sits, a mixer or stirrer, it has a shape similar to that of a hexagon, having two of the sides longer than the other, this shape helps for easy drain and also for compression of the gas formed at the top.

Shortcomings of the Design

- i. It makes use of an extra material for the leg stand and pipes for the input unit making it more expensive.
- ii. Increased pump work
- iii. Due to its shape, it is more prone to corrosion attack
- iv. Due to the shape of the head, it will be very difficult to machine.
- v. Gases can be lost during feeding

3.3.2 Design Concept 2: A Digester with a Hopper For Feedstock Inlet

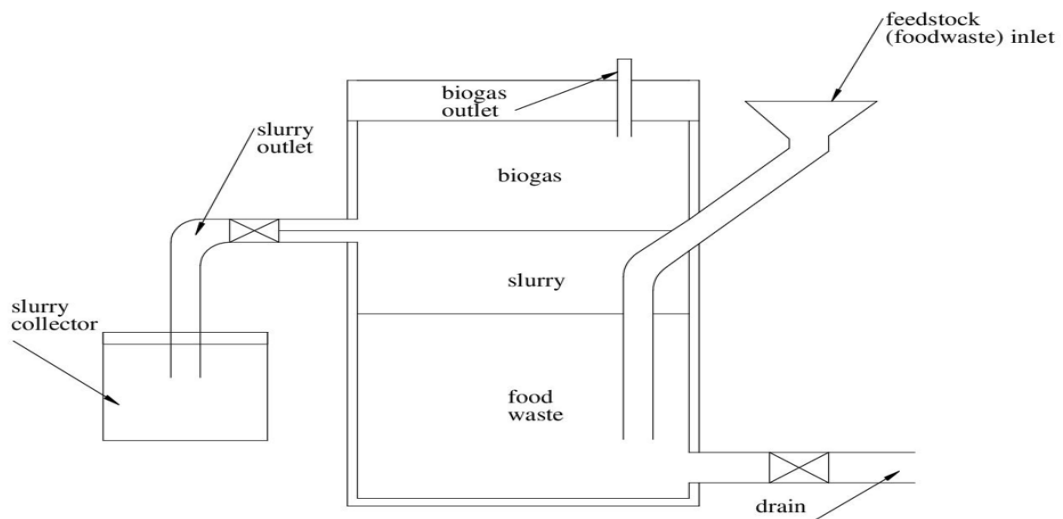


Figure 3.2 - a digester with a hopper for feedstock inlet

Description of Concept

The above concept makes use of a slurry outlet tank, coupled with a one-directional valve, it makes use of a hopper, to which the pipe is connected, the pipe extends down to the bottom of

the digester the outlet gas pipe is located at the top (head) of the digester, it also has an outlet pipe at the bottom of digester tank.

Shortcomings of the Design

- i. No valve to regulate the flow of fluid flow at the inlet unit, so therefore there can be a loss of gas from the tank through the feeding unit.
- ii. Absence of stirrer, for proper mixing of the slurry, so as coagulation of solids at the bottom part of the digester.
- iii. The design does not have a mixing tank and by this, the volume of input cannot be measured, because the volume of slurry leaving through the slurry outlet has to equal the volume of feedstock entering the digester and the feedstock has to be chopped and mixed in a separate container before it is been feed into the digester.

3.3.3 Design Concept 3: A Digester Connected to an External Power Source for Heating and Mixing

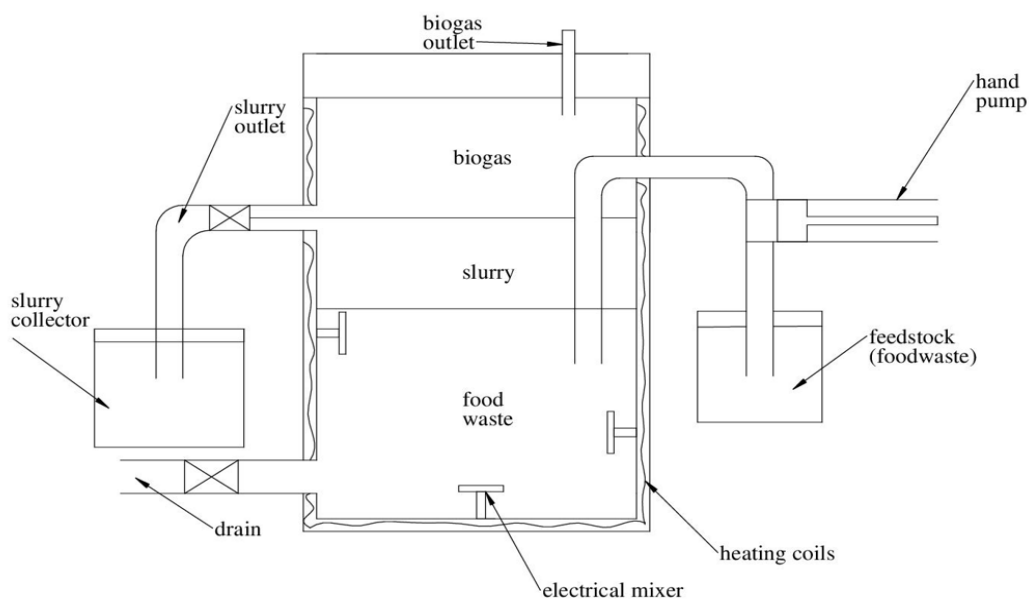


figure 3.3 - a digester connected to an external power source for heating and mixing

Description of Design

The above design makes use of an external power source, which is used for heating the tank and also for turning the motor on the mixer, it has its input unit at the top, through which the feedstock is fed into the tank using a manual hand pump. The design also makes use of two check valves which only allow the flow of fluid in one direction, These valves are positioned at the input unit and at the output unit to regulate fluid flow.

Shortcomings of the Design

- i.** It makes use of an external power source, which is not necessary as it would incur more cost, increase the tendency of a fire hazard occurring, and also increase complexity.
- ii.** The work done by the manual hand pump is not necessary because the feedstock would still fall through toward the bottom of the digester, thereby negating the pump work.
- iii.** By virtue of the input unit being at the top there exists the possibility of there being a loss of biogas during feeding.

3.3.4 Design Concept 4: Semi Conical Digester with Sandbags For Pressurising

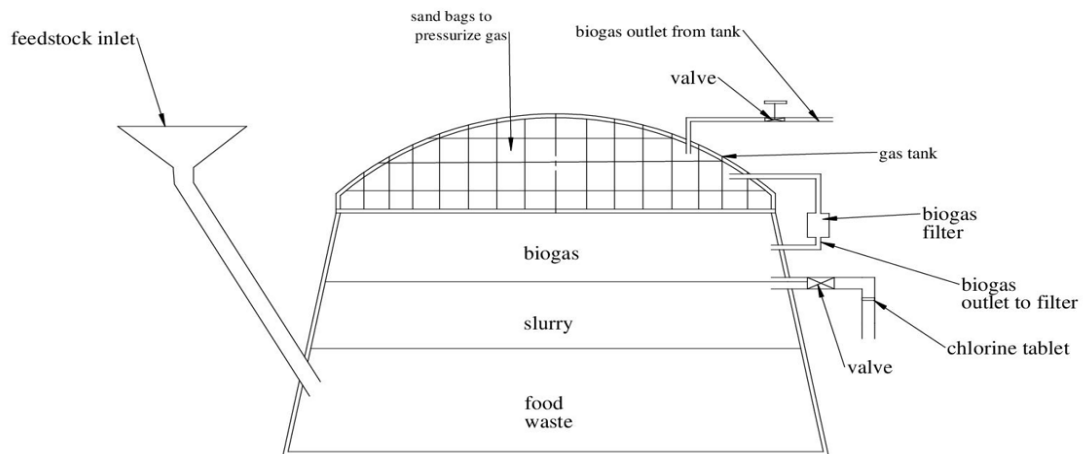


Figure 3.4 - semi-conical digester with sandbags for pressurizing

Description of design

The above design is a dome-like digester, which makes use of a hopper and a hose connected to the digester tank, it has a slurry outlet pipe regulated by a valve for which digested slurry is removed from the digester, and a tin sheet metal separates the gas holder tank from the digester tank, a pipe in which is incorporated with a filter is used to connect the digester tank to the gas holder tank.

Shortcomings of this design

- i. Absence of drain
- ii. Absence of valve at the slurry inlet
- iii. Difficulty in machining the shape of the digester

- iv. It is expensive, as it uses extra materials such as a thin metal separator, secondary gas holder, sand bath to pressurize the gas, filter for the produced gas, and a chlorine tablet.

3.3.5 Design Concept 5: A Digester with Two Manual Valves and a Manual Pump at the Feedstock Inlet

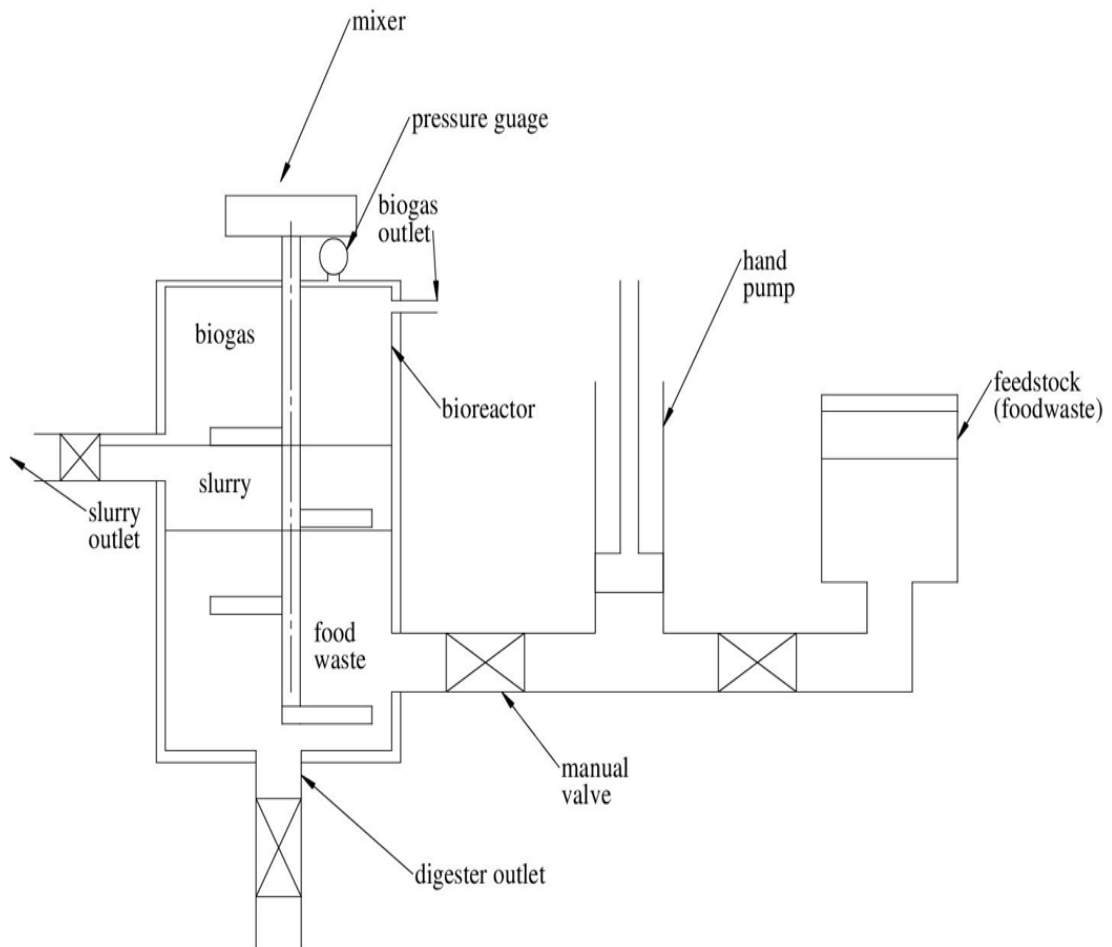


Figure 3.5 - a digester with two manual valves and a manual pump at the feedstock inlet

Description of Design

The above design makes use of a mixing tank, a hand pump from which slurry is pumped into the digester, the flow of the slurry from the mixing tank to the digester is regulated through the use of two non-return valves, it has a pressure gauge at the top(head) and a stirrer located at the

centre of the head, which extends down to the bottom of the digester, it has a slurry outlet located just above the input unit (inlet) and below the gas outlet, both of these access point are regulated by valves, and it drain which is located at the bottom of the tank.

Shortcomings of this design

- i. Due to the position of the drain, an extra support material has to be constructed for the digester to rest on, which will incur more cost.
- ii. The design makes use of two valves at the input unit alone which in turn will incur more cost.
- iii. The design makes use of a hand pump during feeding and by default, getting a hand pump that can be able to work with slurry (biomass and water) as fluid is quite difficult and would eventually need a lot of maintenance
- iv. The length between the digester and the mixing tank has to be long enough to accommodate all the materials used and this can lead to more cost.

3.3.6 Design Concept 6: A Digester with a Screw Pump and a Side Drain

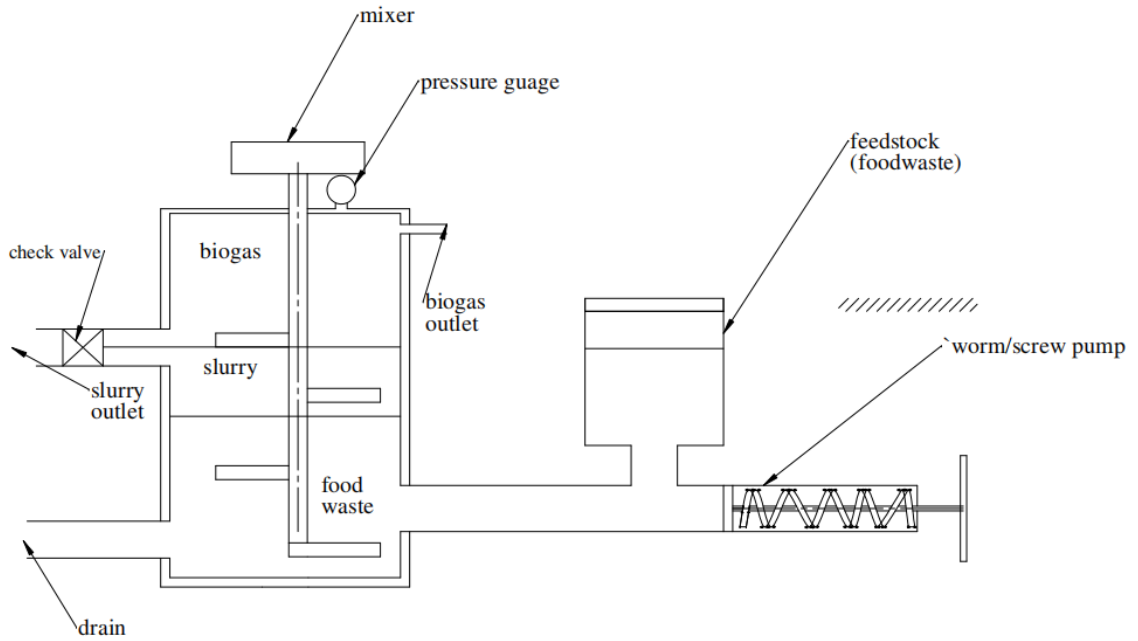


Figure 3.6 - a digester with a screw pump and a side drain

Description of design

The design above Fig 6 works the same way as the diagram in Fig 5, the only difference is that, instead of using a manual hand pump for feeding, it uses a worm screw that as the screw turns, pushes the feedstock into the tank.

Table 3.2 - Comparison between the various conceptual design

Criteria	Fig 1	Fig 2	Fig 3	Fig 4	Fig 5	Fig 6
Use of extra power source	No	No	Yes	No	No	No
Continuous biogas	Yes	No	Yes	No	Yes	Yes

production						
Cost	Expensive	Moderate	More expensive than that of Fig 4	Too expensive	Moderate	Moderate
Containing Stirrer	Yes	No	Yes	No	Yes	Yes
Maintenance	Difficult	Easy	Difficult	Difficult	Easy	Easy
Availability of safety measures (Pressure Regulator)	No	No	No	No	Yes	Yes
Positioning of the input unit	Top	Top	Top	Bottom	Bottom	bottom

From the above table, it is seen that Figure 3.5 and Figure 3.6 are the most practicable designs based on design considerations, but for this project, the design in Figure 3.6 will be chosen because it reduces the cost of using two one-way valves.

3.4 DETAIL DESIGN.

The digester tank, constructed from mild steel, is cylindrical in shape and features a tightly sealed top secured with bolts and nuts to prevent gas from escaping. Functioning as an airtight vessel, the digester has an inlet for introducing feedstock (a mixture of biomass and water) from a mixing tank using a manual hand pump. Within the digester tank, both slurry and gas produced occupy the volume, with an outlet allowing for the periodic removal of digestates. This outlet is equipped with a one-way valve permitting fluid flow in a single direction. Positioned at the top of the digester are the gas outlet and the stirrer.

According to B.S. Thakkar and S.A. Thakkar (2012), vessels, tanks, and pipelines that either facilitate fluid flow or serve as storage containers under pressure are referred to as pressure vessels. The anaerobic digester in this context qualifies as a pressure vessel, specifically a vertical one. The design of the digester adheres to the ASME VIII Division 1 code, involving steps such as material selection, size calculation, determination of cylinder thickness, assessment of internal pressure on cylinder walls, and specification of leg and support dimensions (G. Shibashis, 2008).

Pressure vessels are categorized as either thin or thick shells based on wall thickness. A shell is deemed thin if the ratio of inner radius to thickness exceeds or equals 10; otherwise, it is considered thick-walled (G. Shibashis, 2008). The vessels utilized in this project follow the ASME Boiler and Pressure Vessel Code established in 1914, with designation as thin or thick-walled dependent on the ratio of inner radius to wall thickness (G. Shibashis, 2008).

This portable digester is designed as a vertical thin shell pressure vessel; if the ratio of the inner radius and the wall thickness of the pressure vessel are greater than or equal to 10, ($\frac{r_i}{t} \geq 10$).

where r_i is the inner radius. A temperature of 35°C is adopted for this study.

3.4.1 Volume of the Digester

For determining the sizing of the digester.

$$V = \pi r^2 h$$

h = Straight height, V = volume of the digester.

Volume V = Daily feed input ($m^3 / days$) \times Retention time(days)

3.4.2 Thickness of the cylindrical shell

According to the ASME section eight two sets of equations were provided for determining the thickness of a cylindrical vertical thin-walled pressure vessel.

Case 1 - Circumferential Stress (Longitudinal Joints)

When the thickness does not exceed one-half of the inside radius or P does not exceed $0.385SE$ the following formulas are viable.

$$t_s = \frac{PR}{SE - 0.6P} + C \qquad P_s = \frac{SEt_s}{R + 0.6t_s}$$

Case 2 - Longitudinal Stress (Circumferential Joints)

When the thickness does not exceed one-half of the inside radius, or P does not exceed $1.25SE$, the following formulas shall apply;

$$t_s = \frac{PR}{2SE + 0.4P} + C \qquad P_s = \frac{2SEt_s}{R - 0.4t_s}$$

t_s = Shell thickness

R = Cylinder Radius

C = Shell thickness

P = Designing pressure

S = Maximum allowable stress value

P_s = *maximum* allowable working pressure.

E = joint efficiency for, or the efficiency of, appropriate joint in cylindrical or spherical shells, or the efficiency of ligaments between openings, whichever is less.

Note that: E = 1.0 if a radiated test is used, meanwhile E = 0.7 is used if non-radiated tests are used.

According to the American Society of Mechanical Engineers, the maximum allowable pressure (P_m) is the minimum between P_1 and P_2 . it is worth noting that the actual working pressure of the digester should be less than the maximum allowable working pressure for the design to be considered safe ($P_w < P_m$), where P_w is the working pressure.

The time for the production of biogas varies depending on the temperature and method adopted. In 2002 El-Wakil documented the retention time for complete combustion, in this experiment he made use of different substrates to achieve this result, the table below shows the result from the experiment.

Table 3.3 - Retention time (Time for complete decomposition) for different materials (El-Wakil, 2002)

S/N	MATERIALS	RETENTION TIME
1	Cow and Buffalo Dung	50 days
2	Pig Dung	20 days
3	Poultry Droppings	20 days
4	Night Soil	30 days

Table 3.4 - Methane production from common agricultural waste (Rai, 2004)

TYPE OF WASTE	VOLUME OF YIELD/KG	CONCENTRATION IN BIOGAS (%)
Cow Manure	180-250	60-70
Pig Manure	210-300	58-60
Poultry Manure	350-400	58-65
Human Content	160-300	60-65
Green Plant	250-450	55-62
Straw	150-180	58-60

All types of organic waste are suitable for producing biogas by the process of anaerobic digestion in a biogas plant. The organic materials sourced from human, animal, and plant waste are reduced to 3-6mm in size for adequate digestion. Water is needed in the bio-conversion process, as it enables quicker decomposition and fermentation of waste. In this paper, emphasis

was placed on anaerobic digestion. According to Rai (2004), methane production varies for different agricultural wastes used as substrates as shown in Table 5.

The general equation for anaerobic digestion is given as $C_xH_yO_z + \frac{2(x-y)}{4-z} H_2O \rightarrow \left(\frac{x}{2} - \frac{y}{8} + \frac{z}{2}\right) CO_2 + \left(\frac{x}{2} + \frac{y}{8} - \frac{z}{4}\right) CH_4$

To be able to determine the dimensions of the digester it is necessary to know the gas production rate per day for different feedstock as it applies to this project. **Table 6** shows the biogas production rate for plantain peels and yam peels.

Table 3.5 - Methane production from yam peels and plantain peels

Feedstock	Average biogas production per week (ml per 20L)	Estimated production per day (ml per liter)
Yam peels	1048.6	7.49
Plantain peels	916.3	6.546

Source: (Ojikutu et al., 2014)

Table 3.6 - Methane production from cooked rice and Irish potato peels

Feedstock	Average biogas production per week (ml per 1.5L)	Estimated production per day (ml per liter)
Cooked rice	705.25	67.167
Irish potato peels	210	20

Source: (Mrosso et al., 2023)

From the above tables, an all-inclusive table can be prepared for all the feedstock used in this project.

Table 3.7 - An all-inclusive table for all the feedstock used in this project.

Feedstock	Estimated production per day (liter per liter of feedstock)
Yam peels	0.00749
Plantain peels	0.006546
Irish potato peels	0.020
Cooked rice	0.067167
Cow dung	30

3.4.3 Biogas Properties

Energy value - 21,000-23,000 kJ/Kg

Pressure - 75-250mm H₂O

Density - 1.2 kg/m³

3.4.4 Design Calculations

Digester design - The digester is a cylindrical stand-alone digester with a flat head, the volume, height, and diameter of the digester are gotten as seen below.

Step 1; List all the feedstock and the biogas production rate.

1kg of cow dung produces 35Litres of biogas per day (Khan et al., 2018)

1kg of cooked rice produces 0.067167 Litres of biogas per day (Okeh et al., 2014)

1kg of plantain peels produces 0.006546 Litres of biogas per day (Adeniran, K.A et al., 2020), (Sambo, A.S et al., 2015)

1kg of cow Irish potato peels produces 0.02 liters of biogas per day (Achinas, S et al., 2019), (Mudhowa, J.P et al., 2015).

1kg of yam produces 0.00749 liters of biogas per day (Sambo, A.S et al., 2015)

Step 2; Determination of the percentage composition of the feedstock and the total Gas production rate of the feedstock.

For this project will would assume the percentage composition of all the feedstock is the same that is 20% each, all amounting to 100%

Cow dung - 20% of 35 = 7litres

Cooked rice - 20% of 0.067167 = 0.0134334Litres

Plantain peels - 20% of 0.006546 = 0.0013092Litres

Irish Potato peels - 20% of 0.02 = 0.004Litres

Yam - 20% of 0.00749 = 0.001498Litres

GPR of the total feedstock = 7 + 0.0134334 + 0.0013092 + 0.004 + 0.001498 = 7.02

That is approximately 7Litres per day or 0.007 cubic meters for 1kg of feedstock.

Step 3; Determination of the amount of feedstock required to produce the desired biogas produce and the volume of the digester (Teferra, D.M & Wubu, W. 2018)

Design volume = 0.02 m^3

Amount of feedstock needed per day to produce design volume = $0.02/0.007$

= 2.857 approximately 3

Slurry = Biomass + water (1:1) hence,

3parts of biomass + 3parts of water = 6litres = 0.006 meters cube day

daily feed input = $0.006m^3/\text{day}$

The volume of the digester (V) = $\pi r^2 h$ (daily feed input \times retention time,)

where $r = D/2$,

The volume of digester = $0.006 \times 25 = 0.15m^3$ or 150Litres

Step 4; Determination of the dimensions of the digester (Teferra, D.M & Wubu, W. 2018)

According to the ASME standard for pressure vessels whose internal pressure ranges from 0-250 PSIG, the length-to-diameter ratio is 3. i.e $h = 3D$

$$V = \pi D^2 h / 4 \quad V = 3\pi D^3 / 4 \quad \text{Diameter (D)} = \sqrt[3]{4V/3\pi} \quad D = \sqrt[3]{4 \times 0.15 / 3\pi} \cong 0.4m \quad \text{height(h)} = 3 \times 0.4 = 1.2m$$

Step 5; Determination of the Volume of the Slurry and Gas holder.

In determining the volume of the digester, according to the ASME section eight division one code, it is common practice to make the slurry volume $3/4$ of the digester volume, hence:

$$\text{Volume of Slurry (V}_s) = 3/4 \times 150 \cong 113\text{Litres}$$

$$\text{Volume of Gas holder} = 150 - 113 = 37\text{Litres.}$$

The extra volume remaining in the gas holder can serve in times when the biogas is not immediately in use.

Step 6; Determination of the height of the Gas holder and the Slurry (Teferra, D.M & Wubu, W. 2018)

$$h = 4V / \pi D^2 \quad h = \frac{4 \times 0.113}{\pi \times 0.4^2} = 0.899 \cong 0.9m$$

$$\text{Height of gas holder} = 1.2 - 0.9 = 0.3m$$

Step 7; Design for the mixing tank

The mixing tank is cylindrical in nature

Amount of slurry input = 6Litres = $0.006m^3$

Area = $\frac{Volume}{Depth}$, assuming a depth of 0.15m

$$Area = \frac{0.006}{0.15} = 0.04m^2$$

$$Area = \pi r^2 = \pi \times r^2 = 0.04$$

$$r = 0.113m.$$

Table 3.8 - Manufacturing specifications

SYMBOL		GIVEN	UNIT
<i>V</i>	Design Volume	<i>0.15</i>	m^3
<i>D</i>	Cylinder Diameter	<i>0.4</i>	<i>m</i>
<i>R</i>	Cylinder Radius	<i>0.2</i>	<i>m</i>
<i>S</i>	Permissible Stress	2.482×10^8	N/m^2
<i>E</i>	Welding Efficiency	<i>0.8</i>	
<i>C</i>	Corrosion Allowance	<i>1</i>	<i>mm</i>
<i>h</i>	Height of digester	<i>1.2</i>	<i>m</i>

	Gas yield/per kg of feedstock	0.007	m^3
	Retention Time	25	days
	Maximum feedstock	21.5	kg
<i>P</i>	Operating Pressure		
<i>t</i>	Thickness of shell	1.2	<i>m</i>
	Thickness of head		

Figure 3.7 - orthographic view of the digester design

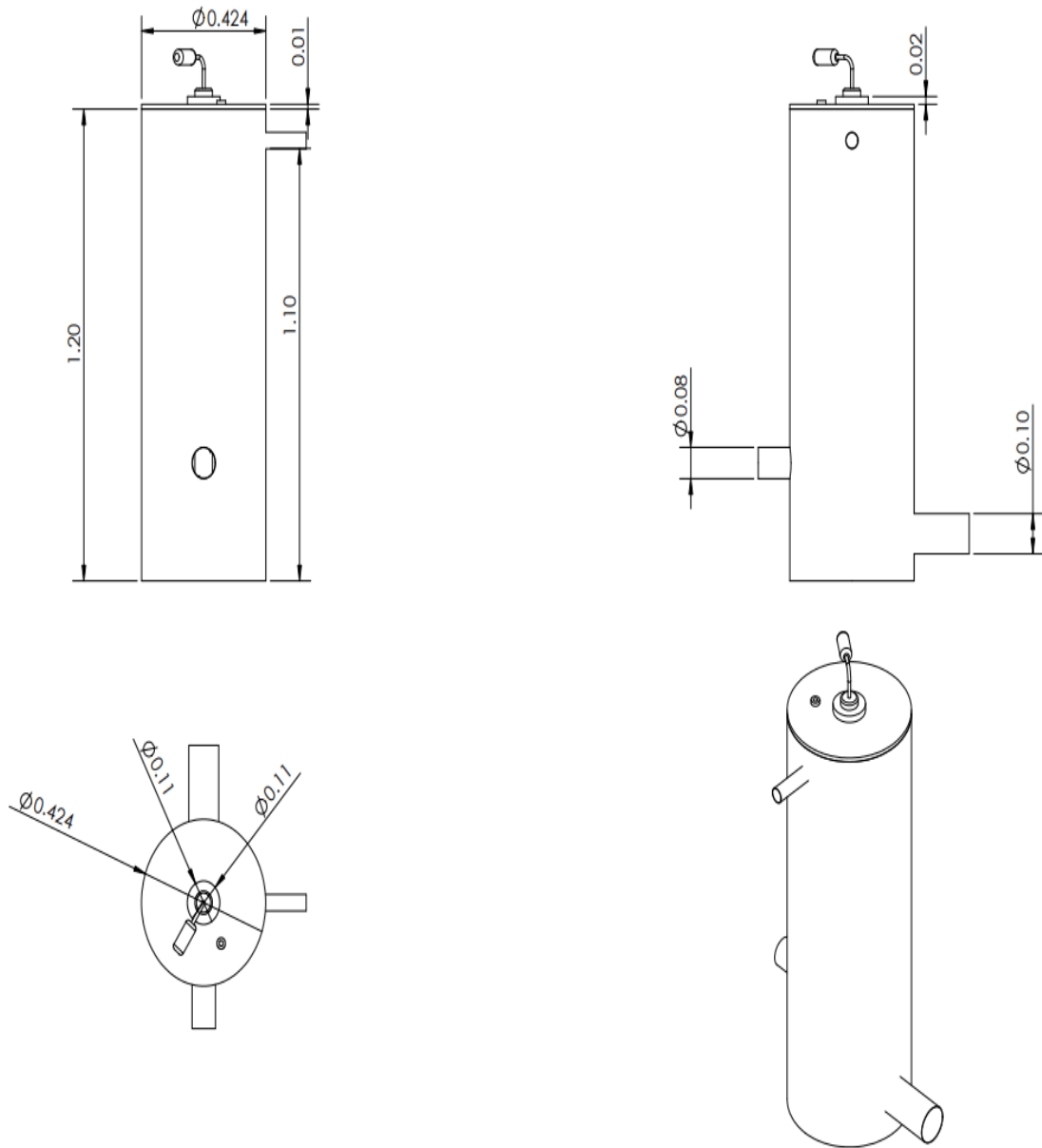


Figure 3.8 - sectional view of the digester design

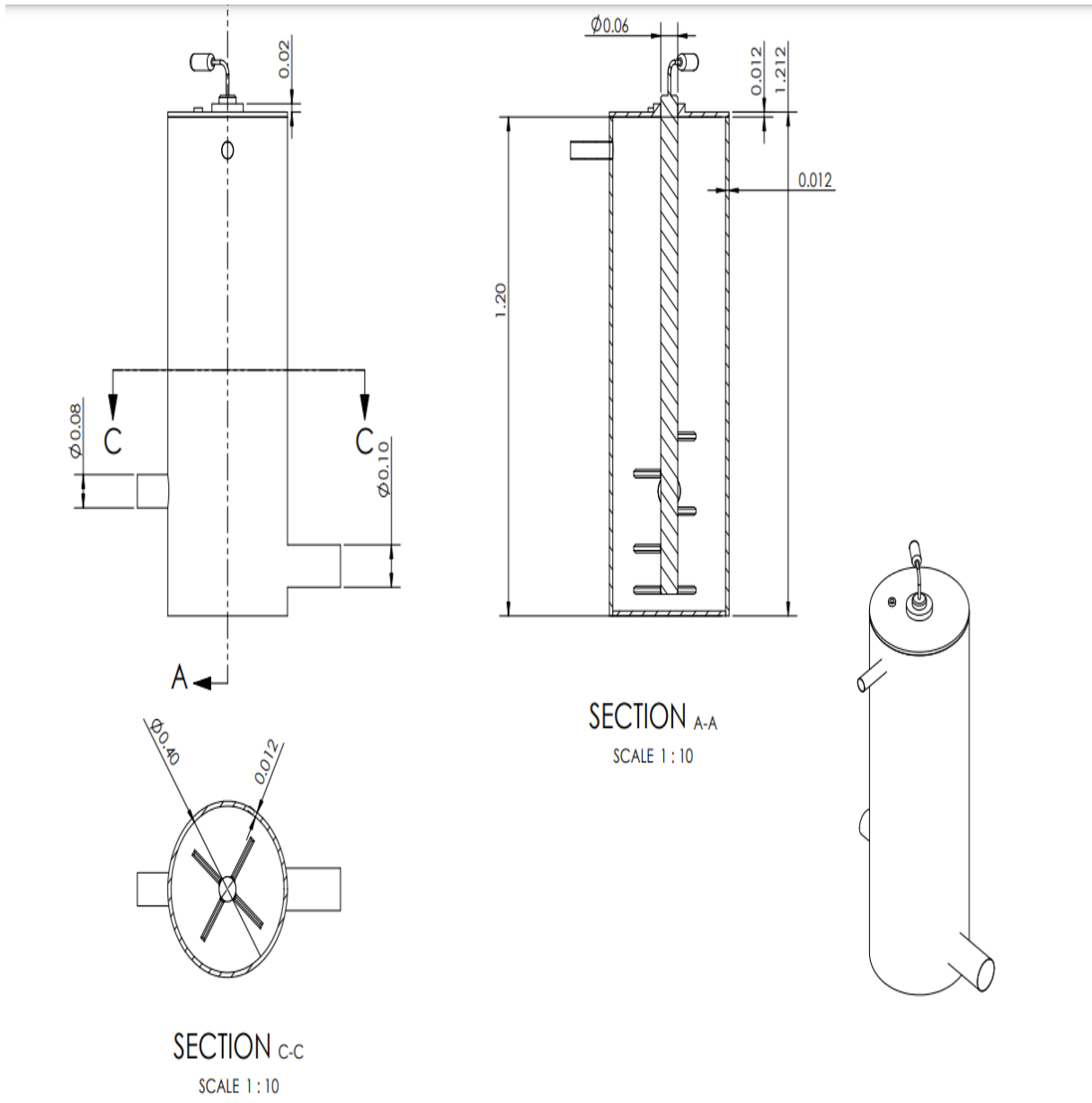


Figure 3.9 - design of slurry outlet and inlet

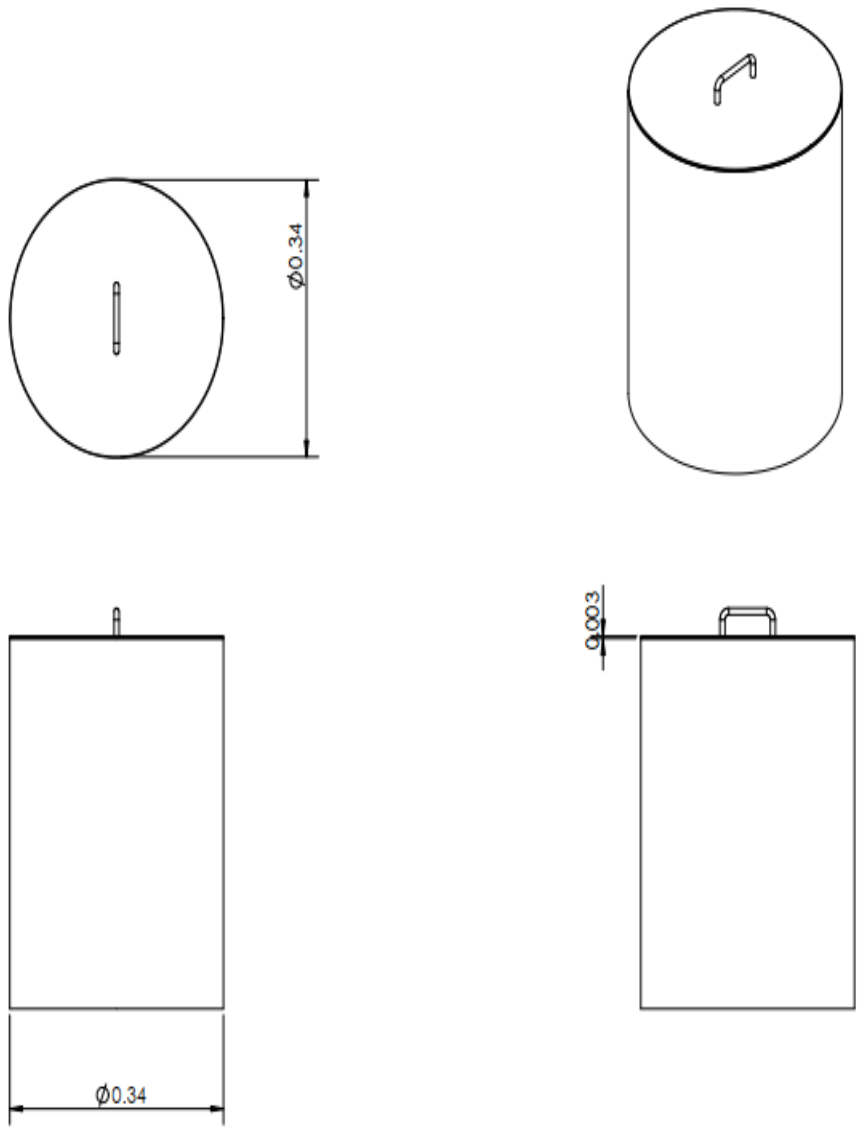


Table 3.9 – Bill Of Engineering Materials and Evaluation

S/NO	PART NAME	PART DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
1	Digester tank	Made from stainless steel sheet 1.0 mm	1	50,000	50,000
2	Inlet valve	Ball gate valve (3 inches)	1	15,500	15,500
3	Outlet valve	Ball gate valve (3 inches)	1	15,500	15,500
4	Digester lid	Stainless steel sheet (1mm)	1	20,000	20,000
5	Stirrer	Stainless steel pipe and blade assembly	1	25,000	25,000
6	Oil seal	Synthetic rubber seal	2	1,500	1,500
7	End cover	60mm X 600mm steel plates	2	700	700
8	Gas regulator	Off-shelf material made of cast brass	1	4,000	4,000
9	Pressure gauge	Mechanical pressure measuring device	1	5,000	5,000
10	Gasket	Synthetic rubber	1	500	500
11	Miscellaneous materials	Coarse and smooth buffers, finishing buffers, etc		1,300	1,300
12	Miscellaneous cost	Diesel, power, transportation, etc		15,000	15,000
13	Finishing	Grinding, cleaning, etc		1,500	1,500
14	Bolts/nuts	M13 bolts/nuts	14	100	1,400
15	Consumables	Stainless electrode, stainless filler rod, etc.		12,000	12,000
16	Labor cost	5 working days	5 days	5,000	25,000

				Total	193,900
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CHAPTER 4

RESULTS AND DISCUSSION.

The components of the biodigester were produced and assembled as shown in the figure 4.1-4.6 below.



Figure 4.1- digester body



Figure 4.2 – to cover



Figure 4.3 - stirrer/mixer



Figure 4.4 - gas regulator



Figure 4.5 - pressure gauge



Figure 4.6 - fully assembled biogas digester

4.1 TESTING

A leakage test was carried out to detect leaks in the welded structure and also to test if the digester head was properly attached to the body. Leaks were detected in various parts of the structure and the biogas digester head and body did not sit properly when due to insufficient sealing. A gasket maker was employed to create a proper gasket seal for the surfaces. A gasket maker was also employed at leak points for sealing. Afterwards, the leak test was carried out again and leakage points were not identified in the structure.

4.1.1 Loading Process.

The biogas digester head was removed to provide better access to the digester body. The loading volume was about 80% of the total volume of the digester body. The ratio of water to feedstock for this experiment was 1:1. The biogas digester was then filled with water to occupy 40% of the vessel. Then the cow dung inoculum which is the seeding agent was added and then finely chopped food waste consisting of rice, potato peels, yam peels, chicken dung, and potato peels was added till the mixture occupied about 80% of the vessel. The digester head containing the stirrer was then placed atop the digester body and the digester was sealed shut with the help of bolts and nuts. Atop the biogas head, a pressure gauge was attached during the manufacturing process. The initial pressure was recorded for the first day. When biogas production starts, the pressure of the vessel increases. Thus the pressure reading would be recorded every day to monitor the gas production

4.2 RESULTS

Table 4.1 – Daily digester pressure readings

Day	Pressure reading (Bar)
Day 1	0

Day 2	0
Day 3	0
Day 4	0
Day 5	0

4.3 OBSERVATION

There was no gas production for the first five days, ideally, there should be gas production by day 2. On further observation of the vessel, leaks were detected in various parts of the vessel and also at the point where the stirrer was attached atop the vessel. When the stirrer was applied to mix the contents of the biogas digester, a foul smell was detected; indicating that the vessel had leaks thus there was no gas production

4.4 LIMITATIONS

Due to a poor manufacturing process, the digester did not meet the ideal design specification. The weld done on the prototype was poor and had several defects and thus had leaks. The stirrer of the prototype digester was attached poorly thus the seal at that point was inefficient. Due to a shortage of funds and also a time limitation the prototype cannot be redone.

CHAPTER FIVE

5.1 CONCLUSION

A biogas digester for household use was designed and food waste was successfully recovered and fed into the digester. The experiment shows that the aforementioned food waste has the potential, and capability to generate biogas. Mixing of the food waste with animal wastes (Cow dung) tremendously improved the biogas production and retention time. Apart from swine and cow dung, other animal wastes like rabbit, goat, and poultry wastes can be utilized to optimize the biogas production from the above feedstock used in this project. The developed biogas technology could be utilized in various homes to provide an alternative means to the ever-increasing cost of cooking with contemporary propane gas and also to reduce the amount of waste loitering around in our environment.

5.2 RECOMMENDATIONS

Due to the presence of leaks in the digester, it is recommended that a more experienced technician able to maximize time with little or no errors be hired. Alternatively, the leak spots should be identified carefully and sealed properly. Quality control measures should be implemented to improve the digester's performance

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