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Fueling a Sustainable Future: Surmounting Challenges and Expanding the Frontisers of Biogas Generation from Pig Slurry.

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Abstract
The Transition to a sustainable energy future present numerous challenge that require innovative solutions. This Research delves into the untapped potential of harnessing biogas from pig slurry as a renewable energy source, Highlighting the work conducted by the esteemed Nigerian institute of industrial statisticians (NIIS). As of June 2022, the production of pigs has reached a staggering 3.1million specimens, creating a substantial opportunity for utilizing their slurry as an organic resource. Through meticulous analysis, it has been determined that pig slurry contains approximately 4,656kg of organic materials generated daily. Drawing from this resource, the daily biogas generation from the fermented pig slurry samples was calculated to be an impressive 1,024m3. Of particular note is the methane formation, which reaches a remarkable 615,615m3 per day, equivalent to an astounding energy output of 22,022Mj/day. The implications of this Research extend beyond mere energy generation. By embracing biogas production from pig slurry., we align ourselves with the United Nations sustainable Development Goals (SDGs). This approach directly contributes to SDGs 7 - Affordable and clean Energy, as well as SDGs12 -Responsible Consumption and production, and SDGs 13-climate Action. By utilizing an abundant waste stream and transforming it into a valuable energy Resource, we address the need for cleaner energy sources while promoting responsible Resource management and reducing greenhouse gas emissions. Expanding the frontiers of biogas generation from pig slurry holds greats promise in our pursuit of a sustainable future. By investing in Research and technology advancements, we can overcome the challenges associated with scaling up this process and maximize it's potential. This innovative approach not only aids in achieving our energy goals but also supports job creation, rural development, and environmental stewardship. Embracing biogas generation from pig slurry is a wise and forward -thinking solutions that addresses the pressing need for sustainable energy sources. By leveraging the findings from NIIS and aligning with the United Nations SDGs, we can create a cleaner and more resilient future, ensuring a balance between economic prosperity and environmental responsibility.
Keywords: SDGS, un, biogas, methane, carbon, hydrogen**.**

1.0 Introduction

In the quest for sustainable energy sources, biogas generation from pig slurry has emerged as a promising solution. Pig slurry, a mixture of pig manure and water, is a valuable organic resource that can be efficiently harnessed to produce biogas, consisting primarily of methane and carbon dioxide (Smith et al., 2019). This renewable energy not only helps reduce reliance on fossil fuels but also presents an environmentally friendly approach to managing the waste generated by the intensive pig farming industry.

However, the successful implementation of biogas generation from pig slurry is not without its challenges. One critical aspect is the effective removal of ammonium and phosphate, which can impede the biogas production process (Liu et al., 2019). In this context, innovative methods such as the utilization of modified zeolite have demonstrated promise in enhancing nutrient removal while simultaneously promoting biogas production (Liu et al., 2019). This approach not only addresses environmental concerns but also ensures efficient utilization of the valuable nutrients contained in pig slurry.

In addition to nutrient management, optimizing the dynamics of microbial communities during anaerobic digestion is vital. The composition and activity of microorganisms play a pivotal role in the breakdown of organic matter and subsequent biogas production (Zhang et al., 2019). Understanding and manipulating these microbial communities can lead to enhanced biogas yields. For instance, research has shown that the incorporation of Fe0 nanoparticles can boost biogas production from pig manure by facilitating favorable interactions among microorganisms (Mahdy et al., 2018).

Furthermore, the intricate relationship between pH and moisture content significantly affects the anaerobic digestion process. These factors influence not only the degradation of organic matter but also the removal of ammonium nitrogen, a primary concern in pig slurry management (Zhang et al., 2018). By carefully manipulating these operating parameters, such as pH and moisture content, optimal conditions for biogas production can be achieved while minimizing potential environmental risks.

To expand the frontiers of biogas generation from pig slurry, researchers have explored advanced pretreatment methods. Alkaline pretreatment, for instance, has shown promise in enhancing the anaerobic digestion process by promoting the breakdown of complex organic compounds and improving biogas yields (Zhang et al., 2018). Incorporating these pretreatment techniques into existing biogas plants can maximize energy production while minimizing the environmental footprint., the successful realization of biogas generation from pig slurry requires addressing challenges related to nutrient removal, optimizing microbial communities, managing pH and moisture content, and exploring effective pretreatment methods. By overcoming these hurdles, we can unlock the full potential of pig slurry as a renewable energy resource, paving the way for a more sustainable future.

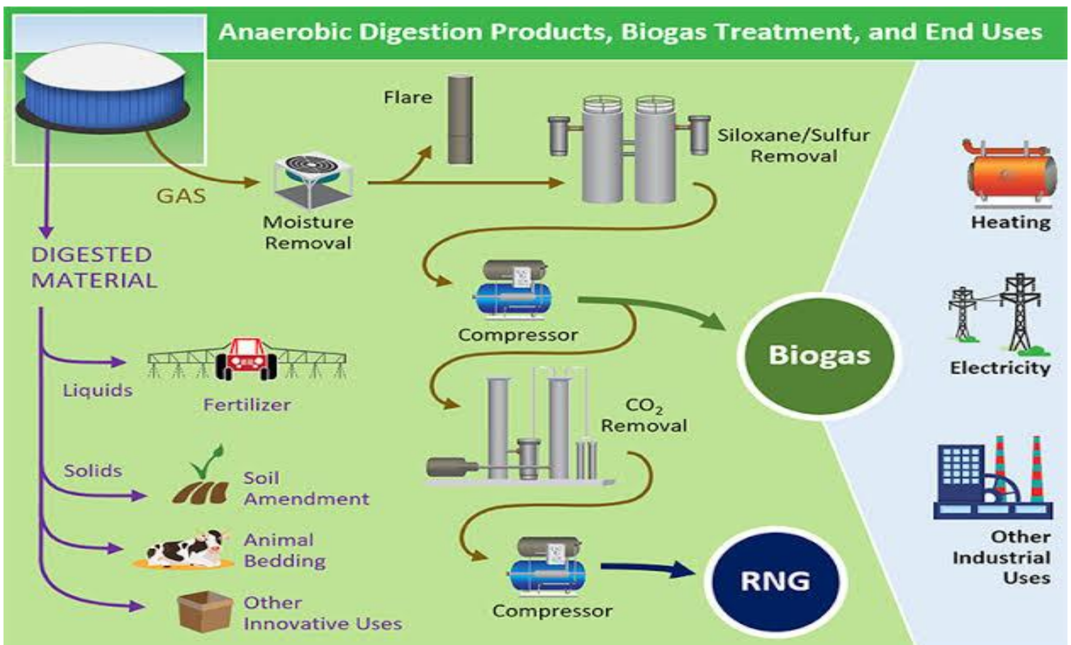


Figure 1: illustrates the intricate and fascinating process of biogas formation from pig slurry.

The journey begins with the anaerobic environment, where microorganisms thrive and play a vital role. The organic materials present in pig slurry serve as the raw materials for biogas production. In this process, complex organic compounds are broken down by the microorganisms through a series of biological reactions. These reactions, known as anaerobic digestion, result in the release of biogas. This gas mixture predominantly consists of methane, which accounts for around 45-70% of the composition. Additionally, the biogas contains approximately 30-55% carbon dioxide, along with other gases such as nitrogen, hydrogen, hydrogen sulfide, ammonia, and residual gases. The biogas formation process depicted in Figure 1 highlights the importance of the anaerobic environment and the crucial role of microorganisms in breaking down organic matter. Through their activity, these microorganisms facilitate the conversion of pig slurry into a valuable and renewable energy resource: biogas. Understanding and optimizing this biogas formation process is essential for enhancing the efficiency and yield of biogas generation from pig slurry. By gaining insights into the mechanisms involved, researchers and practitioners can devise strategies to overcome challenges and maximize the potential of biogas as a sustainable energy source. Figure 1 serves as a visual representation of the complex, yet promising, process of biogas formation, shedding light on the intricate interplay between organic materials, microorganisms, and the production of this renewable gas mixture.

Due to the relatively low energy density of biogas production, this sustainable energy source is particularly suitable for supplying small to medium-scale decentralized or local heat and electricity consumers. It offers a viable solution for meeting the energy demands of various community-based or rural settings, where traditional energy infrastructure may not be easily accessible. The versatility of biogas extends beyond localized applications. It can also be effectively utilized in power plants and district heating systems, thereby contributing to larger-scale energy generation and distribution. By harnessing biogas in these centralized systems, it becomes possible to integrate this renewable resource into existing energy infrastructure, reducing dependence on fossil fuels and promoting a more sustainable energy mix. This research on biogas generation from pig slurry opens up opportunities to explore the potential of this renewable energy source across different scales of energy consumption. By identifying the suitable applications and optimizing the utilization of biogas, we can take significant strides towards achieving a more sustainable future, reducing greenhouse gas emissions, and fostering energy independence.

1.1 Significance of surmounting challenges and expanding the frontisers of biogas generation from pig slurry.

The significance of conducting a study on biogas generation from pig slurry and aligning It with the United Nations sustainable Development Goals (SDGs) Cannot be overstated.

This Research has far reached implications that contribute to multiple SDGs, therefore amplifying its importance in the pursuit of a sustainable future. First and foremost, this study aligns with.

SDGs 7-affordable and clean Energy. By harnessing the potential of biogas from big slurry, we tap into a renewable energy source that can provide affordable and environmentally friendly energy solutions. This not only reduce reliance on fossil fuels but also addresses the issues of energy poverty and promotes access to clean energy for all. Further, the research directly supports

SDGs 12 - Responsible consumption and production. By utilizing pig slurry, which is others considered a waste product as a valuable resource, we promote circular and sustainable practices. This approach reduces the environmental impact associated with traditional waste management methods and encourage responsible resource usage. Additionally, this study aligns with

SDGs 13 - Climate action. Biogas generation from pig slurry offers a significant opportunity for reducing greenhouse gas emissions. Methane, a potent greenhouse gas is a byproducts of pig slurry decomposition. By capturing and utilizing biogas, we effectively mitigate methane emissions and contribute to climate change mitigation effort. By conducting research that align with the United Nations sustainable development goals, we demonstrate a commitment to addressing the global challenges we face. The research on biogas generation pig slurry offers an opportunity to not only a renewable energy solution but also foster economic growth, rural development, and environmental stewardship. it exemplifies the interconnectedness of sustainability goals and emphasize the importance of holistic approach in achieving a sustainable future. The significance of conducting research on biogas generation from pig slurry and aligning it with the United Nations SDGs lies in its potential to provide affordable and clean energy, promote responsible resource usage, and contribute to climate change mitigation. By embracing this Research, we can embrace a more sustainable and Resilient future for all.

2.0 Raw Materials of Biogas Production

Biogas production typically involves the use of organic materials, also known as feedstock, which undergo anaerobic digestion to produce biogas. Some common raw materials used in biogas production include:

i. Animal Manure: Livestock waste, such as cow or pig manure, can be a great source of raw material for biogas production. It contains high amounts of organic matter that can be easily digested by bacteria in the anaerobic digesters.

ii. Agricultural Residues: Crop residues, such as corn stalks, wheat straw, or rice husks, can be used as feedstock for biogas production. These residues are rich in carbohydrates and can be easily broken down by the anaerobic bacteria.

iii. Food Waste: Leftover food from households, restaurants, or food processing industries can be used as raw materials for biogas production. It's a sustainable way to utilize food waste and generate renewable energy.

iv. Energy Crops: Specific crops like maize, sugarcane, or sorghum can be grown specifically for biogas production. These energy crops have a high content of starch or sugar, making them ideal for anaerobic digestion.

v. Sewage Sludge: Wastewater treatment plants often produce sewage sludge, which can serve as a valuable raw material for biogas production. The sludge contains organic matter that can be efficiently digested by the bacteria in anaerobic digesters.

vi. Industrial Waste: Some industries generate organic waste streams that can be utilized for biogas production. For example, food processing residues, brewery waste, or paper mill waste can be used as feedstock.

It's worth noting that biogas production can be a creative process, and various other raw materials can be explored depending on the local availability and the specific goals of the biogas project. Indeed, Nigeria, like many other countries, faces a significant amount of bio-waste generated from manure, primarily originating from animal husbandry. This bio-waste has the potential to be harnessed as a valuable resource for various applications, including biogas generation. The agricultural sector, which includes animal husbandry, contributes significantly to the bio-waste generated in Nigeria. Manure, a byproduct of this industry, is rich in organic matter and can serve as a feedstock for biogas production. By implementing appropriate technologies and infrastructure, the country can effectively convert this bio-waste into biogas, offering a clean and renewable energy alternative. Harnessing the bio-waste from manure not only presents an opportunity for sustainable energy generation but also contributes to waste management and environmental protection. By diverting and utilizing this organic waste, Nigeria can reduce the release of harmful greenhouse gases and odors associated with untreated manure. Exploring the potential of biogas generation from the bio-waste generated by animal husbandry in Nigeria aligns with the objective of fueling a sustainable future. It provides an avenue to address waste management challenges while simultaneously promoting renewable energy utilization. Through research, innovation, and collaboration, we can unlock the immense potential of bio-waste to contribute to a cleaner, greener, and more sustainable Nigeria.

Table 1: The composition of biogas varies depending on the raw materials used in the anaerobic digestion process.

Biogas raw material Based

Constituents	**Agriculture**	**By product of treatment sewage**	**Landfills results**
methane VV%	60 TO 70	56 TO 60	46 TO 55
VV % CO_2	30 TO 50	35 TO 46	30 TO 40
%VVNITROGEN	<1	<1	5 to 15
$H_2S mg/m^3$	<650	<650	<150
Oxygen VV%	0-2	0-2	<10
Silxanes mg/m^3	0 to 50	0 to 50	0 to 50
Ammonis mg/m3	<150	<150	<10

The results presented in Table 1, which provides information on the composition of biogas from different raw materials used in the anaerobic digestion process. **1. Methane Content:** The table shows that the methane content in biogas varies depending on the raw material used. Biogas produced from agriculture sources contains approximately 60% to 70% methane, while biogas derived from sewage treatment by-products has a slightly lower methane content of around 56% to 60%. Biogas obtained from landfills results in the lowest methane content, ranging from 46% to 55%. Methane is the primary component of biogas and is responsible for its combustible properties. **2. Carbon Dioxide Content:** The percentage of carbon dioxide (CO2) in biogas is another important parameter. Biogas from agricultural sources typically contains 30% to 50% CO2, while biogas generated from sewage treatment by-products has slightly higher CO_2 levels, ranging from 35% to 46%. Biogas produced from landfills has CO_2 content ranging from 30% to 40%. The presence of CO_2 affects the energy content of biogas and influences its combustion characteristics. **3. Nitrogen Content**: The table indicates that the biogas produced from these different sources has very low nitrogen content. Biogas from all three sources contains less than 1% nitrogen, with landfills resulting in slightly higher levels, ranging from 5% to 15%. The low nitrogen content is desirable as it minimizes the risk of nitrogen oxide emissions during combustion. 4. **Hydrogen Sulphide (H_2S) Content**: The concentration of hydrogen sulphide, a corrosive and toxic gas, is measured in milligrams per cubic meter (mg/m3). The table shows that biogas from all three sources has a relatively low H_2S content. The levels are below 650 mg/m3, indicating that the biogas is reasonably free from hydrogen sulphide. This is beneficial as it reduces the risk of corrosion and enables the safe use of biogas. **5. Oxygen Content:** The table indicates that the biogas samples analyzed contain very low levels of oxygen. The oxygen content is typically between 0% and 2%, ensuring that the biogas remains highly combustible. The absence of significant oxygen levels prevents unwanted combustion reactions and ensures efficient energy utilization. **6. Siloxanes and Ammonia Content:** Siloxanes and ammonia are additional components that can be present in biogas. The table shows that biogas from all three sources has relatively low levels of siloxanes, ranging from 0 to 50 mg/m3. Similarly, the ammonia content is also quite low, with concentrations below 150 mg/m3 for agriculture and sewage treatment biogas, and below 10 mg/m3 for biogas from landfills. The presence of these substances in low concentrations is desirable as it minimizes the potential for equipment damage and air pollution. In summary, the composition of biogas varies depending on the raw material used in the anaerobic digestion process. The methane, carbon dioxide, nitrogen, hydrogen sulphide, oxygen, siloxanes, and ammonia content of biogas all play significant roles in determining its energy content, combustion properties, and potential environmental impacts. Analyzing these parameters allows for a better understanding of the quality and potential applications of biogas generated from different sources.

Examining the role of manure-based biogas production, specifically focusing on a pig farm, can provide valuable insights into the potential of this renewable energy source for a sustainable future. By highlighting the benefits and challenges associated with biogas generation from pig farm manure, your project can contribute to the broader understanding of the agricultural sector's role in renewable energy production. Through your examination, you can explore various aspects such as the quantity and quality of biogas that can be obtained from pig farm manure, the feasibility of implementing biogas systems on pig farms, and the potential economic and environmental benefits of utilizing manure as a feedstock for energy generation. Additionally, your project can shed light on the technical considerations, operational requirements, and potential integration of biogas systems into the existing infrastructure of pig farms. This research can help identify the best practices, technologies, and management strategies for maximizing biogas production while addressing any practical challenges that may arise. By showcasing the specific example of a pig farm, your project can provide a practical and context-specific perspective on the potential of manure-based biogas production. This can ultimately contribute to promoting the adoption of sustainable practices in the agricultural sector, reducing greenhouse gas emissions, and enhancing energy self-sufficiency

3.0 Environmental Hazards of Animal Husbandry

Animal husbandry plays a significant role in meeting the global demand for food, but it also poses environmental challenges. This expanded write-up aims to explore the environmental hazards associated with animal husbandry practices. Recognizing these challenges is crucial for adopting sustainable approaches that minimize the negative impacts and promote a harmonious coexistence between agriculture and the environment.

i. **Water Pollution**: Animal waste, including manure and urine, can contaminate water sources when not properly managed. Runoff from farms can carry excess nutrients, such as nitrogen and phosphorus, into water bodies, causing eutrophication. This process depletes oxygen levels, harms aquatic life, and disrupts the natural balance of ecosystems.
ii. **Air Pollution**: Ammonia emissions from animal waste contribute to air pollution. High ammonia concentrations can have adverse effects on human health, leading to respiratory problems and exacerbating respiratory conditions like asthma. Additionally, ammonia can react with other air

pollutants to form fine particulate matter (PM2.5), which poses a significant risk to human health and can contribute to smog formation.

iii. **Greenhouse Gas Emissions:** Animal husbandry is a significant contributor to greenhouse gas (GHG) emissions, primarily methane (CH_4) and nitrous oxide (N_2O). Methane is produced during the digestive processes of ruminant animals, such as cattle and sheep, while nitrous oxide is released from animal waste decomposition and the use of nitrogen-based fertilizers. These potent GHGs contribute to climate change and global warming.

iv. **Deforestation:** The expansion of animal husbandry often leads to deforestation, as forests are cleared to create grazing land or grow animal feed crops. Deforestation not only destroys valuable ecosystems but also reduces carbon sinks, exacerbating climate change. Additionally, the loss of forests can contribute to soil erosion, loss of biodiversity, and disruption of local water cycles.

v. **Soil Degradation:** Overgrazing and improper waste management can lead to soil degradation. When animals concentrate in one area, their hooves can damage the soil structure, compacting it and reducing its ability to absorb water. Moreover, excessive application of manure or chemical fertilizers can lead to nutrient imbalances and soil nutrient runoff, causing soil degradation and reducing its fertility.

Sustainable Solutions:

i. **Improved Waste Management**: Implementing proper waste management practices, such as anaerobic digestion, composting, or nutrient management plans, can help minimize water and air pollution from animal waste.

ii. **Precision Feeding:** Adopting precision feeding techniques can optimize animal diets, reducing excess nutrient excretion and mitigating greenhouse gas emissions.

iii. **Sustainable Intensification:** Promoting sustainable intensification practices, such as rotational grazing, agroforestry, or mixed farming systems, can minimize land use and deforestation while ensuring efficient resource utilization.

iv. **Alternative Feed Sources:** Exploring alternative feed sources, such as algae-based or insect-based feeds, can reduce the environmental footprint of animal husbandry by reducing land and water requirements.

v. **Energy Efficiency:** Incorporating energy-efficient technologies, such as renewable energy systems or energy recovery from waste, can reduce GHG emissions and reliance on fossil fuels.

Addressing the environmental hazards associated with animal husbandry requires a multi-faceted approach that combines improved waste management, sustainable intensification practices, and the adoption of innovative technologies. By implementing these solutions, we can mitigate water pollution, air pollution, GHG emissions, deforestation, and soil degradation, fostering a more sustainable and environmentally friendly agricultural sector. Through collaboration between farmers, policymakers, and consumers, we can work towards a future where animal husbandry coexists harmoniously with the environment, ensuring a sustainable and resilient food production system.

3.1 CO: Generation

After dewatering, biogas is often utilized in gas engines to achieve co-generation, where both heat and power are generated simultaneously in the same equipment. This is a highly efficient method that maximizes the energy potential of biogas. The heat generated can be harnessed for various purposes, such as heating buildings and producing domestic hot water. Meanwhile, the power generated can be used for on-site electricity consumption or fed into the grid, contributing to renewable energy generation.

3.2 Direct Fuel Application:

In smaller biogas plants, biogas can be applied directly as fuel without electricity generation. This is a simple and direct utilization method that can be suitable for specific applications, such as cooking, heating, or as a fuel source for industrial processes. By using biogas as a direct fuel, the need for other fossil fuels, such as natural gas or LPG, can be reduced, promoting sustainability and reducing greenhouse gas emissions. The utilization of biogas for heating, production of domestic hot water, and electricity aligns with its similar applications to natural gas or LPG. This versatility makes it viable for a range of energy demands in residential, commercial, and industrial settings. By replacing conventional fossil fuel sources with biogas, we can reduce our dependency on non-renewable resources and contribute to a greener and more sustainable energy mix.,

The utilization of biogas goes beyond co-generation and direct fuel application. Here are a few additional forms of biogas utilization:

1. **Injection into Natural Gas Network:** After cleaning and enrichment, biogas can be further processed to remove contaminants and non-combustible constituents. This purified and enriched biogas, with a methane content typically ranging from 95-97%, can be injected into the natural gas network. This integration allows biogas to contribute to the existing natural gas infrastructure, providing a renewable and sustainable energy source for various end users.
2. **Use as Vehicle Fuel:** Enriched biogas can also be utilized as a fuel for motor vehicles. By utilizing biogas in transportation, we can reduce carbon emissions and promote a greener and more sustainable transportation sector. In countries like Nigeria, biogas is already being used as fuel for motor vehicles, showcasing the potential for renewable energy adoption in the transportation industry. These forms of biogas utilization expand its potential applications and contribute to a more diverse and sustainable energy landscape. They demonstrate the flexibility and adaptability of biogas as a renewable energy source, with the capacity to integrate into existing infrastructure and address various energy demands. Figure 2 illustrates one of these forms of biogas utilization, showcasing the practical application and benefits of utilizing biogas

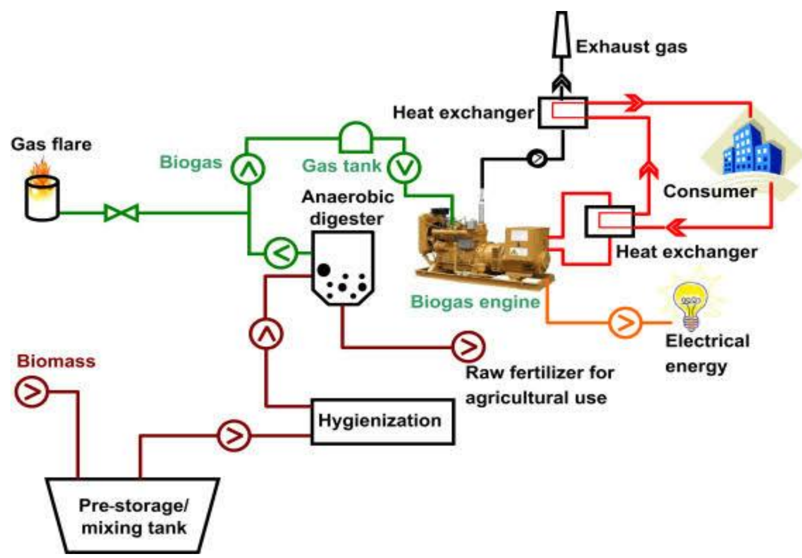


Figure 2: illustrates the potential biogas production in Nigeria.

It depict various factors such as the estimated amount of biogas that can be generated from different sources, the geographical distribution of biogas production, and the potential energy output from biogas projects across the country. Nigeria, with its significant agricultural sector and abundant organic waste resources, holds great potential for biogas production. The large amounts of bio-waste generated, including manure from animal husbandry and other organic residues, can be utilized to produce biogas through anaerobic digestion. This can contribute to renewable energy generation, waste management, and environmental sustainability.

3.3 Biogas Potential from Pig Slurry

Considering the significant pig population in Nigeria, the potential for biogas production from pig slurry is substantial. Pig slurry, which is a mixture of manure and other organic waste, can serve as a valuable feedstock for anaerobic digestion and biogas generation. The organic matter present in pig slurry can be broken down by microorganisms in an anaerobic environment, resulting in the production of biogas. The composition of the biogas typically includes methane, carbon dioxide, and other residual gases. By optimizing the anaerobic digestion process, it is possible to maximize the yield and quality of biogas from pig slurry. The utilization of biogas from pig slurry offers several advantages. It helps manage and treat the organic waste, reducing the environmental impact of pig farming. Additionally, biogas can be used as a renewable energy source, providing heat, power, or even as a vehicle fuel. By harnessing the biogas potential from pig slurry, Nigeria can enhance energy self-sufficiency, promote sustainable agriculture, and contribute to climate change mitigation.

The production of liquid manure in large-scale pig husbandry is influenced by factors such as the number of pigs, their age and weight categories, and the specific technology used for manure removal. The total quantity of liquid manure is determined by the combination of feces, urine, and washing water present in the system. In Nigerian pig farms, where various age and weight categories of livestock are bred simultaneously, it is common for the quantity of manure and slurry to vary significantly. Larger-scale pig farms typically have a higher number of animals, resulting in a larger volume of liquid manure being generated. In contrast, smaller-scale pig farms may produce a relatively smaller quantity of slurry due to the smaller number of animals. It's important to consider the variations in manure production and slurry quantity when assessing the potential for biogas production from pig slurry. The availability and volume of liquid manure play a crucial role in determining the feasibility and scale of biogas projects on pig farms

Table 2 likely presents a summary of the annual pig slurry production based on various literature sources (references [2, 9, 10, 11]). The table is expected to provide an overview of the estimated quantities of pig slurry generated within a given time-frame. To accurately interpret the information in Table 2, it would be necessary to refer to the accompanying data and context provided within the table itself. The data include factors such as the number of pigs, the farming systems or practices considered, and any specific assumptions or methodologies used in the calculations. The summary of pig slurry production from multiple literature sources can help provide a comprehensive understanding of the range and average values for slurry quantities in pig farming. This information is crucial for assessing the potential for biogas production, waste management strategies, and environmental impacts associated with pig farming

Table 2: Specific Number of Pig Slurry

Types of animal	**JN1**	**JN2**	**RK**	**RI.**	
	m /year per animal				
Sow	3,63	5,80	2,50	-	3,98
Boar	4,00	5,40	6,12	-	5,17
Piglet (20-50 kg)	2,40	-	1,80	1,90	2,03
Fatten (50-100 kg)	2,40	2,50	2,50	3,30	2,68
Pig with piglets	-	-	6,12	7,90	7,01
Mean	-				4,17

Based on the average of 4.17 m3 of pig slurry per year per animal and the pig population in Nigeria, we can estimate the total pig slurry production for the country. If the pig slurry production in Nigeria reached approximately 14 million m3 in 2022, we can divide this total by the average amount of pig slurry per year per animal to get an estimate of the total number of pigs in Nigeria. Using the calculation: Total pig slurry production (m3) / Average amount of pig slurry per year per animal (m3/year/animal) = Total number of pigs 14,000,000 m3 / 4.17 m3/year/animal = Approximately 3,355,450 pigs Please note that this is an estimate based on the given average and total pig slurry production. The actual number of pigs may vary depending on various factors such as the specific farming practices, herd management, and waste management systems in place

3.4 Pig Slurry Analysis

We collected four pig slurry samples from a single of Nigeria's largest pig farms run by an agricultural enterprise. The goal of collecting these samples was to analyse and obtain data regarding the pig slurry's biogas generating capability.

Researchers investigated the primary chemical as well as physical characteristics of four pig slurry samples (JN1, JN2, RK, and RI). You looked at density, dry matter content, organic material content, as well as composition of elements. These investigations give important information about the properties as well as prospective biogas generation of pig slurry samples.We used a Mettler Toledo HB43-S type automated moisture analyzer for estimating the dry-matter concentration among the pig slurry samples.

Applying the following equation: moisture content% + dry-matter% = 100%, we were able to quantify the proportion of moisture and determine the dry-matter percentage. The Carlo Erba EA 1108 elemental analyzer was used to collect data on the elemental composition. We used an elemental analyzer to estimate the Total Carbon (TC) content of the dried samples before measuring the Total Organic Carbon (TOC). We measured the Inorganic Carbon (IC) content after determining the Total Carbon (TC) level with the elemental analyzer. Several steps were involved in the study of IC content: We began by pouring sulphuric acid into a closed sample container which contained the dehydrated material. precisely an outcome, carbon dioxide (CO2) was liberated through the breakdown of dry matter's inorganic carbon. The IC content of the substance that was dry was inversely proportional to the CO2 concentration in the gas space. Figures 3 and 4 show the results of this IC study.In accordance with the results shown in the following illustration, the sample labeled "JN2" had the greatest dry matter and organic material content among the analyzed samples. Given its advantageous qualities in terms of dry matter and organic material content, this means the choice of the "JN2" sample was the best option for the yeast fermentation procedure.

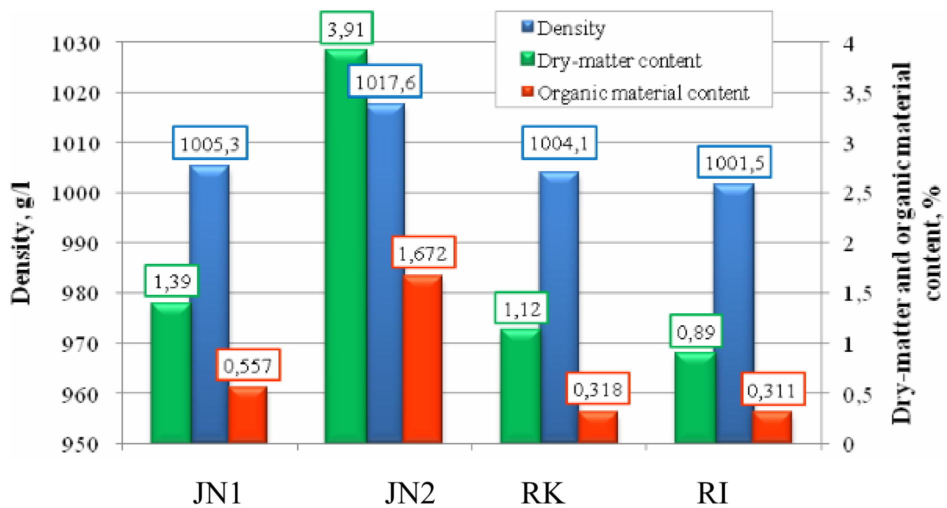


Figure 3: Matter Content - Density Dry and Organic

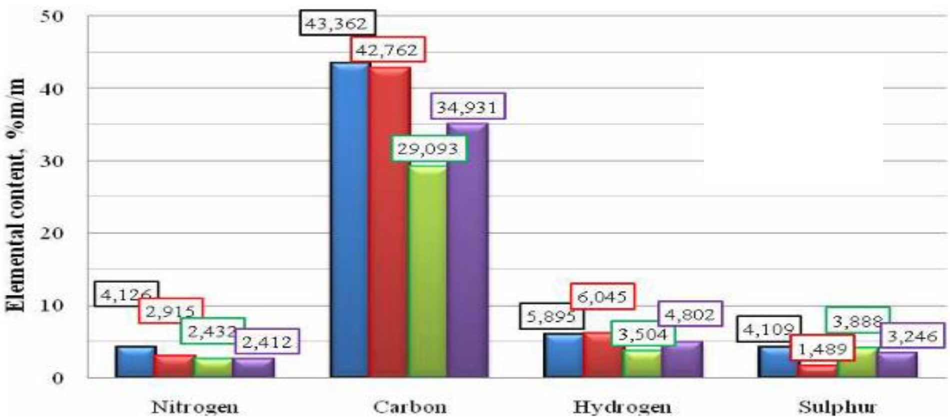


Figure 4: Dry pig slurry and Elemental Content Samples

According to the data in Figure 4, the carbon content, a critical component impacting biogas generation, did not differ considerably across the samples. The carbon-to-nitrogen ratio is critical for the microorganisms engaged in the process. Anaerobic microorganisms use carbon roughly 30 times quicker than nitrogen, resulting in an ideal C/N ratio of 20-30 [12]. If the ratio falls outside of the ideal range, bacteria devour all of the accessible nitrogen, leaving carbon to remain in the starting material.

Indeed, when the carbon-to-nitrogen (C/N) ratio deviates from the optimal range, it can have negative consequences for biogas production. If the ratio becomes too high, the bacteria are unable to efficiently consume the carbon, leading to a slowdown in the fermentation process and a reduction in gas production. Conversely, if the C/N ratio is too low, it results in an accumulation of ammonia, which can inhibit the normal functioning of bacteria. This inhibition can also be detrimental to biogas production. Maintaining an appropriate C/N ratio is crucial for ensuring optimal conditions for the biogas production process. Based on the ratios depicted in Figure 5, which range from 11-15, it is evident that the C/N ratios of the samples were below the optimal range. Consequently, this may result in lower gas production. According to the literature, the specific biogas production of pig slurry typically falls within the range of 300-550 liters per kilogram of organic material [4, 13, 14]. Considering the lower C/N ratios observed in the samples, it's possible that the actual gas production may be towards the lower end of this range or even lower than the range suggested by the literature.

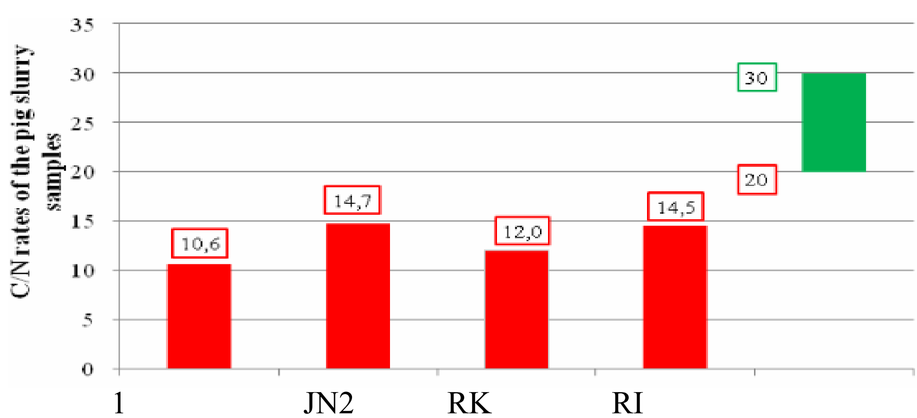


Figure 5: Displays the C/N rates of the pig slurry samples

3.5 Biogas Generation from Pig Slurry

The anaerobic fermentation process was conducted by the Chemical Engineering Department at Imo State Polytechnic in Owerri, Nigeria. The fermentation took place in a batch fermentor equipped with a continuous mixer, operating at a temperature of 54 °C. During this process, the team specifically focused on fermenting the sample labeled as "JN2." The gas production data for this particular sample can be observed in Figure 6.

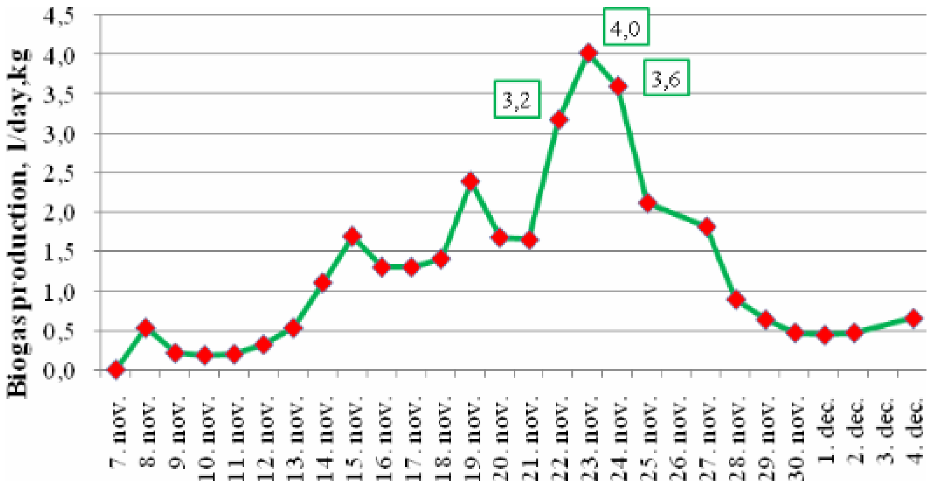


Figure 6: Daily Biogas Production of Sample JN2

"At the Chemical Engineering Department of Imo State Polytechnic, we performed an analysis of the biogas components using the Master gas chromatography. This advanced instrument is equipped with a thermal conductivity detector and a flame ionization detector, both of which were utilized for the measurements. Figure 7 showcases the changes in the composition of the biogas."

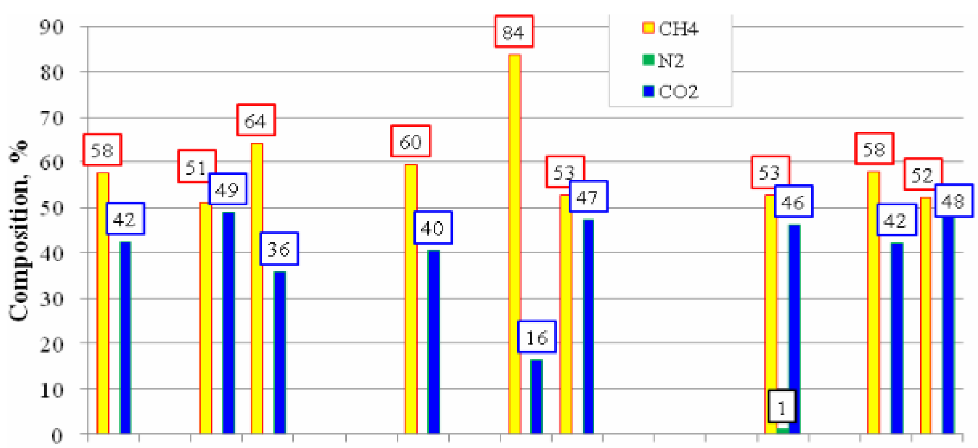


Figure 7: Composition of produced Biogas

3.6 Production Capacity

"We performed calculations for JN Farm, which generates an annual pig slurry volume of 100,000 m3. The objective was to assess the energy utilization of the resulting biogas. It's noteworthy that this quantity of pig slurry, equivalent to the yearly production of a sizable pig farm in Nigeria, was considered for our analysis. Accurately assessing the organic matter content is of utmost importance in the realm of biogas formation, as it serves as a direct indicator of the foundational material involved. To determine the annual quantity of organic material present in pig slurry, several factors must be considered, including the overall slurry volume, the meticulously measured density (1017.6 kg/m3), and the proportion of organic material content (specifically 1.672% based on slurry composition). By meticulously accounting for these variables, we can precisely calculate the precise annual amount of organic material contained within the pig slurry.

$$\text{Organic material} = 100\,000 \frac{m^3}{\text{year}} * 1017,6 \frac{kg}{m^3} * 0,0167 = 1\,699\,392 \frac{kg}{\text{year}}$$

For a given day, the analysis reveals that the sample contains an impressive quantity of 4,656 kg of organic material. Through careful consideration of the fermented sample's quantity, the dry matter content, and the organic material content, we have determined the specific biogas yield for continuous fermentation to be 220 liters per kilogram of organic dry material. This specific biogas yield value can also be expressed as 0.22 cubic meters per kilogram of organic material

$$\text{Biogas production} = 1\,699\,392 \frac{kg}{\text{year}} * 0,22 \frac{m^3}{kg} = 373\,866 \frac{m^3}{\text{year}}$$

Based on our calculations, the daily biogas production at the farm amounts to 1,024 m3. Through our gas chromatography readings, we have determined that the methane concentration in the biogas sample is typically around 60%.

Based on the given information, if the daily biogas production is 1,024 m3 and the methane concentration is approximately 60%, then the methane formation can be estimated as 615.615 m3 per day

To calculate the released heat from biogas production, we can utilize the formula: Released heat = Biogas production (m3) * Heating value (MJ/m3). Given the provided information about the biogas burning, with a methane content of 60% and a heating value of 21.5 MJ/m3, we can now proceed to calculate the released heat. Let's assume the biogas production per year is 236,122 m3, as mentioned. Using the formula, the released heat would be: Released heat = 236,122 m3 * 21.5 MJ/m3. Calculating this, the released heat would amount to a specific value Using the given biogas production value of 236,122 m3 per year and a heating value of 21.5 MJ/m3, we can calculate the released heat. Released heat = 236,122 m3 * 21.5 MJ/m3 Calculating this, the released heat would amount to approximately 5,073,113 MJ per year

$$\text{Released heat} = 373\,866 \frac{m^3}{\text{year}} * 21,5 \frac{MJ}{m^3} = 8\,038\,119 \frac{MJ}{\text{year}}$$

Based on the provided information, the released heat from biogas production is approximately 22,022 MJ per day. Furthermore, the electrical energy equivalent of this generated heat is calculated to be 2,232,811 kWh per year, which is equivalent to 6,117 kWh per day. Similar calculations have been conducted for two other farms, 'RK' with a pig slurry production of 30,000 m3 per year and 'RI' with a production of 12,000 m3 per year. The characteristics of the fermented sample and the methane content of the gas produced were taken into account. A summarized overview of these calculations can be found in Figures 8 and

JN1

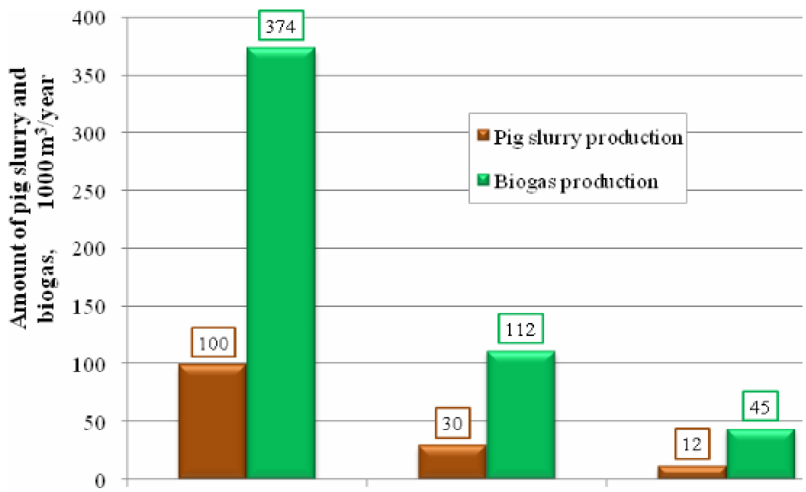
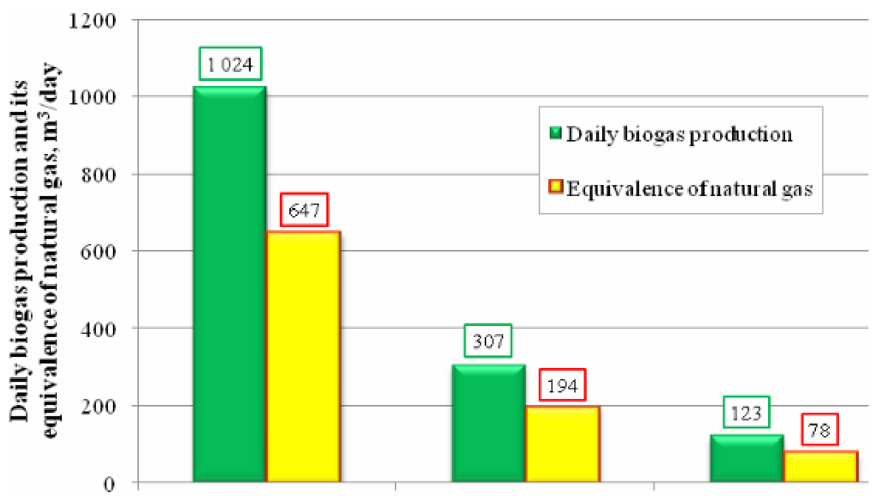


Figure 8: provides data on the annual quantity of biogas that can be derived from pig slurry

It represents the estimated amount of biogas that can be produced from the fermentation of pig slurry as a renewable energy source. The figure showcases the potential biogas production from pig slurry over the course of a year.



Figures 9: provide data on the amount of natural gas that can be saved by utilizing biogas

It shows the estimated quantity of natural gas that can be replaced by the use of biogas for energy generation. The figures highlight the potential savings in terms of natural gas consumption through the utilization of biogas as an alternative energy source.

Figure 10: Pig slurry Anaerobic digestion Biogas plant

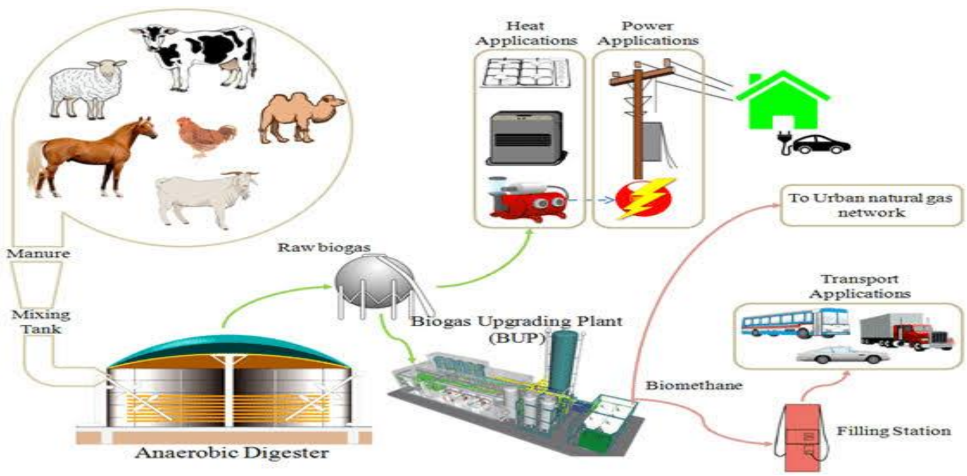


Figure 11: Revolution of Pig slurry Plant

Figure 12: Pig slurry farming

4.0 Summary of Biogas Production and Application

Biogas production is the process of harnessing energy from organic waste through a naturally occurring biological decomposition process called anaerobic digestion. This process involves breaking down biodegradable materials, such as food waste, agricultural residues, and sewage, in an oxygen-free environment, resulting in the production of biogas.

Biogas primarily consists of methane (CH_4) and carbon dioxide (CO_2), with trace amounts of other gases like hydrogen sulfide. It can be used as a versatile source of renewable energy in various applications. Here are a few common ones:

i. **Electricity generation: Bi**ogas can be used in gas generators to produce electricity. This is particularly useful in rural areas or off-grid locations where access to conventional power sources may be limited.

ii. **Heat generation:** Biogas can be used as fuel in boilers, furnaces, and other heating systems. It can provide heat for cooking, heating water, or space heating in residential, commercial, and industrial settings.

iii. **Co-generation**: Co-generation, also known as combined heat and power (CHP), involves using biogas to simultaneously generate both electricity and heat. This maximizes energy efficiency and is commonly employed in larger-scale biogas plants.

iv. **Vehicle fuel: B**iogas can be upgraded and compressed to produce biomethane, which is a renewable alternative to compressed natural gas (CNG). Biomethane can be used as a transportation fuel, powering vehicles such as buses, trucks, and even cars.

v. **Biofuel production:** Biogas can also be further processed to produce biofuels like bioethanol or bio-diesel, which can be used as substitutes for fossil fuels in the transportation sector.

Additionally, the residue left after biogas production, called digestate, serves as a nutrient-rich fertilizer that can be used in agriculture, thereby closing the loop and promoting a circular economy.

Biogas production and applications offer numerous environmental and economic benefits, including reduced greenhouse gas emissions, waste management, and energy independence. It's an exciting field with great potential for sustainable energy solutions

4.1 Pig Slurry Digestion Biogas Plant

In a pig slurry anaerobic digestion biogas plant, the main feedstock or input material is the pig slurry, which is a mixture of pig manure and water. The process converts this organic waste material into biogas through anaerobic digestion.

Here's a step-by-step breakdown of the process:

i. **Collection and pre-treatment**: The pig slurry is collected from the pig farm and stored in a dedicated storage tank. Before the slurry is fed into the anaerobic digestion system, it may go through pre-treatment processes like solid-liquid separation to remove any large solids or impurities.

ii. **Anaerobic digestion:** The pre-treated pig slurry is then fed into an anaerobic digester, which is a sealed, oxygen-free tank. The slurry is mixed with a consortium of microorganisms, typically called methanogens, that thrive in the absence of oxygen. These microorganisms break down the organic matter in the slurry through a series of biochemical reactions and produce biogas as a byproduct.

iii. **Biogas production:** As the microorganisms digest the pig slurry, they produce a mixture of gases, primarily methane (CH_4) and carbon dioxide (CO_2), along with small amounts of other gases. This mixture is known as biogas. It is collected and stored in a separate gas storage tank.

iv. **Gas upgrading and utilization:** The collected biogas undergoes a process called gas upgrading, where impurities such as CO_2, hydrogen sulfide, and moisture are removed to increase the methane content. The upgraded biogas, known as biomethane, can then be used as a fuel for various purposes.

v. **Energy generation:** Biomethane can be utilized in different ways to generate energy. It can be burned in a gas engine or gas turbine to produce electricity. The waste heat generated during this process can be captured and utilized for heating purposes or other industrial processes. Alternatively, biomethane can be directly used as a fuel for heating or cooking.

vi. **Digestate utilization:** After the anaerobic digestion process, the remaining material called digestate is rich in nutrients and can be used as a high-quality fertilizer. It can be applied to farmland to improve soil health and nutrient content, closing the loop and providing a sustainable solution for agricultural practices.

Overall, a pig slurry anaerobic digestion biogas plant enables the conversion of pig waste into valuable biogas while also addressing waste management concerns and promoting sustainable energy production.

5.0 Conclusion

The utilization of pig slurry for biogas generation presents a significant opportunity to fuel a sustainable future while addressing multiple United Nations Sustainable Development Goals (SDGs). By surmounting challenges and expanding the frontiers of biogas production from pig slurry, we can contribute to several SDGs, including SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), SDG11 (Sustainable Cities and Communities), and SDG 13 (Climate Action).

Through the use of additional fermenters and optimization of the fermentation process, such as employing thermophilic fermentation, the methane content produced can be significantly enhanced to around 60%. This increase allows for more efficient and productive biogas generation. Furthermore, by utilizing gas engine co-generation technology, the biogas can be converted into electricity, creating a valuable source of clean and renewable energy.

The production of electricity through co-generation not only contributes to SDG 7 by providing affordable and clean energy but also supports SDG 9 by promoting innovative technologies and infrastructure development. Additionally, the expansion of biogas generation from pig slurry aligns with SDG 11, as it offers sustainable solutions for waste management and reduces the environmental impact of animal husbandry, fostering sustainable cities and communities.

Furthermore, biogas generation from pig slurry plays a vital role in SDG 13 by mitigating greenhouse gas emissions. The utilization of pig slurry as a feedstock for biogas production helps to reduce methane emissions that would otherwise contribute to climate change. This supports global efforts to combat climate change and achieve the targets outlined in the Paris Agreement.

Based on laboratory measurements and energy assessments, it is evident that biogas generation from pig slurry is a viable and sustainable solution. By embracing advanced fermentation techniques, optimizing methane content, and utilizing gas engine co-generation, we can harness the potential of pig slurry to generate renewable energy and contribute to a more sustainable future. By aligning with the UN SDGs, we can address environmental challenges, promote energy access and innovation, and combat climate change, ultimately building a more sustainable and resilient world for generations to come.

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generation, we are reminded of your invaluable contributions, propelling sustainable development and creating a brighter future for generations to come. Your unwavering pursuit of knowledge and commitment to scientific exploration define the epitome of excellence, inspiring us all to reach new heights. Thank you for revolutionizing research and shaping the landscape of scientific discovery."

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