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The Use of Food Waste and Cow Dung in Producing Biogas

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Abstract: Anaerobic digestion is an environmentally beneficial approach to handling and disposing of biodegradable waste and has several advantages over other waste treatment methods. It maximizes energy recovery from organic waste while enabling reduced waste disposal. Currently, there is an increase in the amount of waste, especially in urban areas, which has posed a challenge to the health and comfort of the environment. Therefore, this study aims to evaluate the flame properties of biogas produced by digesting organic waste using various starting materials, decomposition organic waste in anaerobic digestion process including cow dung and food waste from Restaurant Sungai Lang, Sabak Bernam District, Selangor. The objectives of this study are to produce biogas from a combination of food waste and cow dung and to measure the quantity of biogas produced. Organic waste has been tested under room temperature conditions of 28°C. The height of the flame will be measured and tested based on the color that appears from the gas. The results obtained indicated a linear relationship between gas production volume over time such as 46 ml in Week 3 to 95 ml in week 6. Combining cow dung and kitchen waste can produce more biogas than food waste alone. The study also found that burning with a flame produced better results and further verification is needed to come out with the conclusive finding.

Keywords: *Cow dung (CD), Kitchen waste (KW), Anaerobic digestion (AD), sustainable, flame*

1.0 Introduction

Increasing environmental pollution has been associated with waste generation, especially food waste being a significant concern. Food waste including kitchen waste can produce biogas energy sources. Biogas, a clean and renewable source of energy made from organic waste, is particularly suitable for rural areas. This is because Malaysia's hot climate makes it suitable for biogas production, which thrives in hot conditions. In fact, it can also be obtained from materials such as agricultural waste, sewage and food waste also biggest problem currently is the amount of waste that accumulates and is not controlled anywhere, especially organic waste (Ramadan et.al, 2023). Organic waste should convert biogas consist of methane, carbon dioxide and hydrogen sulphide can be a sustainable energy solution and can be used as vehicle fuel or for electricity generation. The implementation of this study was carried out Sungai Lang Restaurant in Sabak Bernam and successfully reduced waste by converting food waste to biogas in dealing with landfill overflow issues.

In this research, a problem statement outlines an issue that needs a solution or a situation that needs improvement. This initiative is implemented to reduce the demand for the use of landfill space because there is data that shows an increasing trend in the use of landfills. This situation depends on the increase in kitchen waste driven by the growing population. Typically, it shows an increase of about 15% to 20% during the festive season, especially in urban areas (Kai et. al, 2020) in Malaysia. Therefore, it should be seen from a perspective that makes waste as a source of energy generation, as stated by (Ahmad et. al,2021). In fact, this situation is expected to worsen during certain festive events such as Deepavali, Hari Wesak and Hari Raya open houses. This can be seen, according to a 2019 report by the Solid Waste and Public Cleaning Corporation (SWCorp), kitchen waste, particularly food waste, is the largest waste category, accounting for 44.5% of total domestic waste in 2018. Projections suggest this could increase eightfold by year 2030. This situation has been identified with households as one of the largest sources of food waste producers. Through the statement of the problem in this research is because more and more waste is thrown into landfills and cow excrement on the road creates a continuous and unpleasant issue that will make the increase in food waste contribute to climate change.

Due to population growth and industrial development, global energy consumption has risen significantly in recent decades. It has been identified that fossil fuels remain the main source of energy. However, it is non-renewable, highly polluting, and its production is expected to decline in the coming decades. To address the increasing demand for renewable energy, it is important to develop a new sustainable energy supply system. According to Wang et al. (2019) and Yik (2020), it has been stated that kitchen waste can be converted into renewable energy, especially biogas, which is economical and can generate electricity and heat. According to Rashid et.al, (2020) found that biogas production from cooked food waste is 40 times higher than from uncooked food waste. In fact, this energy source is economically beneficial and has been supported by the Malaysian Sustainable Energy Development Authority (SEDA).

There is research by Yik Fu Lim (2020) highlighting that food waste fermentation can produce high levels of methane (CH_4), with biogas production reaching up to 0.50 L/g volatile solids (VS). In conclusion, effective food waste management is essential to reduce pollution and increase renewable energy generation, thus supporting sustainable energy development in Malaysia. Increased production of renewable energy plays an important role in reducing greenhouse gas emissions. In addressing this issue there are objectives in this study as follows:

i. To produce biogas from organic matter, specifically a combination of food waste and cow dung.
ii. To measure the quantity of biogas produced by the materials used.

This project was carried out at a restaurant in Sungai Lang, Sabak Bernam to assess whether composting organic waste, such as food waste and cow dung, can produce methane gas. This study uses a combination of two main materials, which are kitchen waste collected from Restaurant Sungai Lang, Sabak Bernam, and cow dung from the surrounding area. Three different mixtures were prepared in this study namely, pure cow dung mixture, cow dung and food waste mixture, and pure kitchen waste mixture, all in the same ratio. A 19-liter plastic container of the same size is used to fill each mixture.

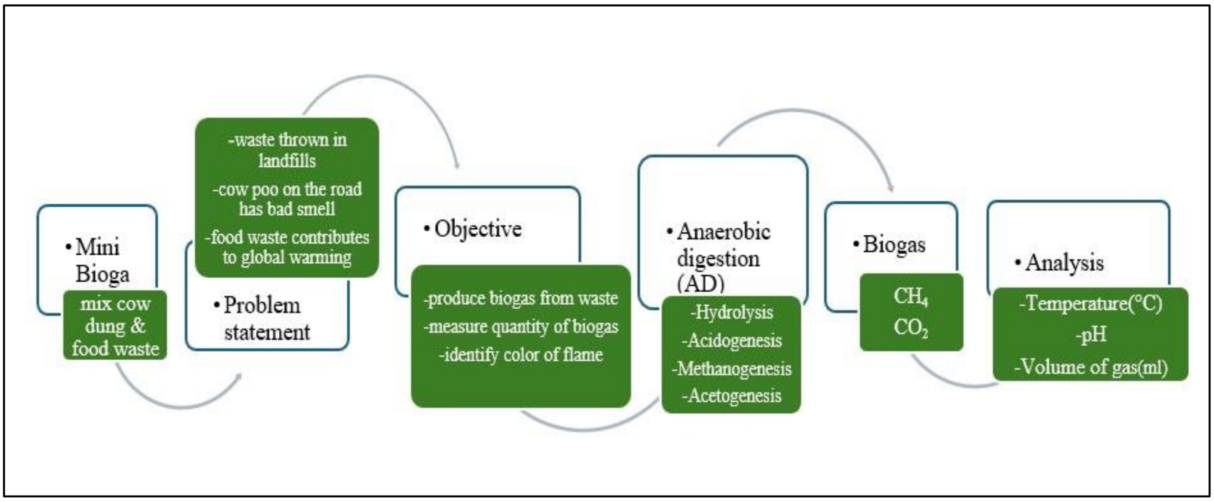
2.0 Literature Review

Anaerobic digestion (AD) is a biological process that breaks down organic materials without oxygen, using microorganisms to manage waste and produce fuel for industrial and domestic use. This process generates biogas, a combustible mixture primarily composed of methane (5065%) and carbon dioxide (25-45%) from organic waste, such as cow manure. Recently, AD has gained attention from researchers and industries for its efficient conversion of municipal and industrial waste into biogas, offering a sustainable fuel source. Anaerobic digestion (AD) has garnered significant interest from the scientific and industrial communities in recent years because of its ability to effectively reduce and convert organic waste from municipal and industrial effluents into a gas mixture primarily made up of carbon dioxide and methane (Wu et, al., 2019; Zhao et al., 2018; Pezhman Kazemi et al.,2021).

The high organic content of waste leads to several environmental challenges. During the decomposition of organic compounds, methane gas is produced, which has a global warming potential 23 times greater than CO_2 in the long term. However, when managed effectively, methane can serve as a valuable renewable energy source, potentially replacing fossil fuels and reducing greenhouse gas emissions. Environmental issues, such as greenhouse gas (GHG) emissions, primarily CO_2 from the extensive combustion of fossil fuels, have made climate change more noticeable (Abdul Sattar Nizami et.al,2018). Composting offers an alternative to landfilling by recovering methane from organic waste. Through composting, microorganisms break down waste with high organic content, transforming it into useful products like compost, an affordable fertilizer and biogas, which can be used to generate electricity or produce biofuel.

Apart from that, there is also composting included through this food waste. There are several factors that affect the composting process, namely nutrients, temperature and pH. The presence of nutrients is important for composting, as most nutrients are found in organic waste. The optimal carbon-to-nitrogen (C/N) ratio for composting is between 25 and 35 (Bo Shen & Lili Zheng et.al,2024). Achieving this ratio is best facilitated by combining kitchen waste with garden waste. As for the temperature, during composting, the temperature of waste material increases due to the release of energy from the degradation reaction of organic matter. The degree of temperature increase depends on the amount of substrate, residual insulation, and ventilation. While the pH of organic waste may change at different stages, from the accumulation of food waste to the maturity of the final compost, among which it is acidic (>5) at the beginning with anaerobic breakdown which can cause the pH to decrease when collected in a container. Next is basic with a pH value (7–9) that is during composting, the pH usually increases, often because of the production of bases and volatilization of organic acids. In the Neutral state, as the compost ages, the pH level becomes stable.

3.0 Methodology



Figures 1. Flowchart of mini biogas mix cow dung and kitchen waste

Figure 1 shows this flow chart describing the mini biogas production process using cow dung and food waste, highlighting the importance of each step in optimizing biogas yield and ensuring effective waste management. In this study the biogas production process requires careful control of factors such as temperature and pH. The temperature was maintained in the mesophilic range (30–40°C), and the pH was adjusted to a range of 6.8 to 7.2. Biogas production was observed over a period of four weeks. Acidogenesis, acetogenesis, methanogenesis, and hydrolysis are the four steps of AD, a multistep, multiphysics, biokinetic degradation process (Rohit Gupta et.al, 2023). At the end of the project, the presence of methane was tested by igniting the end of a rubber pipe connected to a ball valve; the presence of a flame will indicate successful methane production in the vessel.

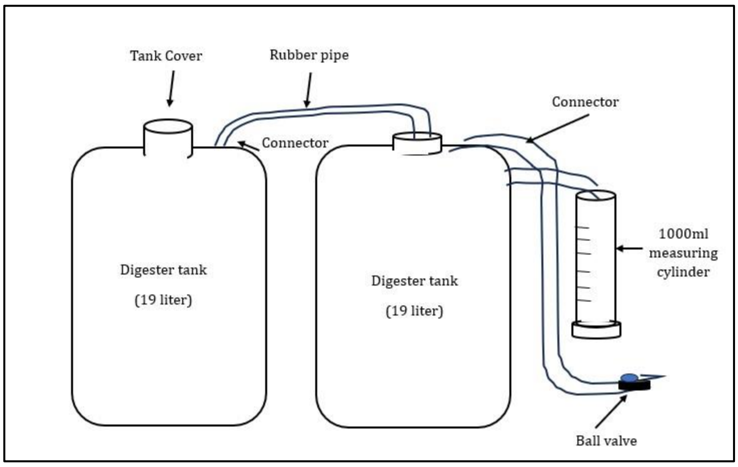


Figure 3: The schematic diagram of the product

Figure 3 shows of reactor design for single stage AD (acidogenesis and methanogenesis operate in the same reactor). Its diagram that provides an overview of the entire product. This diagram illustrates the input process for the 19-liter plastic bottle, which serves as a digester tank, where a mixture of cow dung, water, and kitchen waste is added. Once the organic waste materials are inserted, the plastic bottle is sealed tightly to prevent outside air from entering during the anaerobic digestion process. The natural biochemical process known as anaerobic digestion (AD) turns organic waste into biogas that can be burned. Although apart from organic waste AD has been used for a long time to manage urban and agricultural waste, it is now gaining attention as an alternative energy source, (Md Mosleh Uddin et. al, 2022).

The aim of the process is to produce a product that generates the desired biogas (methane).

The steps involved are as follows:

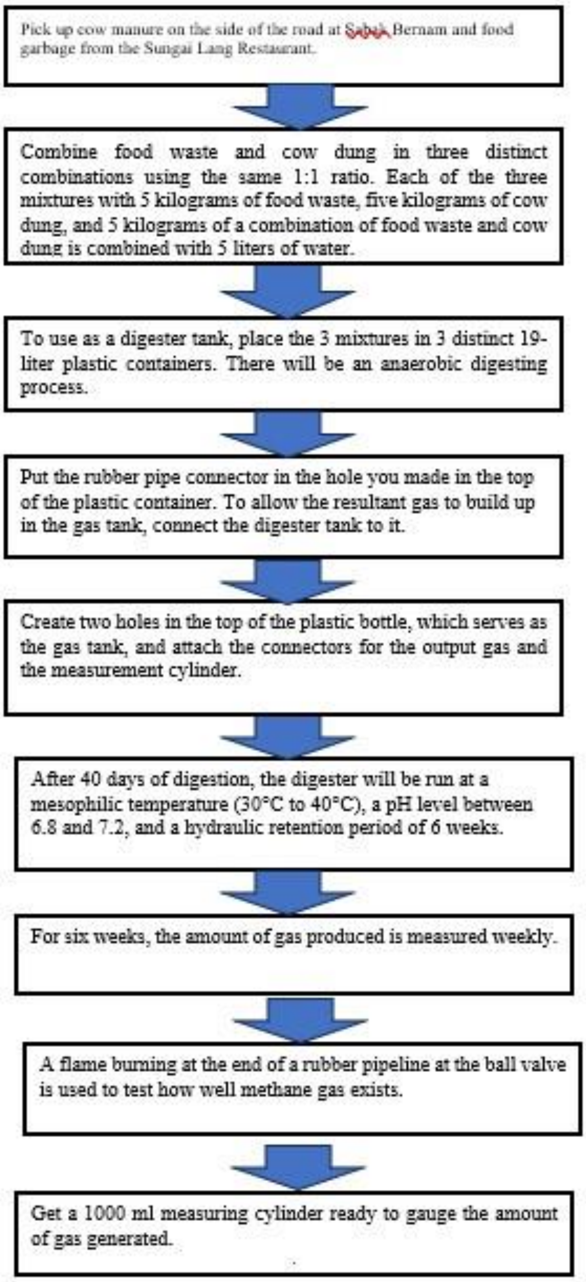


Figure 4: Flow chart of the biogas production process from food waste and cow dung

Figure 4 illustrates the flow chart of the biogas production process from food waste and cow dung in detail for each step of the transformation of organic matter into biogas. It highlights the efficiency of anaerobic digestion as a method for waste management and renewable energy generation. To act as a gas tank where the generated methane gas will collect, a second 19-liter barrel will be filled with water. The gas produced during the anaerobic digestion process is allowed to collect in the digester tank by means of a hole that is punctured to connect a rubber hose to the gas tank. A rubber tube with a ball valve at the end is connected to a connector on the top of the plastic container. This is the gas output for the methane gas's flame testing.

Furthermore, the water-filled plastic container is pierced, and the gas is directed to a 1000 ml measurement cylinder via a rubber tubing.

Finding the amount of methane gas generated in the gas tank that will displace the same amount of water flowing into the measurement cylinder is the goal. Every week, the amount of water entering the measuring cylinder will be noted. Six weeks are allotted for the manufacture of biogas. By lighting the end of the rubber tubing that is attached to the ball valve at the conclusion of the project, the efficacy of the system will be evaluated with a flame appears, it will signify that methane gas is being produced in the plastic bottle.

4.0 Data Analysis and Findings

Table 1 : shows the data of biogas produced in 6 weeks for Mini Biogas from food waste and cow dung

Week	pH	**Temperature °C**	**Volume of Gas (ml)**
Week 1	6.03	28 °C	0 ml
Week 2	6.33	29 °C	29 ml
Week 3	5.80	30 °C	46 ml
Week 4	5.52	30 °C	73 ml
Week 5	5.00	31 °C	86 ml
Week 6	4.90	32 °C	95 ml

The volume of biogas produced over time under various slurry conditions is presented in Table 1. Initially, gas production declined, but as acid concentration increased (indicated by a drop in pH), gas production subsequently rose. This pattern was especially evident in the cow dung and food waste slurry mixture up to day 14. A kitchen waste that produces about 60% methane gas, 30% carbon dioxide, 8% nitrogen, and the remaining 1% to 2% hydrogen sulfide (Anthati Sreenivasulu et.al., 2022). Anaerobic digestion (AD), which converts organic waste into energy or chemical raw materials, is a treatment method with waste treatment and resource recovery benefits (Fang et al., 2020).

During the operational process, the following parameters are considered: pH, temperature, organic loading rate (OLR), and hydraulic retention time (HRT), (Yen-Keong Cheah et.al, 2019). Anaerobic digestion (AD) technology has been receiving encouragement for many years because, in addition to treating organic waste, it can generate biogas, which is a competitive alternative to fossil fuels, (S. Azadeh et.al., 2020). However, this issue is addressed to increase AD biogas production which is a valuable resource for future studies and the advancement of biogas technology globally.

In the first week of the anaerobic digestion process, the system exhibited a pH level of 6.03 close to neutral indicating an environment beginning to support microbial activity but not yet within the optimal range for biogas production. The temperature was consistently maintained at 28 °C, suitable for the growth of mesophilic microorganisms typically involved in anaerobic digestion. Despite these favorable conditions, no gas production was observed, resulting in a recorded gas volume of 0 ml. This initial lack of gas output is common during the early stages of anaerobic digestion, as the microbial community requires time to acclimate and fully activate. During this period, various bacterial groups gradually adjust and start breaking down the organic material, ultimately initiating methane production.

In the second week of the anaerobic digestion process, the pH level rose slightly to 6.33, indicating a gradual shift toward a more favorable environment for microbial growth and activity. This increase suggests that acid-producing bacteria were becoming more active, releasing byproducts that helped steer the conditions toward those preferred by methanogens, the microbes primarily responsible for biogas production. Additionally, the temperature increased by 1 °C to 29 °C, further supporting the mesophilic microbes that thrive at this range. This week saw the production of 29 ml of gas, marking the initial onset of biogas generation. This gas production indicates that the microbial community was adapting to the anaerobic environment, with different bacterial groups beginning to break down complex organic materials into simpler compounds, ultimately leading to the production of methane and carbon dioxide. This initial gas output reflects the early stages of anaerobic digestion, where organic material decomposition has begun but has not yet reached peak efficiency.

In the third week of anaerobic digestion, the pH decreased to 5.80, likely due to increased production of organic acids by acidogenic bacteria breaking down the organic material. This pH drop is typical in early digestion stages, as acids accumulate before methanogens fully adapt. The temperature rose to an optimal 30 °C, which supported enhanced microbial activity. Gas production increased to 46 ml, reflecting the microbial community's ongoing adaptation and its improved efficiency in converting organic waste into biogas, signaling progress in the digestion process.

In the fourth week of anaerobic digestion, the pH further decreased to 5.52, a result of continued acid production by acidogenic bacteria. The temperature remained steady at an optimal 30 °C, supporting microbial activity. Gas production rose significantly to 73 ml, indicating that the microbial community had fully adapted to the anaerobic conditions and was efficiently converting organic material into biogas. This higher gas yield reflects a more advanced, productive phase in the digestion process, with both acidogenic and methanogenic bacteria functioning effectively together.

In the fifth week of anaerobic digestion, the pH further decreased to 5.00 due to continued acid production by acidogenic bacteria. The temperature remained steady at an optimal 30 °C, supporting microbial activity. Gas production increased significantly to 88 ml, demonstrating that the microbial community was fully adapted to the anaerobic conditions and efficiently converting organic material into biogas. This high gas yield signifies an advanced and productive phase in the digestion process, with both acidogenic and methanogenic bacteria working effectively in tandem.

In the sixth week of anaerobic digestion, the pH decreased further to 4.90 due to continued acid production by acidogenic bacteria. The temperature remained stable at an optimal 30 °C, sustaining microbial activity. Gas production rose significantly to 95 ml, indicating that the microbial community was fully adapted to the anaerobic conditions and efficiently converting organic material into biogas. This high gas yield reflects a more advanced, productive phase in the digestion process, with acidogenic and methanogenic bacteria working effectively together.

The data shows a positive trend in biogas production over the six weeks, with gas volumes increasing alongside stable temperatures and gradual pH changes. The steady decrease in pH over time reflects active microbial fermentation, a critical factor for optimizing biogas production. This experiment effectively illustrates the dynamics of anaerobic digestion, underscoring the importance of monitoring these parameters to ensure successful biogas generation.

By looking at the flame that forms when a flame is introduced into the gas outlet pipe, one can determine whether methane gas is present. In this instance, a red flame with a methane concentration of 7.3% and a total gas volume of 73 ml is produced. These experiments demonstrate that the efficiency of biogas produced from different feedstocks may be evaluated by comparison. 73 milliliters of gas are produced even from the nutrients in food waste and cow dung. According M. R. Atelge , (2020) the anaerobic digestion (AD) process effectively degrades organic waste, reducing pathogens and odors. The resulting digestate serves as a valuable fertilizer. However, the current availability of organic materials for biogas production is limited. To expand this industry globally, there is a need for new substrates and improved conversion technologies.

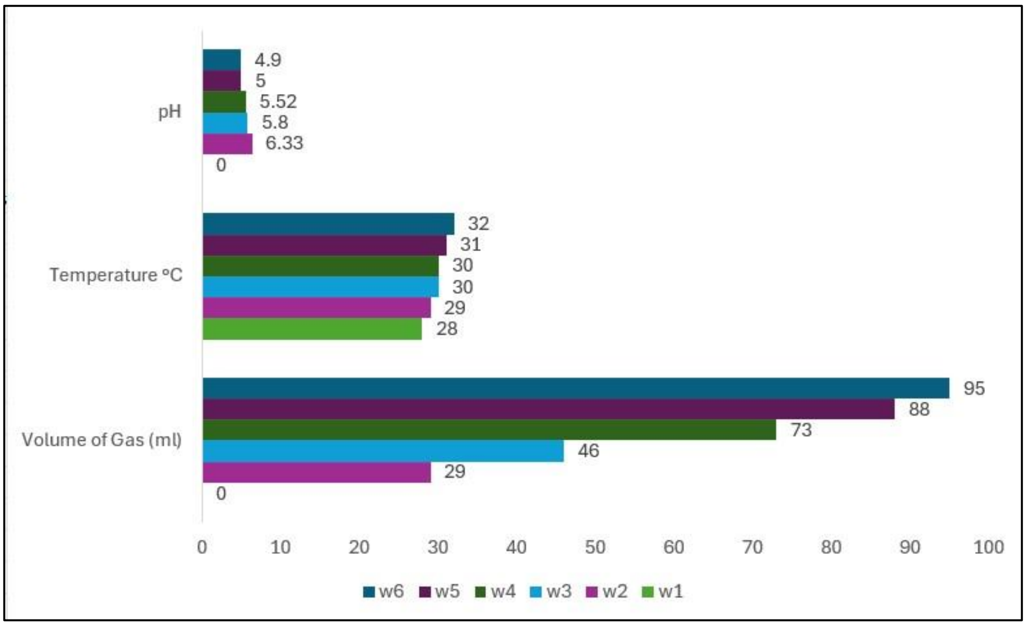


Figure 3: shows the row chart of cow dung, food waste and mix cow dung & food waste

The data in figure 3 presented provides a comprehensive view of biogas production over six weeks, illustrating how changes in pH, temperature, and gas volume evolve throughout the anaerobic digestion process of organic waste.

Initially, pH levels typically decrease as acidogenic bacteria break down organic matter, releasing fatty acids and lowering the slurry's pH. pH is a crucial factor that affects the process's effectiveness by determining and regulating its stability (Xu et.al., 2021). Furthermore, because different bacterial communities require distinct pH ranges (Pramanik, 2019), microorganisms are highly sensitive to pH. This acidification phase is crucial as it prepares the environment for subsequent microbial communities. As the process progresses, methanogenic bacteria become active, consuming these acids and raising the pH gradually towards neutrality. This microbial succession is fundamental to enhancing biogas production efficiency.

Temperature is another key factor influencing biogas production. The stability and optimal range of temperature (usually mesophilic, around 35-37°C, or thermophilic, around 50-55°C) support microbial activity, with stable temperatures fostering consistent gas production.

Any fluctuations can disrupt bacterial processes, potentially reducing the yield and quality of biogas. Temperature is one of the most important factors affecting how well any AD process performs (Nie, E et.al, 2021). Temperature has an impact on methanogenic and volatile acid-forming bacteria, and the enzyme activity that these bacteria release varies with temperature, (Czatzkowska, M et. al, 2020).

Gas volume is monitored as a direct indicator of biogas output. In the initial days, gas production may be minimal as the microbial community adapts to the conditions. However, as pH stabilizes and temperature remains steady, gas volume increases, marking the peak biogas production phase. This increase in volume reflects the transition to more efficient methane production, driven by methanogenic activity. Overall, the data underscores the interconnectedness of pH, temperature, and gas volume in optimizing biogas yield during the anaerobic digestion of organic waste, highlighting key stages and environmental conditions that promote microbial efficiency and enhance gas production.

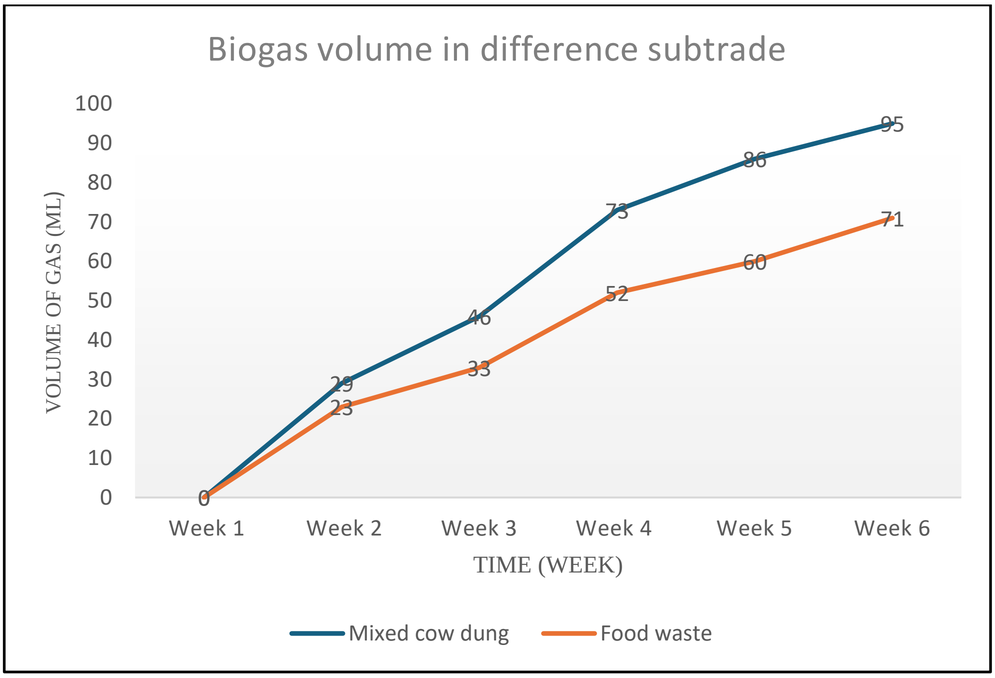


Figure 4: shows the line chart of a comparison of the three mini biogas samples' gas of volumes

The data shows a time series of measurements taken weekly, with observations on gas volume over six weeks. The volume of gas produced during a six week period is recorded in this dataset, which demonstrates a weekly increase in gas volume. A thorough examination of the patterns and potential meanings is provided. Volume at initial zero, is no detectable gas volume (0 ml) in week 1. Its mean that microbial activity or any process that produces gas has not yet begun, or that it is still very early and producing very little gas.

Gas volume increased in weeks (2–6). The gas amount increases to 29 ml in Week 2 and then every week after that, reaching 95 ml in Week 6. This consistent rise suggests an ongoing gas-producing process that is probably becoming better with time. Particularly from Week 3 (46 ml), week 4 (73 ml), week 5 (86 ml) and week 6 (95 ml) there are the biggest increases in gas production between consecutive weeks, indicating an accelerated reaction rate. This pattern is compatible with microbial activity or fermentation, where gas generation increases as reactions progress or bacteria populations increase.

5.0 Discussion and Conclusions

This study states the use of anaerobic digestion technology to produce biogas from food waste and cow dung. The results show that the produced anaerobic digester can serve as a viable waste-to-energy alternative to comparable commercial products from other countries. In addition, the use of high-calorie raw materials with a significant carbohydrate content, such as a mixture of cow dung and kitchen waste, can produce more biogas than food waste alone. The findings also show that biogas production is significantly affected by acid content, especially in raw materials with high protein concentrations. The goal of developing a 19-liter plastic container capable of generating biogas from three different mixtures of cow dung, food waste, and a combination of the two has been successfully achieved. This steady increase shows that the method of producing gas is getting better over time. Biogas volume increased continuously from Week 3 (46 ml) to Week 6 (95 ml). As a result, it was found that burning with a flame produced more effective and superior results.

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