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B.Sc. in Mechanical Engineering Thesis

Biogas From Cafeteria Waste

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May, 2023

Candidate's Declaration

This is to certify that the work presented in this thesis, titled, "Biogas From Cafeteria Waste" is the outcome of the investigation and research carried out by me under the supervision of Dr. Md Hamidur Rahman, Professor, Department of Mechanical & Production Engineering, Islamic University of Technology.

It is also declared that neither this thesis nor any part of it has been submitted elsewhere for the award of any degree or diploma.

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RECOMMENDATION OF THE BOARD OF SUPERVISORS

The thesis titled “Biogas From Cafeteria Waste” submitted by Shoaib Hasan Student No: 180011115; Afsana Akter, Student No: 180011247; Minhazul Alam, Student No: 180011129; has been accepted as satisfactory in partial fulfillment of the requirements for the degree of BSc. in Mechanical Engineering on 19th May, 2023.

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ABSTRACT

World is currently moving on non renewable energy which is fossil fuel.Study shows Fossil fuels will be gone in a few years (Oil: 51 years,Coal: 114 years,Natural gas: 53 years)[1] Climate change,Ozone layer decay,and the current situation of the world due to the Ukraine Russia war once again remind us that Renewable energy is a Future And Biogas is a Renewable Energy.Energy crises, solid waste management, and climate change are three of the world's most pressing issues right now. [2] Fossil fuels, which are rapidly running out, could be effectively replaced by biogas, a renewable, effective, and carbon-neutral kind of energy. Here, we describe how to produce biogas from anaerobic digesters under mesophilic conditions to calculate the best biogas production from different mixing ratios and methane yields.[3]

NOMENCLATURE

AD- Anaerobic Digestion
HRT- Hydraulic retention time
VP- Vegetable peels
CM- Cow manure
IUT - Islamic University of Technology

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CHAPTER 1.1 : INTRODUCTION

The greatest way to meet the world's energy needs is to develop renewable and sustainable energy sources . The ecology should not be harmed by the development of renewable energy, which is highly desirable. Renewable energy production from locally and easily accessible materials is undoubtedly very advantageous and lowers the cost of its production. Moreover, if we use waste for energy production , we can manage the waste which is beneficial for our environment, also it is going to solve lots of hassles regarding waste management.Currently, biogas-generating technology is a good example of a dual-purpose technology because the biogas it produces may be used to meet energy needs while the organic waste is a valuable resource.Fertile soil is helpful. Biogas is a form of renewable energy that can be created from the breakdown of animal and plant wastes. It is made up of methane, carbon dioxide, and trace amounts of nitrogen and hydrogen sulfide [4].

When biologically degradable organic matter is digested anaerobically, the quantity and type of the material introduced to the system determines how much methane is produced. Anaerobic digestion can therefore be used in a variety of ways to produce energy from leftover food, fruit and vegetable waste, and cow manure. One-phase digestion, two-phase digestion, and dry are the most popular ideas nowadays[5]

Under oxygen-poor or oxygen-free circumstances, anaerobic digestion (AD), a waste-to-energy technique, uses microbes to produce biogas. It is a colorless, flammable gas that is created from a variety of sources, including animal manure, plant material, human waste, energy crops, industrial waste, and municipal waste, among others, to produce primarily methane (50–70%), carbon dioxide (20–40%), and traces of other gases like nitrogen, hydrogen, ammonia, hydrogen sulfide, water vapour, etc. [6]. Compared to other solid fuels, it is cleaner, smokeless, and easier to use [7]. For a specific amount of time, the digesters are incubated under mesophilic (25–35°C) or thermophilic (45–60°C) conditions. The management of solid waste has become an environmental concern because of the ongoing rise in trash generation and the significant negative effects of incorrect disposal on the environment and civic duty. In Dhaka, homes, streets, markets, businesses, clinics, and hospitals are the primary sources of municipal solid garbage.[8]

The demand for energy is anticipated to rise by 50% by 2025. In order to create sustainable, economical, environmentally friendly energy, research into developing renewable energy sources is ongoing [9,10].Biofuels are environmentally friendly and renewable, which considerably reduces the demand of fossil fuels [11].

As a result of its biodegradability and high nutrient content, food waste is an excellent substrate for anaerobic digestion. The biological methane potential of typical food waste is calculated to be 0.44–0.48 m2 CH_4 /kg of the additional volatile solid, with a typical food waste containing 7–31 wt.% of total solid [12,13,14].

Biomass energy is environmentally friendly and requires less production energy, and solutions to waste problems such as food waste and manure include gasification, pyrolysis and plasma technologies. Anaerobic Digestion (AD) of organic matter is a better option than traditional technologies, as it transforms biodegradable substrates into biogas and stabilizes solid residues.Co-digestion has been found to improve the digestion process. The AD process can be divided into 4 phases: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Hydrolysis is the first stage of the organic waste decomposition process, breaking down large organic polymer chains into smaller molecules such as simple sugars, amino acids and fatty acids.Acidogenesis produces ammonia, hydrogen, carbon dioxide, hydrogen sulphide, volatile fatty acids, organic acid, and low alcohols. Acetogenesis produces acetic acid, carbon and energy sources, while methanogenesis produces methane gas. All three processes involve close cooperation between oxidative organisms and methane producing organisms. Methanogenesis is the final stage of AD, where methanogens produce methane from hydrogen, carbon dioxide and acetate as well as intermediate products from hydrolysis and acidogenesis. Methanogens are archaea and are sensitive to pH changes and heavy metals and organic pollutants.[15]

An estimation of the generation of CH_4 under typical climatic circumstances in Denmark using a model that measures the production from co-digested municipal organic waste that has been stored. A model calculating the CH_4 production in storage tanks containing digested municipal organic waste was developed using data from laboratory batch tests and temperature observations in eight full-scale storage tanks. On farms receiving digested slurry, temperatures recorded in separate storage tanks had a linear relationship with air temperature. Danish farms normally empty their storage tanks on a regular basis, which limits the amount of CH_4 that is produced from storage each year. This study looked into the possibility of methane emissions from urban organic waste that has been anaerobically digested. Methane has a potential for 23 times as much global warming as CO_2.[16]

It is explained how to measure the methane potential of organic solid waste in a lab. 400 cc of inoculum from a thermophilic biogas plant was added to triplicate reactors containing 10 grams of volatile solids, and they were incubated at 55 C. Over the course of 50 days, methane production was monitored by taking regular samples on a gas chromatograph. Based on the findings, a detection threshold of 72.5 ml CH_4 /g VS was determined. Due to the use of non-standardized inoculum and waste heterogeneity, the estimation of methane potentials is a biological method that is subject to very significant fluctuation. There are suggested methods for dealing with repeatability and reproducibility.[17]

Therefore, the purpose of this study was to examine the capacity of anaerobic digestion for biogas production and the quality of the biogas utilizing leftover rice and vegetable peels, including papaya, bottle gourd, pumpkin, and potato.And using this biogas as a fuel for cooking.

CHAPTER 1.2 : LITERATURE REVIEW

The anaerobic digestion of food waste is a complicated biochemical process. Based on temperature and input substrate,different strains of bacteria digest complex chains of carbohydrates,fats and proteins into their component parts. Anaerobic digestion occurs in four separate phases: hydrolysis, acidogenesis, acetogenesis,and methanogenesis. The last stage of the process, methanogenesis, is where the biogas is produced.

There are several types of anaerobic digestion, but for food waste, studies have shown that mesophilic (35 C) is the most stable

Thermophilic digestion (55 C) allows for faster methane extraction and therefore has a lower substrate retention time and can be considered in situations where size is a restriction but has been shown not to be as stable and more sensitive to input composition when dealing with food waste

In order to configure an AD system in the urban environment, special consideration must be paid to standing gas, fire, and building codes as well as health and safety regulations for handling food waste. [18]

Operational parameters of anaerobic digestion process:

1.Anaerobic environment

Anaerobic digestion (AD) is a biological process that relies on the activity of microorganisms to break down organic matter into biogas. In order to maximize the efficiency of this process, various operational parameters of the digester need to be optimized. Two of the most critical parameters are temperature and pH.

2.Temperature

Temperature plays a crucial role in the activity of microorganisms involved in AD. The optimal temperature for mesophilic microorganisms and anaerobic bacteria is between 30 to 40 degrees Celsius. Mesophilic and thermophilic microorganisms flourish between 30 and 40 degrees Celsius, while anaerobic bacteria thrive above 60 degrees Celsius. However, mesophilic microbial communities are more adaptable to environmental changes and require less energy, making them more practical for AD operations. At lower temperatures, there is less ammonia available, therefore ammonium's effect is less significant than at higher temperatures. In order to produce more biogas, mesophilic bacteria must grow for a longer period of time in the digester. More than half of breakdown is hastened by a thermophilic mode of action, which is especially advantageous for fatty materials. This produces additional biogas. Because CO_2 is less soluble at higher temperatures, the CO_2 concentration in biogas is 2–4 percent higher in thermophilic digesters. However, the added energy and instability make thermophilic mode of action less practicable in developing nations.

3.pH

pH is another critical parameter in AD operations. Typically, AD operations with a significant biogas output are stable when the pH is between 6 and 7. After digestion, acidogenesis occurs at a lower pH (5.5–6.5) than methanogenesis (6.5–8). A continuous buffering capacity of 3,000 mg/L is necessary at all times. In AD systems that are too acidic, lime is typically employed to increase the pH. In contrast, sodium bicarbonate can be used to alter pH. Local businesses may even offer their surplus lime solutions for free. Lime typically costs less than other materials. Common lime side effects include precipitation and pipe clogging. Both sodium bicarbonate and sodium hydroxide are entirely soluble and rarely precipitate, contributing to higher expenses. However, sodium bicarbonate and sodium hydroxide can be more difficult to obtain than lime. For fast alleviation, sodium salts are recommended. Lime can be used as a backup pH adjuster for substrates with a pH of less than 7.

In summary, optimizing operational parameters such as temperature and pH is crucial to maximizing the efficiency of AD operations. The optimal temperature range for mesophilic and anaerobic microorganisms is between 30 to 40 degrees Celsius. The pH of AD operations should be maintained between 6 and 7, with a continuous buffering capacity of 3,000 mg/L. Lime is typically employed to increase pH, while sodium bicarbonate and sodium hydroxide can also be used. The choice of pH adjuster should take into account factors such as cost, availability, and potential side effects.

4.Carbon/Nitrogen (C/N) ratio

The ratio of carbon to nitrogen present in the feed material is called C: N ratio. It is a crucial factor in maintaining a perfect environment for digestion. Carbon is used for energy and nitrogen for building the cell structure. Optimum condition for anaerobic digestion to take place ranges from 20 to 30. This means the bacteria use up carbon about 20 to 30 times faster than they use up nitrogen.When there is too much carbon in the raw wastes, nitrogen will be used up first and carbon left over. This will make the digestion slow down and eventually stop. On the other hand if there is too much nitrogen, the carbon soon becomes exhausted and fermentation stops.The nitrogen leftover will combine with hydrogen to form ammonia. This can kill or inhibit the growth of bacteria, especially the methane producers (Trinayan, 2014). For optimal performance of the microbes, the pH within the digester should be kept in the range of 6.5 - 7.5.

5.Hydraulic retention time

The average time spent by the biomass inside a continuous biogas plant before it comes out from the digester is known as the hydraulic retention time, also abbreviated as HRT. The required retention time for completion of the AD reactions varies with differing technologies, process temperature, and waste composition. The retention time for wastes treated in mesophilic digester range from 10 to 40 days. Lower retention times are required in digesters operated in the thermophilic range (Gizachew, 2011).[19]]

6.Inoculation and start-up

Inoculation and start-up are crucial steps in establishing an efficient anaerobic digestion process. Inoculation involves the introduction of microorganisms into the digester that can break down the organic matter in the feedstock and produce biogas. Cow manure is a common inoculant as it contains a diverse range of bacteria, including acidogenic and methanogenic bacteria, that are essential for the anaerobic digestion process.

The recommended amount of cow manure required for efficient inoculation is typically 10 percent of the total volume of the operating reactor, although using more can be beneficial.

Diluting the cow manure with water in a 1:1 ratio before adding it to the digester can also aid in distributing the bacteria evenly throughout the substrate.

During start-up, the microbial population in the digester needs to acclimate to the feedstock gradually. This can be achieved by increasing the daily feeding load over time and allowing for the development of a balanced microbial population. Sudden changes in feedstock composition or operating conditions can disrupt the microbial community and lead to acidification of the digester. This is because methanogenic bacteria are more sensitive to changes than acidogenic bacteria.

Acidification occurs when the pH of the digester drops, inhibiting methanogen activity and causing the accumulation of volatile fatty acids (VFAs), which further decrease the pH. This can lead to digester failure if not addressed promptly. To avoid acidification, manure can be added to increase the buffer capacity of the digester.

In the initial weeks of start-up, the majority of the gas produced is carbon dioxide, which is non-combustible. As the microbial population becomes established and the methane content of the gas increases, the biogas becomes suitable for use as fuel. High-quality biogas typically contains 55-70 Vol.-% methane.

7.Organic Loading Rate

The Organic Loading Rate (OLR) is a critical parameter in anaerobic digestion systems as it measures the amount of organic substrate delivered into the reactor over a specific time period. This parameter indicates the system's biological conversion capacity and is a key control parameter for continuous systems.

Overloading the system with too much substrate results in a substantial increase in volatile fatty acids, which can lead to acidification and ultimately cause system failure. Therefore, it is crucial to maintain the appropriate OLR for the system to function efficiently and effectively.

In industrialized countries, anaerobic treatment of biowaste typically utilizes continuously stirred reactors with an OLR of 4-8 kg VS/m3 reactor and day. This configuration results in the elimination of 50-70% of volatile solids (VS).

However, in developing nations, unstirred anaerobic digestion systems are more prevalent. These systems require a lower OLR of less than 2 kg VS/m3 reactor and day to function optimally. This lower OLR is deemed appropriate for these systems due to their design and operational constraints.

In summary, the OLR is an essential parameter in anaerobic digestion systems that indicates the system's biological conversion capacity. It is crucial to maintain an appropriate OLR to prevent overloading, which can lead to acidification and system failure. The appropriate OLR varies depending on the type of system used, with continuously stirred reactors requiring higher OLRs than unstirred systems.

8.Mixing

Mixing and churning of fresh material in the digester is an essential aspect of the anaerobic digestion process. It helps to inoculate the digester with the necessary bacteria and prevents temperature variations within the reactor. Furthermore, proper mixing can reduce the production of scum and froth, which are common problems associated with AD plants.

In the digester, filamentous microorganisms can produce scum and froth. These bacteria tend to grow in AD plants with low substrate concentrations. Scum and froth can obstruct gas pipes, leading to difficulties in equipment operation, corrosion, and slurry displacement. Therefore, it is essential to manage these issues to ensure the efficient operation of the AD plant.

In large-scale AD systems, a stable 20-60 cm foam layer on the surface is usually maintained. However, depending on the reactor type and the total solid (TS) concentration of the digester, the equipment and procedures for mixing and stirring can vary. In some AD systems, stirring is not utilized, such as fixed-dome, floating-dome, and tube digesters. Instead, passive mixing is achieved by reducing digestate outflow, which is equal to the daily feeding load, and replenishing it through the intake. This type of recirculation helps flush the input pipe by combining new feedstock with bacterial digestate.

Overall, proper mixing and stirring are crucial for the efficient operation of an AD plant. It helps to prevent issues such as scum and froth formation, temperature variations, and equipment failure. Therefore, it is important to consider the reactor type and TS concentration of the digester when selecting the appropriate mixing and stirring procedures.

9.Inhibition

Anaerobic digestion is a complex process that relies on the activity of a diverse community of microorganisms. For the process to proceed efficiently, it is essential to avoid conditions that inhibit microbial activity. Inhibition can result from a wide range of factors, including high concentrations of certain substances. These substances can be toxic to the microorganisms, causing them to die or become inactive.

One of the most common inhibitors in anaerobic digestion is ammonia, which is often present in livestock manure, wastewater, and other organic waste streams. Ammonia can inhibit microbial activity at a wide range of concentrations, and the level of inhibition depends on several factors, including the pH and temperature of the reactor, the concentration of other substances in the substrate, and the microbial community's adaptability to ammonia.

At normal pH values, most of the total inorganic nitrogen in anaerobic reactors is in the form of ammonium (NH4+). However, as the pH value and temperature increase, the proportion of ammonia (NH3) in the total inorganic nitrogen increases. This undissociated form of ammonia is more toxic to the microorganisms than the protonated form. When ammonia concentrations in the reactor are too high, undissociated ammonia can diffuse through the cell membranes of the microorganisms, altering the intracellular proton and potassium balance. This inhibition can result in an accumulation of intermediate digestion products such as volatile fatty acids (VFA), which can cause the digester to become acidic.

In general, anaerobic microorganisms can adapt to higher ammonium concentrations over time, but this can result in a decrease in methane output. Therefore, it is essential to manage the substrate's ammonia content and prevent excessive accumulation in the reactor. This can be achieved by adjusting the feeding rate, pH, and temperature of the reactor and by maintaining a healthy microbial community that can tolerate the ammonia concentration. Additionally, it is important to avoid the presence of other potentially harmful compounds, such as hydrogen sulfide, organic acids, heavy metals, and disinfectants, that can also inhibit the anaerobic process.

10.Demand for Oxygen in Biochemical Processes

Biochemical Oxygen Demand (BOD) is an essential parameter in measuring the performance of an anaerobic digester. It is an indirect measure of the quantity of biodegradable organic compounds in a sample. The BOD test involves measuring the amount of dissolved oxygen consumed by aerobic bacteria over a 5-day period while breaking down the organic compounds present in the sample.

To perform the BOD test, a sample of the sludge is collected, and a known quantity of oxygen is added to the sample. The sample is then incubated at a controlled temperature for five days. During the incubation period, aerobic bacteria consume the biodegradable organic compounds present in the sample, using oxygen for respiration. The amount of oxygen consumed during this period is measured to calculate the BOD value.

To measure the carbonaceous BOD (cBOD), an antioxidant is added to the sample to prevent the oxidation of nitrogen and ammonia. This method is used to measure the biodegradable organic compounds in sludges with high protein content, such as those from sewage treatment plants.

Another parameter used to assess the biological activity of an aerobic sludge is the oxygen uptake rate (OUR). The OUR measures the rate at which oxygen is consumed by microorganisms in a sample of activated sludge over a specific experimental period. The OUR value is used to estimate the amount of organic material available for microbial activity in the sample.

In summary, BOD is a measure of the biodegradable organic content in a sludge sample, while cBOD is used to measure the organic content in high-protein sludges. Oxygen uptake rate (OUR) is a measure of microbial activity in an aerobic sludge sample over a specific period. These parameters are essential in evaluating the performance of anaerobic digesters and optimizing the efficiency of the biogas production process.

11.Chemical Oxygen Consumption

COD is commonly used to measure the total amount of organic matter present in a sample, including both biodegradable and non-biodegradable components. As such, it is often used as a measure of the pollution load in wastewater and other environmental samples. The COD test is simpler and faster than the BOD test and can be completed within a few hours, whereas BOD testing requires several days. The COD test is particularly useful in situations where rapid results are needed, such as in the operation of wastewater treatment plants.

COD reduction can be used as a measure of the efficiency of anaerobic digestion, as it reflects the amount of organic matter being degraded in the digester. However, it should be noted that not all organic compounds are equally susceptible to anaerobic degradation. Some compounds, such as lignin and cellulose, are more resistant to degradation and will not contribute significantly to COD reduction. Therefore, COD reduction alone cannot provide a complete picture of the efficiency of anaerobic digestion, and other measures such as biogas production and volatile solids reduction should also be considered.

In conclusion, ⑲ COD is a widely used measure of the amount of organic matter present in a sample, and it ⑪ can be used to evaluate the efficiency of anaerobic digestion. However, it should be noted that it is not a perfect indicator of (100) the efficiency of anaerobic digestion, and other measures should also be considered to obtain a comprehensive understanding of the process.

The BOD/COD ratio is a useful tool for evaluating the biodegradability of sludge. As mentioned before, COD measures the total ㉘ amount of organic matter present in the sludge, while BOD measures the amount of oxygen consumed by aerobic bacteria during a five-day period. The ㉖ BOD/COD ratio is calculated by dividing the BOD value by the COD value.

If the BOD/COD ratio is high, it suggests ㉘ that the sludge contains a significant proportion of biodegradable organic matter, which can be easily degraded by microorganisms. This is desirable in anaerobic digestion, as the ② microorganisms present in the digester can efficiently convert the biodegradable organic matter into biogas.

On the other hand, a low BOD/COD ratio indicates that a high proportion ② of the organic matter present in the sludge is non-biodegradable. In this case, the efficiency of anaerobic digestion may be reduced, as the microorganisms will have difficulty breaking down the non-biodegradable components. Therefore, a high BOD/COD ratio is generally preferred in anaerobic digestion.

(72) It is important to note that the BOD/COD ratio can vary (88) depending on the source and composition of the sludge. Therefore, the ratio should be interpreted with caution and used in conjunction with other measures of sludge quality.

12. (78) Total Solids (TS)

Total solids (TS) are an important parameter used to characterize the properties of sludge in anaerobic digestion systems. TS refers ㊸ to the dry matter content present in a sludge, regardless of whether it is organic or inorganic. The determination of TS is usually done by drying a sludge sample at a constant temperature of around 103-105 degrees Celsius until it reaches a constant weight. The difference between the ㊼ weight of the sample before and after drying gives the TS content of the sludge.

TS content is a critical operating parameter for anaerobic digestion systems since it affects the volume of sludge to be processed, the heating requirements, and the quantity and quality of biogas generated. High-TS anaerobic digestion has recently gained popularity due to its potential for smaller digester capacity and lower heating requirements. This is because high-TS anaerobic digestion involves higher solids content, which results in a higher biogas yield per unit volume of sludge.

Moreover, high-TS anaerobic digestion has been found to be more efficient in the conversion of organic matter to biogas than low-TS anaerobic digestion. This is because high-TS anaerobic digestion results in higher residence times of the solids in the digester, allowing for better microbial activity and improved digestion of the organic matter. Additionally, the higher temperature in high-TS digestion results in improved pathogen reduction and higher destruction of weed seeds.

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Finally, high-TS anaerobic digestion has the added benefit of producing digestate with high levels of solids that can be used as a soil amendment. This is because the high-TS digestate has a higher nutrient content, including nitrogen, phosphorus, and potassium, which makes it an ideal fertilizer. Moreover, the solids in the digestate can burn, providing a source of energy that can be used for space heating or electricity generation.

13. Volatile Solids (VS)

Volatile solids (VS) are a measure of the organic matter content of sludge, and are typically expressed as a percentage of the total solids. The VS test involves burning a dried sludge sample at a high temperature of 550°C for a specific duration of time, during which the organic matter is oxidized and converted into gases such as carbon dioxide and water vapor, leaving behind the inorganic matter or ash. The weight loss due to this volatilization process is then calculated as a percentage of the original sample weight, and represents the VS content [20].

VS is considered a more appropriate measure of the organic content of sludge than total solids, as it only includes the portion of solids that can be easily decomposed by microorganisms during anaerobic digestion. VS is therefore a better indicator of the potential biogas yield from the sludge. Additionally, VS is less affected by inorganic matter such as sand, grit, and heavy metals, which may be present in the sludge and can interfere with the digestion process [21].

COD and VS are both useful indicators of the organic matter content of sludge, and can be used to calculate the organic loading rate (OLR), which is a critical parameter in anaerobic digestion. OLR refers to the amount of organic matter added to the digester per unit volume or mass of sludge, and is a measure of the capacity of the digester to process the organic matter and produce biogas [22].

In summary, while total solids provide a measure of the overall solids content of sludge, volatile solids are a more accurate indicator of the organic matter content, which is a critical parameter in anaerobic digestion. Both VS and COD can be used to calculate the organic loading rate, which is an important factor in optimizing the performance of anaerobic digesters.

CHAPTER 2.1 : METHODOLOGY

A combination of fruit and vegetable peels (VP) and leftovers from the IUT students' cafeteria is being utilized alongside cow dung (CM) as substrates for biogas production. To carry out this process, 2-liter cylindrical plastic bottles have been repurposed as anaerobic digesters. Specifically, one of the plastic bottles has been set up to process leftover rice from the cafeteria along with cow manure, while the remaining two bottles are dedicated to papaya peels and potato peels mixed with cow manure and urea.

The plastic bottles serve as miniature anaerobic digesters and offer a regulated environment for the organic components to break down. The complex organic compounds are broken down by bacteria and other microorganisms in the system as the peels, leftovers, and cow dung move through the anaerobic digestion process. As a result of this breakdown, biogas is created, which mostly comprises methane and carbon dioxide.

1. Construction of the Anaerobic Digesters :

The plastic bottle being used in this project has specific dimensions and features that make it suitable for the anaerobic digestion process. With an overall height of 12.4 inches (31.5 cm) and a diameter of 4.33 inches (11 cm), the bottle provides a cylindrical shape that allows for efficient utilization of space.The bottle has a capacity of 67.6 ounces or 2 liters, providing sufficient volume to accommodate the organic substrates, such as fruit and vegetable peels, leftovers, and cow dung, along with the necessary liquid medium. This volume ensures an adequate amount of material for the anaerobic digestion process to take place effectively.To enable the biogas production within the bottle, special two-way valves have been attached to the cap. These valves play a crucial role in the system by allowing the release of biogas while ensuring airtightness to prevent any leakage of biogas into the surrounding environment. The airtight seals on the valves maintain the desired anaerobic conditions inside the bottle, where the microorganisms responsible for anaerobic digestion can thrive.

The integration of these valves not only ensures the controlled release of biogas produced during the anaerobic digestion process but also safeguards against the escape of biogas, which contains valuable methane and other gases. By preventing the leakage of biogas into the ambient air, the system maximizes the capture and utilization of this renewable energy resource.

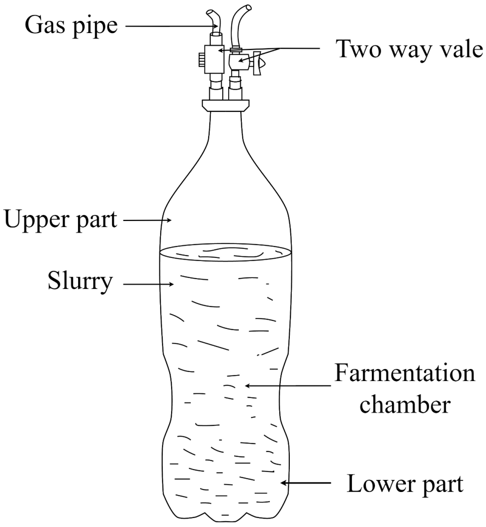

Figure 1 : Schematic Diagram of The Setup.

Here The Plastic Bottle (2 Liter) has an overall **height of 12.4” (31.5 cm) and diameter of 4.33” (11 cm)**. The Bottle (2 Liter) holds a volume of 67.6 oz (2 L). In the cap two way valves have been attached to the bottle. The valves are fully airtight in order to prevent the leakage of biogas to the ambient air.

2. Substrate Collection:

*2.1 Vegetable Peels***:** In order to gather the vegetable peels (VP) used in this study, a collection process was carried out at the cafeteria of IUT. Careful attention was given to ensure that a representative sample of vegetable peels was obtained. The collection involved hand-picking a portion of the cafeteria's waste, with a focus on including peels from all the different fruit varieties commonly used in the cafeteria. This meticulous selection process aimed to incorporate a diverse range of vegetable peels, thus enhancing the nutritional composition and overall effectiveness of the biogas production.

VP were gathered for the current study from the cafeteria of IUT. A portion of the wastes were hand-picked, and great care was made to incorporate all of the fruit varieties used in the cafeteria .

2.2 Leftover Rice:

To obtain the leftover rice required for this study, samples were collected from the students' cafeteria at IUT. As students often have leftover rice after their meals, the cafeteria was an ideal location to source this particular substrate. By utilizing this readily available waste material, the study aimed to not only minimize food waste but also capitalize on a high-carbohydrate substrate that could contribute to the production of biogas

2.3 Cow Manure:

Cow manure for present study was collected from the cattle farm within common localities.

2.4 Urea: To control and regulate the pH level within the system, urea was selected as a pH adjustment solution. Urea is a cost-effective option that is readily accessible from local shops. By incorporating urea, the study aimed to create and maintain optimal pH conditions for the microbial activity involved in the anaerobic digestion process. This strategic addition of urea helps ensure the stability and effectiveness of the biogas production system.

Overall, the collection of substrate materials involved a careful selection process for vegetable peels, gathering leftover rice from the cafeteria, sourcing cow manure from a local cattle farm, and procuring urea as a pH control agent. These different substrates and additives were chosen with the objective of maximizing biogas production efficiency while considering local availability and cost efficiency.

3.1 Substrate Preparation:

Vegetable peels and leftover rice were collected from the IUT cafeteria. Other food items were separated from the rice carefully. The peels separated in the very beginning of the cooking process, so it was unmixed. The amount and variety of VP and leftover rice utilized to produce biogas are presented.

Names of wastage	Weight in percent
Rice	50%
Papaya peels	50%
Potato peels	50%

After the biodegradable organic waste was collected, the wastes were blended by the blender.the wastes were prepared for feedstock.

3.2 Preparation of Mixed Wastes:

Slurry of approximately 1 Kg of the mixed waste (consisting of 85% of VP or Rice, 10% cow manure and 5% urea mixed with cow manure) and in about 1:1 of tap water wasfed into the digester. The VP or leftover Rice portion of the mixed waste fed into the digester consisted of wet weights of waste as indicated in Table.

Figure 2 : Leftover Rice slur in the digester.   Figure 3 : Potato peels and papaya peels slur.

4. Experimental

4.1 Start-up : To initiate the anaerobic digestion process, a slurry was prepared by combining stored cow manure, tap water, and urea in a 1:1 ratio by weight. This slurry mixture served as the starting material for the digestion process. The slurry was carefully prepared and allowed to undergo digestion for a period of 12 days. During this start-up phase, the microorganisms present in the slurry began breaking down the organic matter, initiating the production of biogas.

4.2 Feeding and Operating : Once the slurry was ready, it was transferred into the digester, ensuring proper placement within the container. The digester's valves were then tightly fitted to form an airtight seal. In order to remove any air from the digester and create a vacuum, a pump was used to extract air from the system. This step was crucial to establish the anaerobic conditions necessary for the microbial activity and biogas production.To maintain the ideal conditions for anaerobic digestion, the digester was covered with a black cloth. This covering prevented any light from reaching the system, as exposure to light can hinder the anaerobic process. Additionally, the digester was placed inside a chamber where a specific temperature was maintained. This temperature control ensured an optimal environment for the microorganisms to thrive and enhance the efficiency of the biogas production.

4.3 Preparation of Incubator for Temperature Control (Mesophilic and Thermophilic) :In order to conduct experiments that require precise temperature control, it is important to have a well-designed and functional incubator. In the laboratory, an incubator was constructed using a combination of insulating materials and temperature control equipment.

The incubator was built using 3-inch thick Styrofoam insulation on five surfaces, while a heavy 2-inch thick plyboard was used on the top surface to provide additional insulation. The temperature was controlled using 14 bulbs with ceramic holders, which were connected to a temperature controller.

To maintain a stable temperature of 37°C throughout the experimental procedure, two sensors were inserted into the incubator. These sensors were connected to the temperature controller, which was programmed to turn off the bulbs when the temperature reached 37°C, and turn them back on when the temperature dropped to 36.5°C. The bulbs would remain on until the temperature reached 37.5°C, ensuring that the temperature was always kept within a tight range of ±1°C.

To prevent heat from escaping, the incubator was lined with thick insulation on all sides. Once the temperature inside the incubator reached the desired level, the experimental setups were placed inside the temperature-controlled box and allowed to remain there for a specific duration of time.

Overall, this setup provided precise temperature control, which is critical for many experiments in microbiology, biochemistry, and other fields. By carefully controlling the temperature, researchers can ensure that their results are accurate and reliable, leading to more meaningful discoveries and advancements in science.

Figure 4 : Custom made incubator.

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Overall, this setup provided precise temperature control, which is critical for many experiments in microbiology, biochemistry, and other fields. By carefully controlling the temperature, researchers can ensure that their results are accurate and reliable, leading to more meaningful discoveries and advancements in science.

4.3 Data Collecting and Analysis Method : Throughout the experiment, regular monitoring of the digesters was conducted to identify any potential leaks or signs of excessive pressure that could cause bursting. This monitoring was crucial to ensure the safety and proper functioning of the anaerobic digesters.

To assess the progress and success of the biogas production, the gas produced within the digesters was analyzed. This analysis involved collecting gas samples through the valves using a Gas Analyzer. The Gas Analyzer provided valuable information about the composition of the biogas, including the percentage of methane and carbon dioxide. By analyzing the gas, researchers could determine the efficiency of the anaerobic digestion process and make any necessary adjustments to optimize the biogas production.

The digesters were checked repeatedly so that no leakage or bursting out occurs. We analyzed the produced gas through the valves using Gas Analyzer.

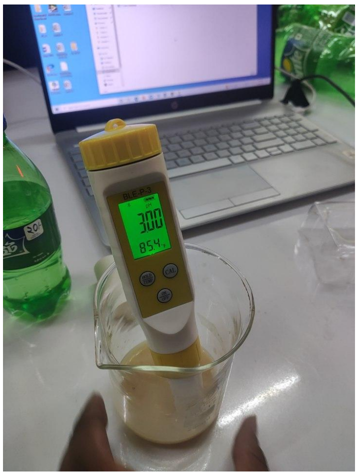

Figure 5 :Digital pH meter.

Figure 6 : Gasboard-3200 Plus Gas Analyzer.

CHAPTER 3.1 : RESULT AND DISCUSSION

The three main phases of the AD process are hydrolysis, acetogenessis, and methanogenesis. Long-chain insoluble organic compounds that are present in the feedstock material are first broken down into shorter chains by the action of enzymes during the hydrolysis phase, and then they are subsequently degraded by the activity of organisms. Long-chain carbohydrates are broken down by cellulolytic bacteria into dimeric molecules, which are then converted to monomeric sugar molecules, lipolytic bacteria into fatty acids, and proteolytic bacteria into their monomeric building blocks known as amino acids. During the acidogenesis phase, the monomers that are produced serve as a substrate for microbes. The rate of hydrolysis is slower than the pace at which acid and methane are produced afterwards..

Thus, the conversion of complex raw materials into simple monomers is the rate-limiting step. A few studies used chemical compounds to promote the hydrolysis phase (Molino et al., 2013). The hydrolysis phase's monomers are transformed into simple organic acids, hydrogen, and carbon dioxide in the second phase. Acetic acid, propionic acid, butyric acid, and ethanol are produced as a result of the acidogenesis of fats, proteins, and carbohydrates. Finally, during the third phase, methanogen bacteria produce the gas by either fermenting acetic acid to produce CH_4 and CO_2 or (ii) reducing CO_2 to CH_4 by using hydrogen gas or formate produced by other bacteria. Acetic acid reacts with methanogenic bacteria to produce 70% of the methane produced by reacting with methanogenic bacteria(Mital, 2009); but an increase in acetic acid concentration above 0.8 g/L can lead to AD failure (Zhang et al., 2014).

We completed 25 setups for our experiment in all over the course of six months. In the setups, co-digestion was applied. Kitchen wastes including leftover rice and vegetable peels from papaya, potatoes, bottle gourds, and pumpkins have been employed. Additionally, we put up a cowdung and water mixture in various ratios as a reference to understand the amount of methane created during digestion.
A Gasboard-3200 Plus, Gas Analyzer ㊷ was used to determine the percentage of different gas present in the sample. Next the pH was determined using YIERYI Bluetooth Digital pH meter.

Therefore, from our 25 setups, except the cowdung water setups, that papaya setups' biogas output is pretty excellent.
62.58% of the methane was produced in 60 days.
73 days were needed from the setup date to generate 80.75% of the methane.

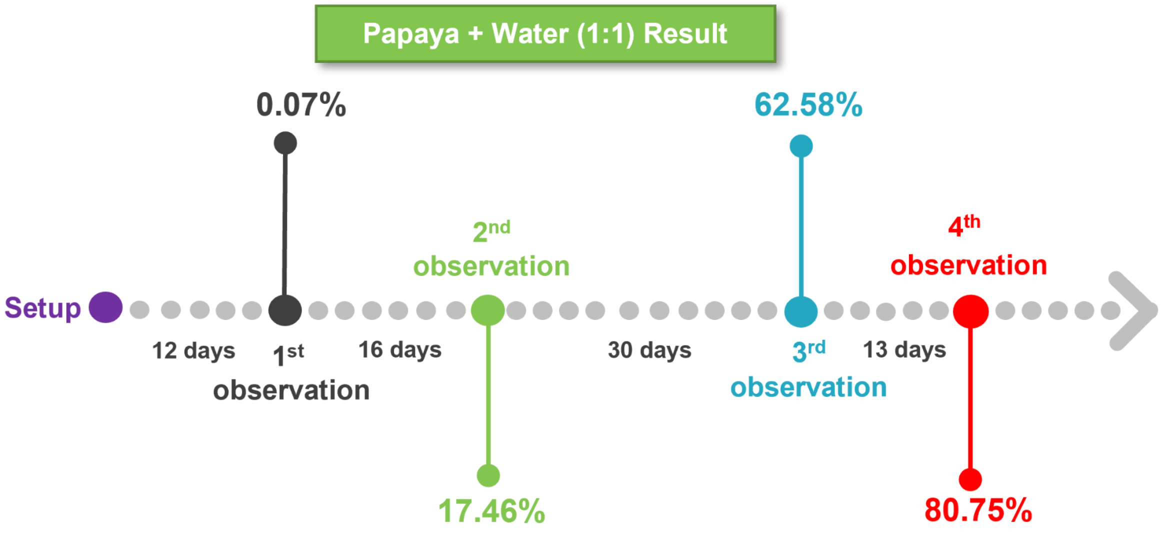

Figure 7 : Papaya Peel Result with time period.

However, there is room to shorten the time frame.As a base, we first utilized NaOH and KOH.The base we used next was urea.
Because,We found urea is better suited in controlling PH.Because

- Less urea is required.
- Urea is cheaper than NaOH and KOH.

Now we have several potential urea-based setups that can be used to produce methane

1.1. Biogas from Papaya peel

1.1.1. papaya peel and water (1:1) setup including 10% cow manure, and 20 g urea.(P2). This Figure appears to show the results of an experiment measuring the biogas production from a mixture of papaya peel, cow dung (10%), potassium hydroxide (KOH), and sodium hydroxide (NaOH) over time. The horizontal axis shows the number of days (HRT) and the vertical axis shows the percentage of biogas produced from the mixture at each time point.

The data in the Fig. 7 shows that there was an initial lag period of 9 days, during which little to no biogas is produced.CO_2 level is 65% and P^H level is 5 (Fig. 8) which suggest that the biogas digester is producing biogas.Initially 50 ml 2 Molar KOH was added to the set up.

As the days pass, the level starts to decrease. This is likely due to the consumption of by the microorganisms in the biogas digestor, which could lead to changes in the acidity of the digestor. After 13 days, the biogas production begins to increase At day 29, the level is 49.7, and the P^H level is 6.5, which suggest that the microorganisms are still active and producing biogas.Again 10 ml 3 Molar NaOH was added to the set up.Methane percentage increased upto 62.58% within 61 days and reaching a peak of 80.75% at day 77.

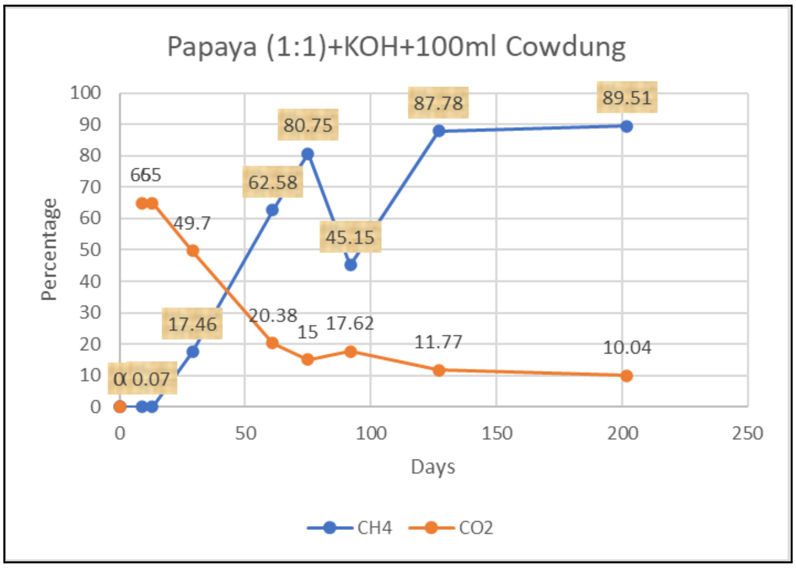

Figure 8 : CH_4 and CO_2 production with time from papaya peel and water (1:1) setup.

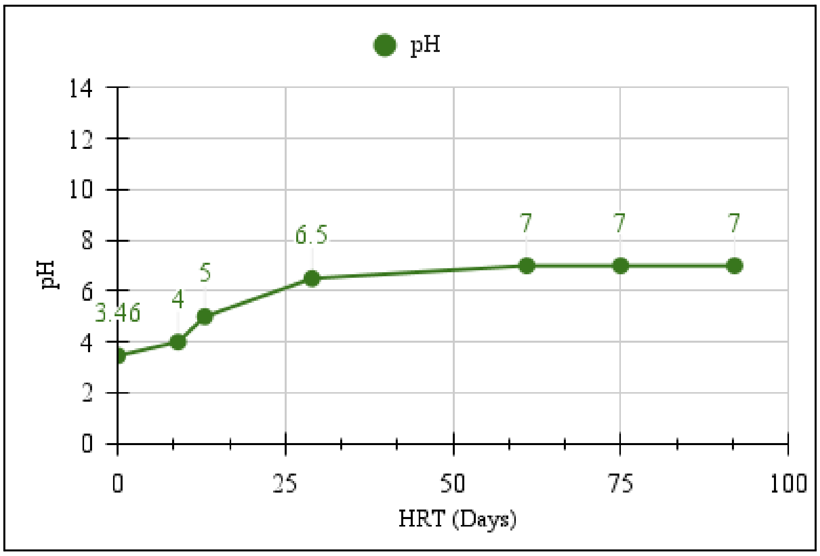

Figure 9 : pH profile of papaya peel and water (1:1) setup.

At day 75, the level is 20.38, and the P^H level is 7, which suggest that the microorganisms are almost consumed the organic matter and production is low.After couple of days, the level is 15 and the P^H level is 7.

At day 92, the level is 17.62, which indicates that the microorganisms are producing biogas again but not as much as the initial stages. After this point, the biogas production begins to decrease, with a measurement of 45.15%.The final measurement of methane yield 89.51%.

1.1.2. papaya peel and water (1:1) setup including 10% cow manure, and 20 g urea.(P2). Due to papaya's consistent P^H and suitability for biogas production, two additional papaya setups were created in a 1:1 ratio with water.One of them contains 20 g of urea (P2) and 10% cowdung.Another one has 15 g of urea and 20% cowdung (P3). 0.82% Methane was produced from this setup within 16 days. Within 33 days, 0.82% of the CH_4 from Setup was created, and the CO_2 level rose to 65%. The graph shows that the subsequent cessation of methane synthesis was caused by the substrate becoming basic due to the rising P^H.Then methane production increased and the final measurement is 24.43%.

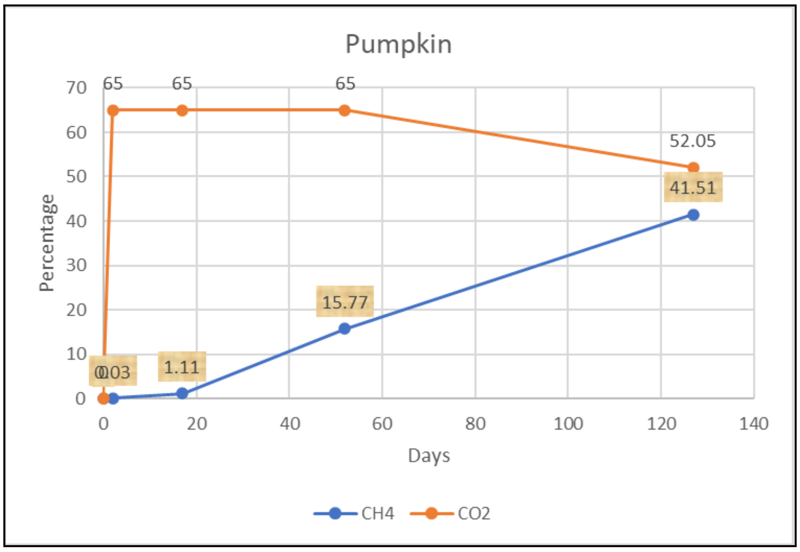

Figure 10 : CH_4 and CO_2 production with time from papaya peel and water (1:1) setup including 10% cow manure, and 20 g urea.

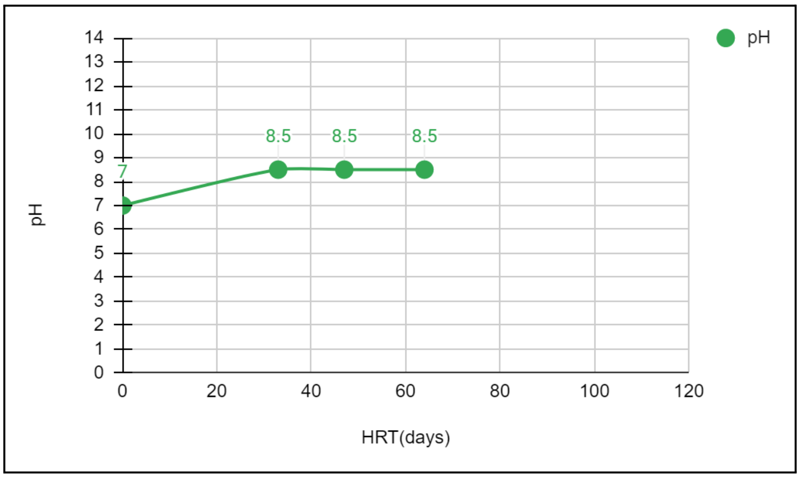

Figure 11: pH profile of papaya peel and water (1:1) setup including 10% cow manure, and 20 g urea.

1.1.3. papaya peel and water (1:1) setup including 20% cow manure, and 15 g urea(p3).P3 is yet another possible arrangement. CO_2 production has already begun after 17 days of observation. From the Fig. 11. it can be seen that On day 17, it is 65%. The methane increased from 10.23% and then finally reached to 26.21 %.

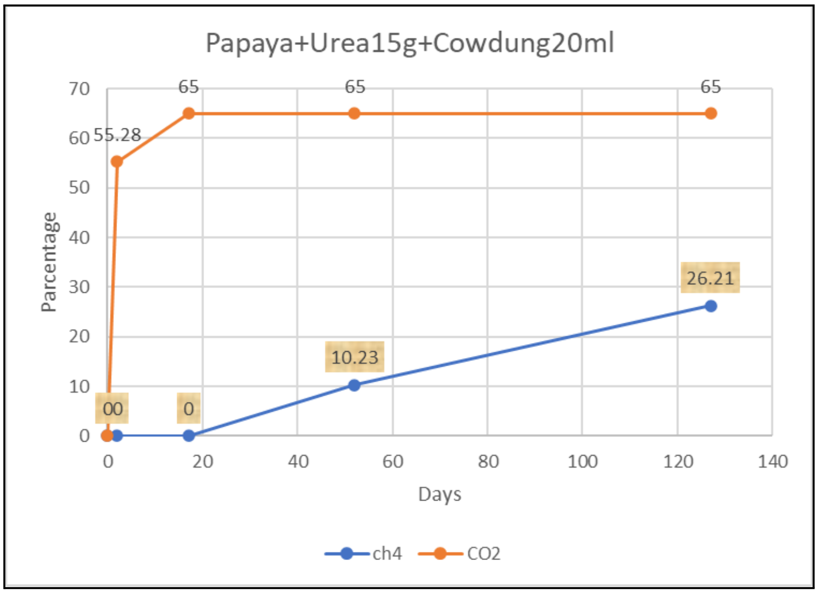

Figure 12 : CH_4 and CO_2 production with time from papaya peel and water (1:1) setup including 20% cow manure, and 15 g urea.

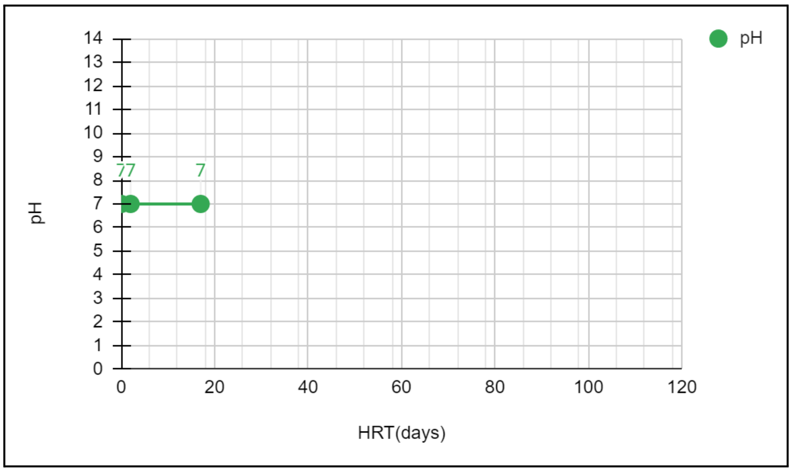

Figure 13 : P^H profile of papaya peel and water (1:1) setup including 20% cow manure, and 15 g urea.

1.2. Other vegetables

Result shows the ability to create methane also exists with pumpkin peels, bottle gourd peels, and a mixture of papaya and bottle gourd peels.

*1.2.1. pumpkin peel and water (1:1) setup including 20% cow manure and urea***.** Figure demonstrates that after 17 days, the CH_4 production in a different potential that uses pumpkin peels and water setup went up to 1.11%. The setup's CO_2 level was 65%, and the P^H was in ideal range. The final measurement is 41.51% methane.

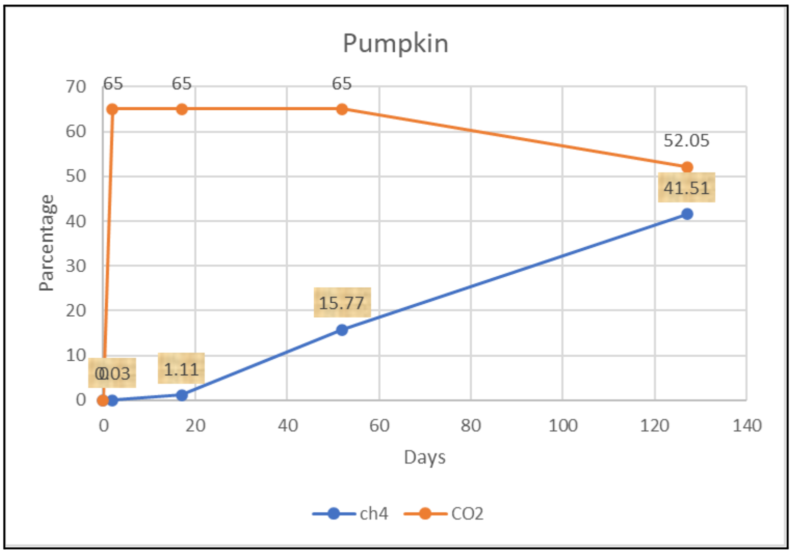

Figure 14 : CH_4 and CO_2 production with time from pumpkin peel and water (1:1) setup including 20% cow manure and urea

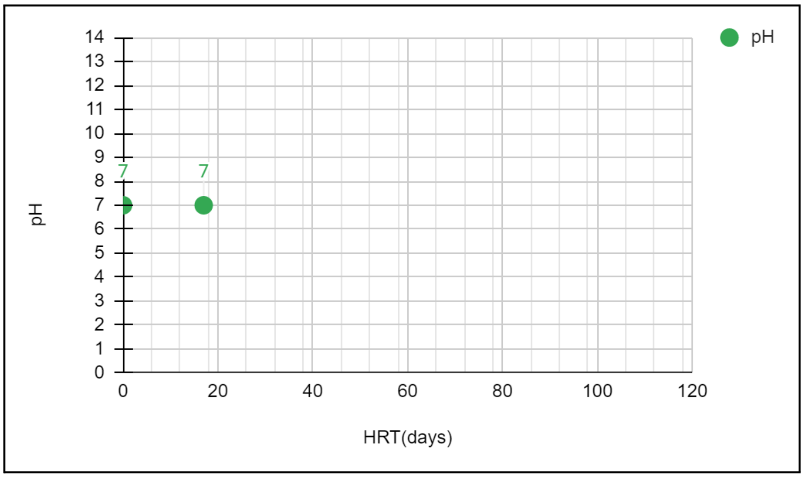

Figure 15 : P^H profile of pumpkin peel and water (1:1) setup including 20% cow manure and urea.

1.2.2. Bottle gourd peel and water (1:1) setup including 10% cow manure 20 g urea. The bottle gourd peel (20 g urea) setup produces 0.37% methane in 30 days.The P^H level is stable, and the CO_2 level has increased for up to 47 days.After that, it began to fall, and a small percentage of methane was discovered. The CO_2 level then rose once more.

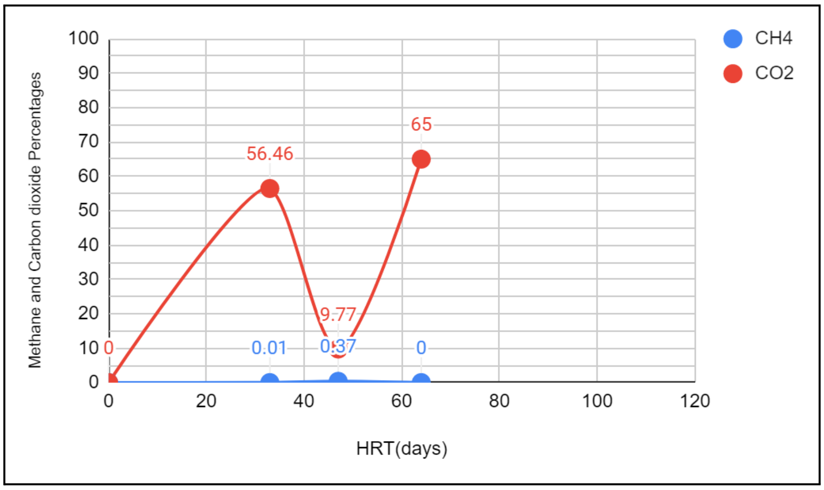

Figure 16 : CH_4 and CO_2 production with time from bottle gourd peel and water (1:1) setup including 10% cow manure 20 g urea.

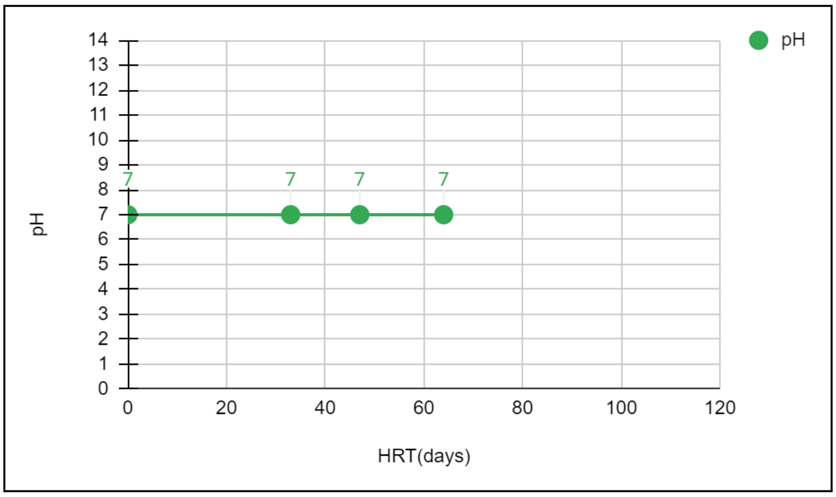

Figure 17: P^H profile of bottle gourd peel and water (1:1) setup including 10% cow manure 20 g urea.

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1.2.3. *Potato peels setup with 15 g urea and 20% cow manure*. Potato peel also has potential to produce methane because CO_2 level reached 65% within 17 days but the P^H is slightly acidic which might hamper the methanogenesis process.The final measurement is 28.9% methane.

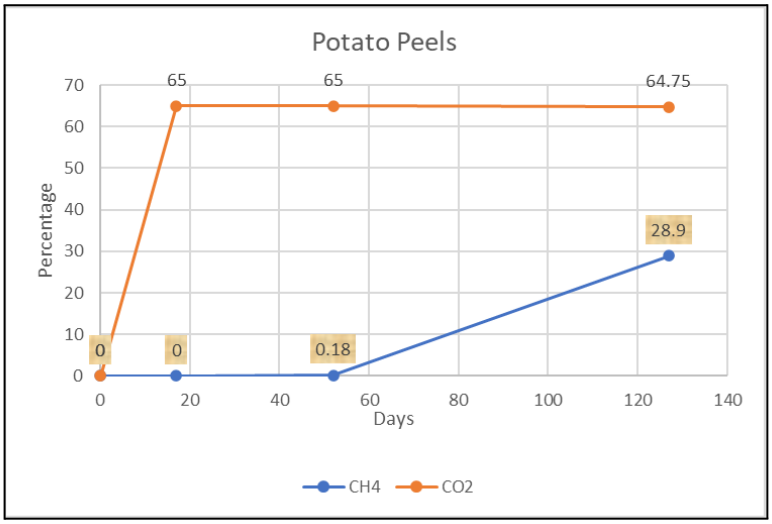

Figure 18 : CH_4 and CO_2 production with time from Potato peels setup with 15 g urea and 20% cow manure.

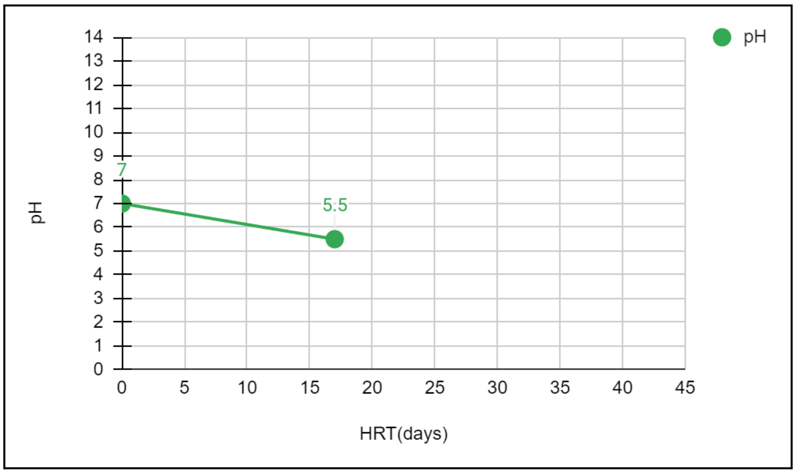

Figure 19 : P^H profile of Potato peels setup with 15 g urea and 20% cow manure.

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1.3. Mixed vegetables

1.3.1. Papaya and bottle gourd . According to the graph, a mixture of papaya and bottle gourd peels and pumpkin peels, respectively, yield 4.61% and 1.1% of methane. Due to the ideal pH range shown in Fig. 14. this setup produced 4.61% CH_4 in just 17 days shown in Fig. 13. The possibility of producing methane from this setup is also present.And the final measurement is 66.96%.

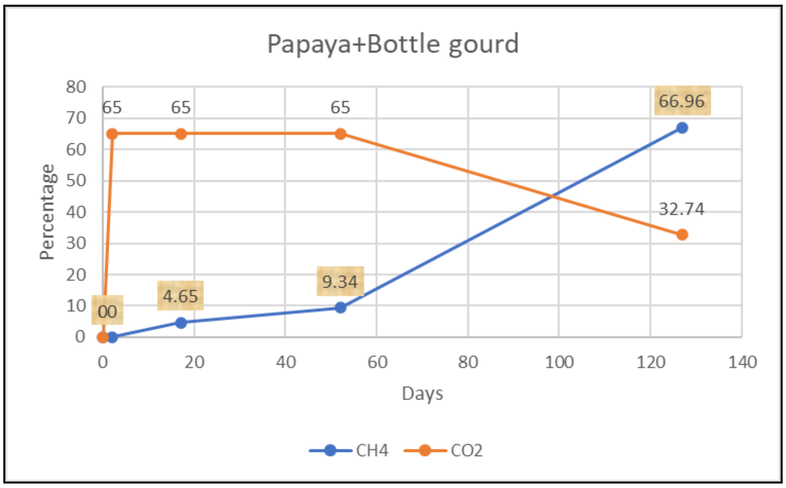

Figure 20 : CH_4 and CO_2 production with time from papaya peel,bottle gourd peel and water (1:1) setup including 20% cow manure and urea.

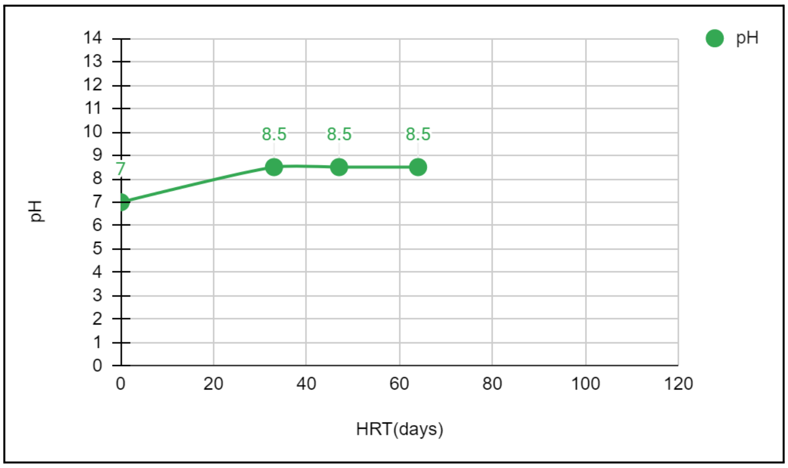

Figure 21 : P^H profile of papaya peel,bottle gourd peel and water (1:1) setup including 20% cow manure and urea.

1.3.2. *Papaya, potato, pumkin, bottle gourd and rice.* A mixed vegetable and rice setup was made with Papaya, potato, pumkin, bottle gourd and rice.Which showed a very little amount of methane at day 55 but as time went on the methane percentage increased and went up to 16% at 130 days.

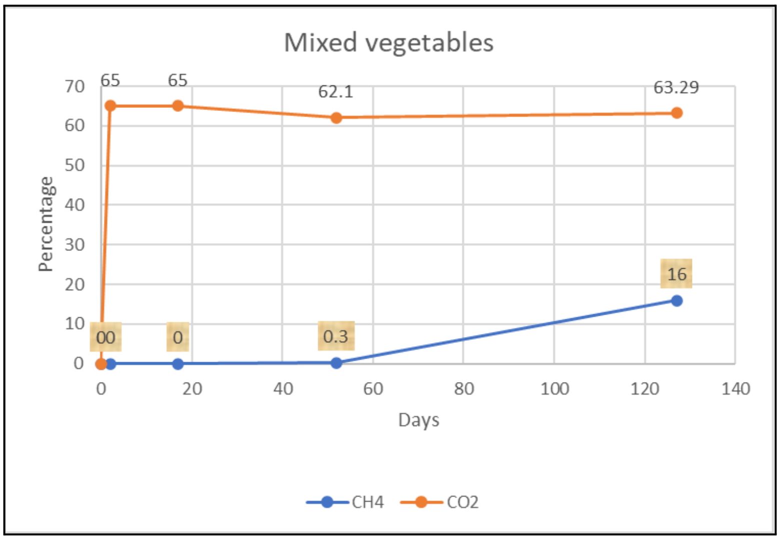

Figure 22 : CH_4 and CO_2 production with time from Papaya, potato, pumkin, bottle gourd and rice.

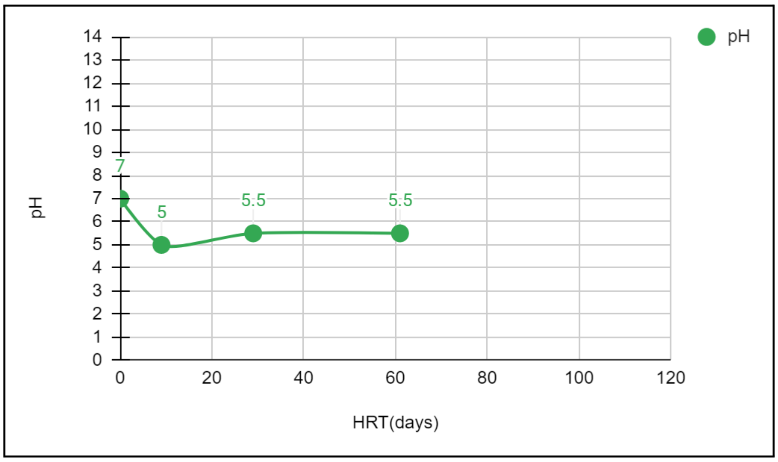

Figure 23 : P^H profile of Papaya, potato, pumkin, bottle gourd and rice setup.

1.4. *Rice setups*

1.4.1. *Rice and water mixed in different ratios(1:1,1:2,1:3) including cow manure and base.* The Fig. 26. shows that the pH is fluctuating and it's not in the ideal range that's why it can be seen that there is no significant methane yeild (Fig. 25).The pH is very acidic compared to the ideal range.

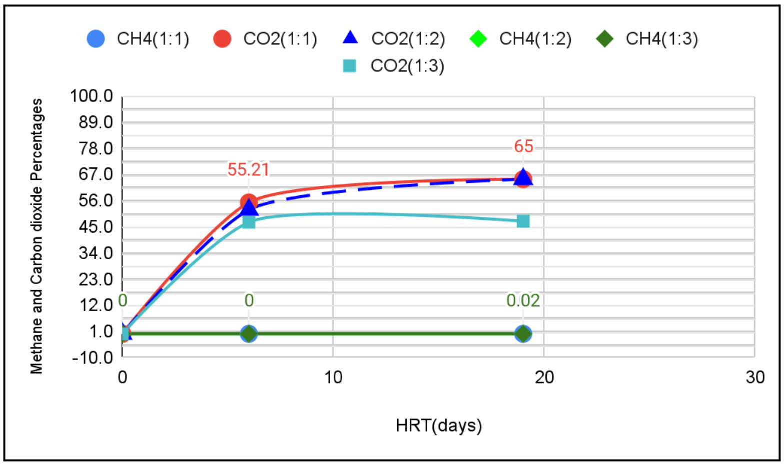

Figure 24 : CH_4 and CO_2 production with time from Rice and water mixed in different ratios(1:1,1:2,1:3)

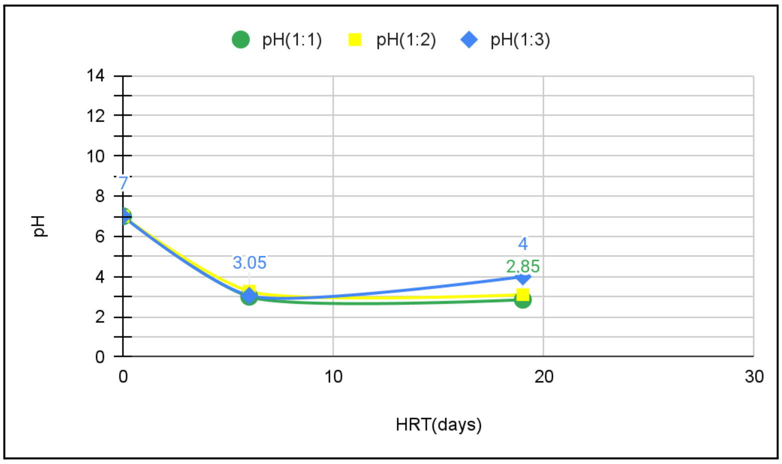

Figure 25 : P^H profile of Rice and water mixed in different ratios(1:1,1:2,1:3)

1.4.2. *Molasses and Yeast.* Molasses is a thick, syrup-like substance produced by the sugar refining process. To concentrate the sugar, sugar cane juice or sugar beet juice is boiled down. Molasses is used as a sweetener and flavoring in a variety of foods, including baked goods, sauces, and marinades, and it is also a key ingredient in the manufacture of rum. Molasses can aid in biogas production by providing organic matter for anaerobic digestion. In the absence of oxygen, microorganisms break down organic matter such as food waste, animal manure, or sewage to produce methane (biogas). Adding molasses to the organic matter mixture adds carbon, which the microorganisms can use as a food source, resulting in an increase in biomass.

Yeast is a single-celled fungus that is essential in many food and beverage production processes. Yeast is used in the production of bread, beer, and wine, as well as in the production of biofuel. Yeast ferments sugar in the food and beverage industries, producing carbon dioxide and alcohol. The carbon dioxide produced by yeast causes dough to rise, making bread light and fluffy, while the alcohol produced during fermentation provides flavor and aroma to beer and wine. Yeast can be used to produce ethanol from sugar or other organic matter in biofuel production.

In this study, molasses and yeast were used in two different setups. In both setups, rice is mixed with water in a 1:1 ratio, along with 15 g urea. Then, in one setup, 25 mL molasses is added, and in the other, 4g yeast is added. Fig. 25 depicts the production of CH_4 and CO_2 over time. Although no methane is produced at first, the CO_2 level rises to 65% within 17 days. Both setups have a slightly acidic P^H (Fig.26) Maintaining the P^H in the ideal range requires additional research to yield positive results.

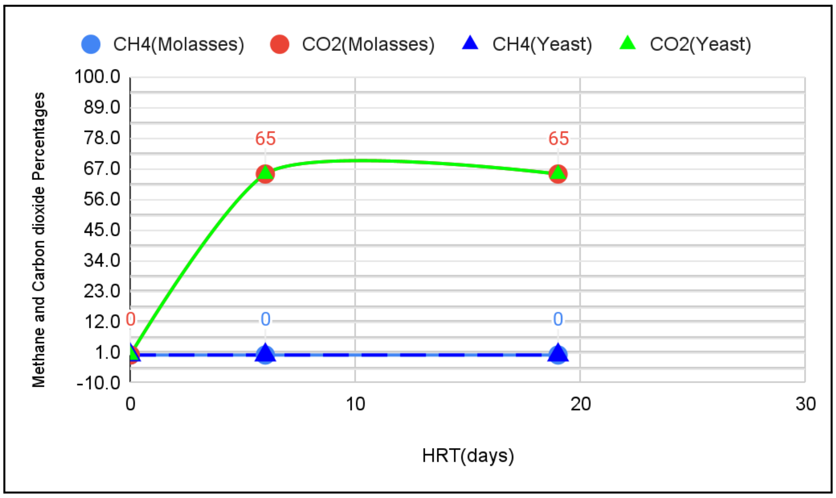

Figure 26 : CH_4 and CO_2 production with time from Rice and water (1:1) setup including molasses and yeast in different setups

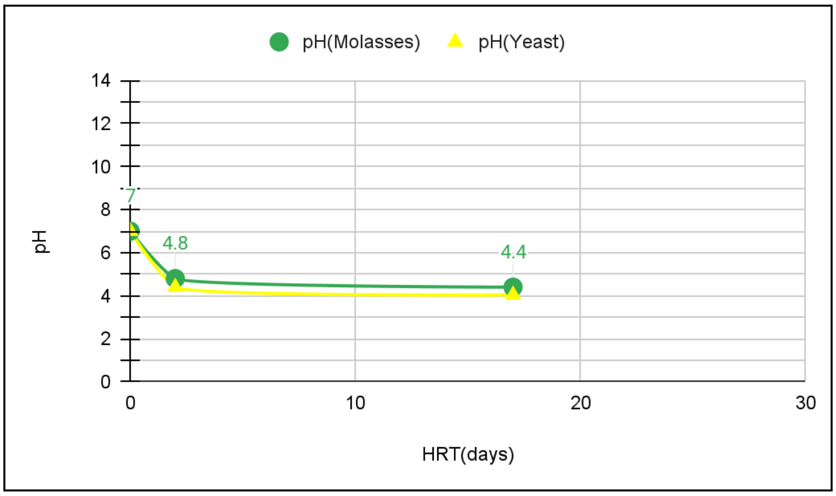

Figure 27 : P^{H} profile of Rice and water (1:1) setup including molasses and yeast in different setups.

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CHAPTER 4.1 : CONCLUSION

We are all dependent on food in one way or another. But humans are unable to eat food in its entirety. A certain amount of it is wasted. Additionally, this trash can be used by creating biogas from it. Segregation of food waste at source does not only reduce Cafeteria waste sent to the landfill, through anaerobic digestion, it could potentially produce huge biogas, which is equivalent to a potential electricity or kitchen purpose. Further study should be carried out to identify the cost of biogas plant construction and its optimal supply chain system. These biogas plant feedstocks should also be considered to maximize the biogas production. This study shows that papaya peels produce 80% of the methane that is produced. Papaya peels are frequently available as a kitchen waste. A substantial amount of biogas may be produced if a biogas digester were to be constructed next to the café with the necessary setup. And cooking is possible with this gas.

Factors and findings:

1.If pH drops below 5.5, the acid-producing bacteria can become dominant. If pH rises above 8.0, methane-producing bacteria can be inhibited.For both cases Methane won't produce.

2.The best ratio for biogas production is typically a mixture of 45-50% organic matter, such as food waste, and 55-60% water.

3.Maintaining a vacuum and optimal pH in a biogas chamber can present several challenges:

a.Leaks: Maintaining a vacuum requires a leak-proof system. Any leaks can disrupt the anaerobic conditions and reduce biogas production.

b.pH fluctuations: The pH level can fluctuate due to changes in the composition of the feedstock or changes in temperature, making it difficult to maintain the optimal pH range for biogas production.

4. Adding cow dung to a food waste biogas chamber can have several effects such as improved pH balance,increased biogas production,and improved quality of biogas.

5. Vegetable peels with cow dung have the highest potentiality to produce better quality Methane such as papaya peels with little cow dung produced 80% CH_4 .

6.Adding a base, such as sodium hydroxide (NaOH) or potassium hydroxide (KOH), in the initial setup of a biogas plant can have the following effects:

a.Adjusting pH: The base can be used to adjust the pH of the biogas plant to the optimal range (7.0 to 7.5) for biogas production, ensuring that the anaerobic bacteria can function efficiently.

b.Stimulating biogas production: By adjusting the pH, the base can help to stimulate biogas production by promoting the growth of methane-producing bacteria.

c.Reducing contamination: Adding a base can reduce the risk of contamination by undesirable microorganisms, as the high pH can inhibit their growth.

d.Improving biogas quality: A well-controlled pH can improve the quality of the biogas, leading to a higher methane content and a lower content of unwanted byproducts.

It is important to note that adding too much base can have adverse effects, such as inhibiting the growth of the methane-producing bacteria and reducing biogas production. Therefore, it is crucial to carefully control the amount of base added to the biogas plant to ensure maximum biogas production and optimal biogas quality.

7.Controlling the pH Improved biogas quality can result in a better energy output from the biogas plant, as the higher methane content means that more energy can be obtained from the same volume of biogas.

8.Controlling the pH can provide a platform for further optimization of the biogas process, such as the addition of nutrients to improve biogas production.

In conclusion, biogas production is a promising technology for sustainable energy generation, but it requires careful optimization of various factors to ensure optimal biogas production and quality. Controlling pH, feedstock composition, and vacuum maintenance are critical for achieving maximum biogas production and minimizing environmental pollution. The use of additives, such as bases, can help to adjust pH and improve biogas quality, but their use must be carefully controlled to avoid adverse effects. The optimal feedstock composition and maintenance of vacuum are also crucial for optimal biogas production. Further research is needed to explore the potential of biogas production and optimization for sustainable energy generation.

CHAPTER 4.2 : FUTURE SCOPE

Here on IUT the biogas we are producing is not only confined to utilization at iut , it has a greater prospect for Bangladesh too.

Biogas can be upgraded to become a fuel for various end-uses, such as electricity production, transportation, and residential and commercial buildings.

Bangladesh can solve a significant portion of its energy deficiency by utilizing biogas.The ongoing projects might be a motivating aspect for the future making plans in this place. In Spite of having limited herbal resources and technological drawbacks, the current initiatives and upcoming opportunities have genuinely installed a handy platform for a higher answer to the energy crisis.

The three basic end uses for biogas are:

- Large Biogas Plant beside IUT cafeteria
- Mini Biogas plant for domestic kitchen
- Production of heat and steam

One of the cleanest renewable fuels is compressed biogas. Through the processing of trash, an indigenous fuel is created, and an organic byproduct is produced. Solar and battery waste will be produced if we utilize solar energy, and wind energy will also produce trash, but with biogas, we are not producing any significant waste at the end of its life.

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