Investigations on the Effect of Ultrasonic Pre-Treatment on Cow Dung Slurry with Sludge Water and Food Waste for Biogas Production

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CANDIDATE'S DECLARATION

I, ABHISHEK KUMAR, 2K21/THE/01, of M. Tech (Thermal Engineering), hereby declare that the project Dissertation titled "**Investigations on the Effect of Ultrasonic Pre-Treatment On Cow Dung Slurry with Sludge Water and Food Waste for Biogas Production**" which is submitted by me to the Department of Mechanical Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship, or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled "Investigations on the Effect of Ultrasonic Pre-Treatment On Cow Dung Slurry with Sludge Water and Food Waste for Biogas Production" which is submitted by ABHISHEK KUMAR, 2K21/THE/01, Department of Mechanical Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge, this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

In the present work, Ultrasonic pre-treatment was performed on cow dung slurry in anaerobic conditions to observe the methane quality and hydraulic retention time (HRT). There were four anaerobic digesters designated as B1, B2, B3, and B4 with the capacity of 10 litres each, had the ratio of cow dung:sludge water: food waste is 1:1.5:1 respectively with the additive of 10gm jaggery / kg-cow dung with organic loading rate (OLR) of 6 kg total solid (TS) $m^{-3}day^{-1}$. Initially, the HRT was 17 days at room temperatures varied between 28ºC and 32ºC respectively. B1 and B2 were treated by ultrasound for 35 minutes (230V, 18kHz, 1.5kW) at 50ºC and 60ºC (Thermophilic condition) respectively. It was observed that B1 had the maximum Methane (CH_4) yield in the biogas which was 13.4% more than B2, 52% more than B3, and the least Methane yield in the biogas was observed in B4. At Mesophilic condition (30 ºC - 40 ºC) the methane yield was found 30% lower as compared to B1. Response Surface Methodology (RSM) was used to determine the most favourable ultrasonication time, temperature, and hydraulic retention time in this study for ultrasonic pre-treatment of cow dung for the production of biogas. This was accomplished with the help of a software programme (Design Expert 12.0.1.0). In order to analyse the result of the variables and their interlinkage to establish their optimal values, quadratic result datas for the responses were created, and a 3-Dimension response surface map was generated. The ultrasonication time, temperature, and retention period following HRT were determined by numerical optimisation to be 35 minutes, 60°C, and 8 days respectively.

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Place: Delhi

Date: 31/05/23 ABHISHEK KUMAR

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Abbreviations/Symbols	Descriptions
CDs	Cow dung slurry
FW	Food Wastes
Usp	Ultrasonic pre-treatment
Usp+CDs+FW	UCDf
CDs+FW	Cdf
Usp+CDs	UCDs
HRT	Hydraulic Retention Time
TS	Total Solid
VS	Volatile Solid
OLR	Organic Loading Rate
AD	Anaerobic Digestion
RSM	Response Surface Methodology
ANOVA	Analysis of Variance

CHAPTER-1
INTRODUCTION

1.1 Background

In the current scenario, where the globe struggles with issues like energy security, the consequences of utilising conventional fuels, environmental degradation, and global warming. Renewable and alternative fuel research is now in demand and growing in popularity. Energy production from waste, also known as waste-to-energy (WTE), is a process of converting waste materials into electricity or heat. A waste management technique called "waste-to-energy" involves igniting garbage to create energy. Usually, this process involves burning, which produces heat that can be used to create steam, which may then be used to power turbines to produce electricity. Gasification is a different technique that includes heating waste products to create a gas that may be burnt to provide power. Anaerobic digestion of organic waste, including food waste, agricultural waste, and sewage sludge, yields biogas, a sustainable energy source. As long as there is a supply of organic waste, biogas may be generated continually in contrast to fossil fuels, which are limited and non-renewable.

By collecting and using methane gas that would otherwise be released into the environment and contribute to climate change, biogas production lowers greenhouse gas emissions. With a warming potential 25 times larger than carbon dioxide, methane is a powerful greenhouse gas. Reducing the quantity of organic waste dumped in landfills, where it might contribute to the creation of methane gas, is possible with the aid of biogas production. This trash may instead be utilised to create biogas and other beneficial byproducts like fertilisers and soil improvements. The generation of biogas can improve energy security by lowering reliance on fossil fuels, which are frequently imported from other nations. Local waste resources may be used to make biogas, which can be a dependable source of energy for nearby towns via the creation of jobs in the waste management and renewable energy industries as well as via the sale of biogas and other byproducts, biogas production may have a positive impact on the economy. For the treatment of organic waste and the creation of biogas, a sustainable energy source, anaerobic digestion is a proven process. The process entails the microbial breakdown of organic material in the absence of oxygen, which produces biogas composed of methane and carbon dioxide. The method is constrained, nonetheless, by poor methane yields and sluggish hydrolysis rates. It has been demonstrated that ultrasonication increases mass transfer and breaks down complex organic molecules into simpler forms that are more readily digested by microbes, increasing the efficiency of anaerobic digestion. Response surface methodology (RSM) is being used in this work to optimise the ultrasonication-assisted anaerobic digestion process for the generation of biogas. A central composite design (CCD) will be used to examine the effects of ultrasonication duration, ultrasonic power, and substrate concentration on the generation of biogas. In order to create a prediction model that may be utilised to improve the procedure, the findings will be analysed using RSM.

A proven technique for creating biogas, a sustainable energy source, is anaerobic digestion. The method is constrained, nonetheless, by poor methane yields and sluggish hydrolysis rates. Anaerobic digestion has been proven to be more effective when ultrasonicated, however it is unclear what the ideal circumstances are for the procedure. Response surface methodology (RSM) will be used in this study to optimise the ultrasonication-assisted anaerobic digestion process for the generation of biogas. A central composite design (CCD) will be used to examine the effects of ultrasonication duration, ultrasonic power, and substrate concentration on the generation of biogas. RSM will be used to analyse the outcomes and create a prediction model that can be applied to improve the procedure.

According to several studies, potential feedstock for the generation of biogas includes wastes from college canteens, industrial effluents, sludge water, agricultural wastes, cattle manures etc [1]–[5]. As of March 2021, Maharashtra had over 931 thousand biogas plants, making it the state with the most biogas plants in India. Second-place Karnataka has around 513 thousand plants. There were more than five million biogas plants in India [6]**.**

According to **Gutierrez A.S. et al.** using biogas instead of firewood for cooking can cut the amount of greenhouse gas emissions by 11% [7]. **Assuncao L. R. C. et al.** stated only 5% of the biogas generated globally gets converted to biomethane, fed into the petrol distribution system, or utilised as a fuel for vehicles [8]. Worldwide food loss amounts to around 1.3 billion tonnes per year, or about one-third of all food produced. Because it is sustainable, converting food waste into energy has tremendous environmental implications [9]. The wastes in different proportion with feed shows enhanced biogas production for an optimum proportion. **Bernard et al.** had shown in their experiment that optimum proportion of cowdung, vegetable waste and water was 1:1:2 respectively which yield 13.2% more methane [10]. Another research on optimum proportion of cattle manure, food waste and sewage sludge were 70%, 20% and 10% respectively produced 31% more methane yield at 36 ºC(mesophilic condition) while 67% more methane yield at 55ºC(thermophilic condition) [11]. **Viswanath P. et al.** suggested that using fruit wastes and vegetable wastes to cow dung at two different HRT of 16 days and 24 days in which the yield gas formation was 74.5% and 59.03% respectively with methane content of 51 to 53% under mesophilic conditions [5]. **Jyothilakshmi R. et al.** calculated the biogas from cow dung was 0.264 m^3/kg volatile solid (VS) while from domestic waste it was 0.425 m^3/kg volatile solid (VS). This experiment suggest that domestic wastes are potential feedstock for biogas production with 2 times efficient than cowdung slurry.

Biowastes are also a great feedstock for biogas production as well as solid waste management. In the context of solid waste management, biowastes are often divided into six categories: paper, glass, organic, plastic, metals, and others. An effective approach for turning biowaste into sustainable fuel for uses such as electricity production, heating, drying, and cooling is anaerobic digestion (AD). It is possible to use the biogas created by the anaerobic digestion of organic materials such as food scraps, cellulosic biomass, and animal manure as fuel for cooking, running motors, and producing power [13].

IC engines and natural gas network can benefit greatly from biogas since it can be upgraded to biomethane. In the previous ten years, the installed capacity for producing biogas has more than quadrupled globally, and the development is spread out due to resources being readily available and developed national regulations. Around 90% of the world's biogas is produced in Europe, China, and North America combined [14]. The world's most widely used clean fuel, biogas, really has its roots in India. It was first found in the middle of the eighteenth century, and it progressively became the technology of choice for addressing the energy shortage in rural hinterlands. Yet in the last ten years, it has expanded to play a bigger role from the standpoint of waste to energy.

The use of conventional energy sources, which are widely accessible and appear to be inexpensive, continues to pose a threat to biogas as a sustainable energy source[15]. However, some studies demonstrate that pre-treatment techniques [2], [16]–[18]. The use of food wastes [10] , sewage sludge [19] ,and the impact of ultrasonication (in the production of biogas have made the fuel an affordable and sustainable source for underdeveloped villages to use for cooking.

Nand K. et al. suggested anaerobic digestion [AD] of canteen/mess waste food with cow-dung in various proportions, the methane quality could be improved up to 50% and the hydraulic retention time could be shortened to 20 days as opposed to using cow-dung alone, which has methane quality of 41% at HRT of 30 days [1]. **Azman S. *et al.*** found lab scale ultrasonication pre-treatment (USp) which increases the methane quality by 18% but require high specific energy which is negative energy balance between production of biogas and requirement of specific energy, but this can be cheaper pre-treatment at large scale [20]. **Alagoz B.A. et al.** compared the pre-treatment with microwave and ultrasonic and found that microwave assisted pre-treatment required 9 times more specific energy than ultrasonic pre-treatment and enhanced only 10-15% biogas/methane yield. [21] found the ultrasonic pre-treatment on food waste showed optimum yield of biogas also the VS removal rate would be maximum with Usp.

1.2 Anaerobic digestion(AD)

Anaerobic digestion is a biological process that decomposes organic material without the need of oxygen, producing biogas and nutrient-rich digestate as byproducts. It is a natural process that takes place in places like swamps, marshes, and animal gastrointestinal tracts. Anaerobic digestion is the controlled process of degrading organic waste materials, such as food waste, animal manure, agricultural leftovers, and wastewater sludge. It is used in waste management and renewable energy production. An anaerobic digester is a closed system where the process takes place.

The following are the main procedures in anaerobic digestion:

I. **Feedstock preparation:**The organic waste material is collected and processed for digestion as feedstock. In order to enhance the surface area for microbial activity, this may require shredding or grinding.

II. **Anaerobic Digester:** The anaerobic digester, a sealed and oxygen-free environment, is where the processed waste material is put. Depending on the volume and kind of waste, the digester may be a tank, lagoon, or specialised system.

III. **Microbial Activity:** A complex microbial population, comprising bacteria, archaea, and other microorganisms, may be found in the anaerobic digester. The organic material is broken down by these bacteria through a variety of metabolic processes.

IV. **Biogas Production:** Biogas is produced as the organic matter breaks down. Methane (CH4) and carbon dioxide (CO2) make up the majority of biogas, with trace quantities of other gases. It is a renewable energy source that may be used to heat homes, produce electricity, or power cars.

V. **Producing Digestate:** Digestate is the term for the byproduct of anaerobic digestion. It can be used as a fertiliser or soil amendment since it is nutrient-rich.

Numerous advantages of anaerobic digestion include:

- **Renewable Energy:** Anaerobic digestion produces biogas, which may be utilised as a renewable energy source to lessen dependency on fossil fuels and reduce greenhouse gas emissions.
- **Waste management:** It offers a practical method for handling and treating organic waste, keeping it out of landfills and lowering its environmental impact.
- **Recycling of Nutrients:** The digestate generated may be utilised as a fertiliser that is rich in nutrients, completing the nutrient cycle and fostering sustainable agriculture.
- **Methane Reduction:** Anaerobic digestion aids in limiting the atmospheric emission of methane, a strong greenhouse gas. Biogas is produced by capturing the methane released during the decomposition of garbage.

Anaerobic digestion is an important procedure that helps with waste management issues, encourages the production of renewable energy, and supports the sustainable use of resources.

1.3 Ultrasonication pretreatment

Before further processing, a substance or material is subjected to an ultrasonic pretreatment procedure sometimes referred to as ultrasonication, sonication, or ultrasonication. It is frequently used to increase process efficiency and raise the calibre of the finished product in a variety of sectors, including as food, medicines, wastewater treatment, and the manufacture of biofuels.

The substance or material is subjected to strong acoustic cavitation during ultrasonic pretreatment. Cavitation is the term used to describe the fast pressure fluctuations brought on by sound waves that cause small bubbles to rapidly develop, expand, and implode in a liquid media. The bubbles produce localised hot areas and high-energy situations when they burst or implode, which has a variety of physical and chemical impacts. Following are some of the main advantages and uses of ultrasonic pretreatment:

- **Disintegration and Cell Disruption:** Ultrasonication may efficiently disintegrate cell walls, membranes, and structures, allowing intracellular contents to escape. This is very helpful in procedures like extraction, extraction of bioactive substances, and disruption of microorganisms for microbial inactivation or enzyme release.
- **Homogenization and Particle Size Reduction:** Ultrasonic pretreatment can increase mixture homogeneity, boost particle dispersion, and decrease particle size. This improves the process efficiency and product quality for uses such emulsification, suspension stabilisation, and particle size reduction.
- **Extraction and Enhanced Mass Transfer:** The release and diffusion of chemicals are encouraged by the acoustic cavitation produced during ultrasonication, which boosts the effectiveness of extraction procedures. For the recovery of valuable chemicals from diverse matrices or the extraction of bioactive compounds from plant materials, this is used in businesses including food, pharmaceuticals, and herbal medicine.

- **Cleaning and Degassing:** Applications for ultrasonic pretreatment include cleaning and degassing. Contaminants, organic residues, and adherent particles can be removed thanks to the cavitation bubbles that form close to surfaces and quickly burst. It is frequently used in sectors including precision manufacturing, optics, and electronics.
- **Treatment of Wastewater:** Ultrasonication is used in the treatment of wastewater to speed up the breakdown of organic contaminants and increase the effectiveness of following treatment procedures like biological treatment or chemical oxidation.
- **Production of biofuel:** Ultrasonic pretreatment can increase the effectiveness of biomass pretreatment for the generation of biofuels. It facilitates the release of sugars from biomass, enhances enzymatic accessibility, and aids in the breakdown of lignocellulosic structures.

The efficiency of ultrasonic pretreatment is dependent on a number of variables, including the frequency and strength of the ultrasound waves, the length of the therapy, and the properties of the substance or material being treated. To get the desired results, the best settings for each individual application must be found.

1.4 Objectives

- The objective of this research is to find the alternative source of energy from the waste management.
- This research suggests the effective optimized technology for producing biogas in anaerobic digesters with optimum waste utilization.
- This research must be very useful for village people where they are deprived from having LPG cylinders. Since they are having almost all feedstocks which are required to produce biogas. Biogas must help them in prevention from burning coal and cowdung directly which cause their severe health issues.
- This research also help in reducing environmental pollution created by burning of biomass directly.
- Among various techniques for producing anaerobic biogas, the technique proposed in this research is one of the most effective method for efficient use of waste and large production of high quality biogas in shorter time interval.

1.5 Scope and limitations

- This research requires further improvement in energy input for ultrasonication, the renewable energy source must be integrated with ultrasonicator machine. This will make process energy positive.
- Further research on choosing of feedstocks and their pretreatment methods, use of suitable additives which enhance the rate of reaction and yield more methane content and optimized the process of waste management.
- Conventional energy source input limit the use of ultrasonication pretreatment at lab scale , but at large scale we can produce more sufficient energy whatever we used for.

CHAPTER-2
LITERATURE REVIEW

2.1 Biogas

Biogas is a term for a sort of renewable energy that is created when organic matter breaks down in the absence of oxygen. Methane (CH4) and carbon dioxide (CO2) make up the majority of its composition, with traces of other gases like nitrogen, hydrogen sulphide, and water vapour. Anaerobic digestion (AD) and anaerobic fermentation are processes that use microorganisms to break down biomass, such as food scraps, manure, sewage sludge, and energy crops. The end result is biogas.

The method of manufacturing biogas entails collecting the organic waste in a sealed container called a digester. Inside the digester, bacteria and other microorganisms break down the waste through a series of biological reactions, known as anaerobic digestion. As a byproduct of this process, biogas is produced; this biogas may be collected and used as a sustainable energy source. There are several uses for biogas:

- Biogas may be burnt directly to create heat for cooking or other purposes that require heat, as well as electricity. In combined heat and power (CHP) systems, it may also be utilised in gas turbines or internal combustion engines to concurrently produce electricity and heat.
- Vehicle Fuel: Biomethane may be created by upgrading and purifying biogas to eliminate contaminants like carbon dioxide and hydrogen sulphide. Natural gas vehicles (NGVs) or cars that have been modified to run on gasoline or diesel fuel can utilise biomethane as a fuel, either by itself or in combination with natural gas.
- Injection into the Natural Gas Grid: Biomethane may also be injected into the current natural gas grid, allowing for distribution and usage in a variety of operations, including industrial processes, home and commercial heating, and cooking.

The creation and use of biogas have the following advantages:

- Renewable Energy: Biogas is created from biological waste, which would otherwise degrade and release methane, a powerful greenhouse gas, into the environment. As a result, biogas is a renewable energy source. We can cut back on greenhouse gas emissions and our dependency on fossil fuels by capturing and using biogas.
- Waste Management: The generation of biogas offers a sustainable method for handling organic waste, such as food waste, livestock manure, and agricultural byproducts. An efficient waste treatment technique, anaerobic digestion decreases waste volume, lessens odours, and eradicates germs.
- Energy Independence: Communities and businesses may become more energy independent by producing biogas locally from a variety of organic feedstocks.
- In order to produce important energy and nutrient-rich digestate, which may be used as a biofertilizer to improve soil fertility and lessen the need for artificial fertilisers, biogas generation fosters a circular economy.

Overall, biogas is a flexible and sustainable energy source that may help slow down climate change, cut waste, and encourage a more ecologically friendly method of producing energy and managing trash.

2.2 Optimization Factors

The optimization factors which are very essential in terms of efficiency of the process, higher yield of biomethane, sonication time, ultrasonication temperatures, number of days after HRT, quantity and quality of methane, slurry ratios, pH values etc. The ultrasonic timing should be optimum to ensure optimum methane quantity and quality. All these factors plays important roles in optimizing overall processes and deep study has been done in this literature review section. A technique Response surface methodology adopted to compare the predicted data to actual experimental dat

2.3 Response Surface Methodology

RSM uses a range of mathematical, statistical, and graphical methodologies, techniques, and tools to develop, improve, and optimise a process. When our answer variables are impacted by a variety of independent factors, it may also be used to do modelling and analysis. RSMs generally involve the following stages:

1. The experimenter must go from the vicinity of the response's ideal operating conditions to the present operating settings. The steepest ascent approach is applied in the response optimisation instance. The responsiveness may be decreased using the same strategy, also referred to as the steepest descent method.

2. After the experimenter has come near to the ideal response, he or she must evaluate a sophisticated model to see how the response and the factors selected relate to one another. RSM designs, a particular type of experiment design, are used to accomplish this. The ideal operating settings that produce a maximum or minimum response are found using the best model.

3. It's possible that several responses may need to be improved at once. For instance, a researcher may want to lessen defects while increasing strength. In these circumstances, the ideal settings for each of the responses may provide opposing values for the variables. In order to achieve the best outcomes for all of the given restrictions, an appropriate configuration must be chosen. Desirability functions are helpful at this stage.

2.3.1 Applications of RSM

Due to its advantages over conventional one-variable-at-a-time optimisation, such as the capacity to generate large amounts of data from a small number of experiments and the capacity to assess the interaction effect between the variables and the response surface, RSM is now widely used in the optimisation of analytical procedures. When using this method for experimental optimisation, you must first choose an experimental strategy, fit a suitable mathematical function, and then evaluate the fit of the model before generating predictions based on the experimental findings. The central composite design is still the symmetrical second order experimental design that is most frequently employed for the development of analytical techniques. Prior until recently, the area of chromatography, closely related technologies, and electrochemical methods were the only ones that used desirability functions for multiple response optimisations. On the other hand, its concepts may be applied to the development of procedures using various analytical techniques that call for the concurrent investigation of the ideal conditions for a number of solutions. As an alternative to traditional modelling, an adaptive learning technique that incorporates neural networks and experimental design may be utilised to depict a dependence connection. This approach has proven to be more accurate in data learning and prediction than the traditional RSM. It is crucial in the design, formulation, development, and analysis of new research results and products, and it is used most frequently in the industrial sector. It might be applied to improve present research and goods. RSM is commonly applied in the fields of determining chemical composition, food science, biological industries, etc.

2.3.2 Study on RSM

Chun et al., 2015 [34] study was hailed as a victory for the waste-to-wealth idea. The collected poultry manure was analysed and pre-treated to eliminate too much ammonia-N, which inhibited the formation of biogas. The simultaneous impact of the variables: agitation (110-130 rpm) and reaction time (2-4 days) on the biogas generation was examined using a Central Composite Design (CCD) with five replicates at the centre points. Response surface methodology (RSM) was then used to design and analyse the experiment using Design Expert V7.0 software.The biogas output from the initial Chemical Oxygen Demand (COD) was used to evaluate the performance of the biogas generation, and it was discovered that it ranged from 0.49 to 4.37 mL/g COD.The ANOVA revealed a significant relationship between agitation and reaction time and biogas output. All of the responses were predicted using a quadratic model. 120 rpm of agitation and 3.3 days of reaction time were found to be the ideal parameters. A biogas production of 44.5×10^{-4} L/g COD was attained under these circumstances. This accounted for 5.82% of the model prediction error. It was therefore recommended that the models discovered may be applied to maximise the biogas generation from wastewater from chicken manure.

2.3.3 Stat-ease Design Expert

RSM technique can be applied in "Design Expert" software, a statistical and mathematical tool. It provides test matrices for screening up to 50 variables. The statistical significance of these variables is assessed using analysis of variance (ANOVA). Graphical tools make it easier to see how each component affects the desired outcomes and spot data irregularities. The needed number of test runs may be determined with the help of a power calculator. An

ANOVA is used to assess statistical significance. A numerical optimizer that is based on tested prediction models aids the user in choosing the best values for each of the experiment's variables."Design-Expert" provides 11 visuals in addition to text output for the residuals evaluation. The programming determines the key effects of each component as well as the relationships between them by altering the values of all components at once. A response surface methodology technique may be used to visualise a design space with a small number of trials. RSM provides an estimate for the value of responses for any conceivable combination of the elements by altering the values of all variables simultaneously, which enables it to comprehend a multi-dimensional surface with non-linear shapes. The process' ideal solutions may be found using the optimisation function.[]

2.4 Study on Bio-methane

Nand et al., 1991 [1] had done exepriment on canteen waste for biogas genearation in anaerobic digesters under mesophilic condition and found the methane yield upto 50% and also the gas yield of $0.981 m^3\ kg^{-1}$ volatile solid (VS), while the organic loading rate was found to be 100 kg total solid $(TS) m^{-3}\ day^{-1}$. They foud in their experiment that the canteen waste enhance the methane yield as well as reduce tne HRT to 20 days. They found the reason of high methane yield was the high content of starch and fats present in these wastes. This experiment suggest waste utilization in energy generation.

Vijayakumar et al., 2022 [4] studied the biochemical conversion of food wastes into biogas geneartion. In this review they focussed on characterisation, fabrication, and variables across time that influence biogas production. They also found variables that affect production efficiency include temperature, HRT, pH, and organic loading rate. They anticipated the optimum biogas yield at C:N ratio is 20–30:1. The pH of the slurry will change when there is a change in the C:N ratio. It has been noted that when the digester's pH is between 7 and 8, a good biogas yield would result. The performance of the microbial community will be determined by the organic loading rate, even if the organic loading will be determined by the digester's size. Biogas yield will be improved by proper selection of feedstocks, pretreatment technology and additive inhibitors. They examined the various pretreatments and additives used. In nature, there are many different bacteria that will directly boost an enzyme's activity to increase efficiency, which can quickly cut down on the HRT. Acetomycetes, a bacterial species, and other microbial cultures improved methane synthesis while decreasing COD levels.

Viswanath et al., 1992 [5] experimented on fruit and vegetable wastes for the production of biogas in anaerobic digesters and reported maximum biogas yield of 0.5- 0.6 m^3 kg^{-1} VS at the HRT of 20 days also the optimum loading rate was 40 kg TS m^{-3} day^{-1}. They found the maximum yield of biogas was 74.2% within 12 hours of feeding at 16 days HRT while at 24 days HRT the maximum yield reduced to 59.03%, while the average methane yield was found 51-53%. They suggested feedstocks which can be used for biogas production from fruit wastes of mango, pineapple, orange, banana,jackfruit and tomato etc.

Gutierrez S. G. et al., 2022 [7] identified Potential for agricultural wastes and livestock manure to reduce the need for fuel for cooking in rural regions. The situation involving the Colombian department of Cordoba. The 1334 TJ of biogas required to replace cooking firewood and the 390 TJ required to power home electricity may be supported by using 26% of the biogas-based energy potential found. By using biogas instead of cooking with firewood, GHG emissions may be cut to 11% of what they would otherwise be. In comparison to geomembrane tubular digesters, which need 2.4 times as much initial capital as fixed dome digesters, polyethylene tube digesters appear to be the most practical home technology.According to this study, using biogas instead of firewood for cooking can cut the amount of greenhouse gas emissions by 11%. To evaluate the effect of fugitive emissions on the department's residential digesters' capacity to contribute to global warming, however, a more in-depth research was required.

Stephen Bernard et al., 2020 [10] used vegetable waste and cow dung for production of biogas in 4 anaerobic digesters BG_1, BG_2, BG_3, BG_4(water content of 5L,10L,15L,20L respectively). They found that the optimum ratio of cow dung:vegetable waste:water to be 1:1:2. In their experiment they measured pH value for 60 days and found that BG_4 showed almost same final pH value as initial day but lowest biogas production. The reason behind that was low respiration and presence of more water content.Cowdung biogas typically developes with a pH influence between 6.2 and 7.8, and it has a high methane concentration. According to tests, the pH level on the first day is close to 8, which is an ideal range for the growth of anaerobic degradation. For $BG_1$and BG_2, the pH value from the previous day is now in the acidic range.In BG 1, biogas output was strong and 13.2% greater than in BG 4. In BGs 1 and 2, the high respiratory sub- strate is visible. The oxidation process that produced carbon dioxide and water was made possible by the oxygen present in the air. According to the cumulative data, BG 2 consistently produced high levels of biogas throughout the experiment, and for the best outcomes, the ratio of cowdung to vegetable waste to water was kept at 1:1:2.

Ounnar et al., 2012 [22] Performed experiment on cow dung for the production of biomethane. The laboratory experimentation findings were utilised as support in this work. 440 kg of cow dung were mesophilically anaerobically digested in an experimental digester with a capacity of 800 litres, producing 26.478 m^3 of biogas over a period of 77 days with an average optimum methane content of 61% . The utilisation of cow wastes, which are widely available in Algeria, or even home wastes, is encouraged by these results.

Karrabi M. et al., 2023 [23] studied in order to produce sustainable biogas in continuously fed digesters, this study intended to create an integrated energy recovery system that allows for the modification of feedstock and management of digester operational parameters. A modern energy recovery system was prototyped and installed in a genuine working environment for pilot studies after a variety of system components were designed and integrated. The system was set up to measure the moisture level of the feedstock, determine how much water has to be injected to improve the substrate quality, and then show that information to the operator. In order to prevent any potential obstruction of the biogas production process, the system also monitors the operational parameters of the digester and suggests remedial action. Efficiency and economic viability of an integrated energy recovery system for productive biogas applications have been investigated. When operating in continuous mode with complete monitoring and control of digester temperature, pH, %TS, and agitation, the system's VSR is 71%. This makes the system, even with substrates that have a low C/N ratio, 33% more efficient than the traditional one. Methane production and quality were greatly increased by 22%–25% as a result of the integration of a secondary reactor to capture leftover gas downstream of the first reactor. The instance of a chicken farm has been provided to show the value of the designed technology for profitable biogas applications.

Lahbab A. et al., 2021 [24] in their experiment on vegetable peels codigestion with cow dung for biogas production found that co digestion ratio (CDR) of vegetable peel and with cow dung of 3:1 produced the optimum yield of methane which was improved by 23-26% as compared to other CDR of 2:,1.5:1,1:1. The yield of methane that was produced ranged from 170 to 135.5 ml (CH4)/g VS.

Otieno E.O. et al., 2023 [25] found optimized biogas production from pineapple waste co digested with livestock stocks. The numerical optimisation results showed that the maximum biogas yield was 1.98 m^3 when the pH was 6.0, temperature was set at 30ºC, and pineapple mixing ratio was set at 62.5%. The results from this study can serve as a basis for policy makers in developing strategies to direct adoption of biogas produced from agricultural waste as a key green energy for the economy. When the pH value was 6.0, the temperature was 30 C, and the pineapple content was 62.5%, the biogas output was at its highest point of 1.98 m3 per day. Therefore, as it produces clean energy and lowers waste creation, co-digestion of organic wastes like pineapple and animal waste (cow dung and slaughterhouse waste) should be encouraged.

Sambo A.S. et al., 1995 [26] studied effect of effect of temperature, pH, carbon/nitrogen ratio and retention time on biogas production from cowdung were investigated. The findings demonstrated that temperature significantly affects the generation of biogas. Both thermophilic (50–60°C) and mesophilic (30–40°C) procedures can produce the highest output. When temperatures rise beyond 60°C, gas production begins to decrease and finally stops. The findings also demonstrated that the best gas generation happens at pH 7, then pH 9, whereas pH 4 appears to be too acidic for significant gas production.The nutrient addition suggested that greater calcium carbonate concentrations have a tendency to increase biogas production rates. According to research on mixing ratio and retention time, digesters with a larger proportion of cowdung produce more biogas and have longer retention times.

Jelínek M. et al., 2021 [28] quantified the impact of replacement of traditional cooking fuels by biogas. This study's goal was to evaluate the effects of biogas's partial substitution of conventional cooking fuels in two of the most common BGP sizes (6 m^3 and 9 m^3). In central Vietnam, semi-structured interviews with owners of biogas plants, masons, and biogas facilitators were part of a two-phase data gathering process. This study's goal was to determine how much the small-scale biogas facilities in central Vietnam contributed to global warming. The existing and projected GHG emissions from cooking activities were calculated using information on home energy use and the fuel mix ratio. These emissions were employed to calculate the GWP under various scenarios.It was advised to promote the improvement of BGP operation, ensure the excellent technical condition, and give the BGP owners better training based on the findings of this and previous research. The strategy may be used in other developing nations with small-scale biogas facilities of the Chinese type, despite the method's use being highlighted in the context of Vietnam.

Novotny V. et al., 2022 [35] studied the production of biohydrogen from biogas, according to a preliminary lifecycle analysis, electrolysis, which separates hydrogen and oxygen from water, displaces 13–19 tonnes more carbon dioxide every tonne of hydrogen generated from waste.In terms of finances, these systems are supported twice: initially by fees for receiving garbage and ultimately by sales of energy and hydrogen.

Banik S. et al., 2004 [31] studied substrates for spawn runs were disinfected with 2% formalin and 0.1% $KMnO_4$ in boiling hot water, using around 60% of the substrate, the maximum biological efficiency of the mushroom was achieved. All of the biogas residual slurry manures, including those made from cow dung, chicken manure, jute caddis, and municipal solid waste, have the ability to considerably raise oyster mushroom productivity over control while also enhancing the nutritional value of the mushroom yield. Due to the biogas residual slurry manure treatment used in the cultivation of mushrooms, the protein content rose while the carbohydrate content decreased.

According to **Khan S.A. et al., 2021 [30]** this evaluation placed particular emphasis on examining the potential of the carbonaceous substance "Biochar" and how it may be used by all three businesses to improve the biogas industry. Extensive discussion of the role that various biochar properties play in the biogas industry in overcoming difficulties with biogas production, syntrophic microbial activity, interspecies electron transfer, biomethane enrichment, and high-pressure bottling is based on a systematic review of the literature. The study found that characteristics like high pH, cation exchange capacity, electrical conductivity, and adsorption capacity improved the various biogas sector subsidiaries.

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According to **Linyi C. et al., 2020 [32]** in this study Anaerobic digestion (AD) with alkali pretreatment has been studied as a method to break down complex organic materials, such lipids. Using batch tests and long-term trials, AD of food waste (FW) with alkali pretreatment was carried out for 70 days in two reactors. The purpose of this study was to assess reactor performance in comparison to that of untreated FW and to examine the effects of alkali pretreatment on solubilization and biogas generation. The preparation with alkali made it easier for organic materials to dissolve. Overall, this investigation suggested an alkali pretreatment with 1% CaO as a viable AD of FW approach. This method might be applied realistically to break down complex organic waste and lessen the blockage of fats, oils and grease (FOG) in FW. However, it is cost-effective since CaO is less expensive than other alkalis. However, the ideal CaO concentrations should be modified according to the FW composition, pH, reactor temperature, and other factors.

2.5 Design of Anaerobic digesters

Jyothilakshmi R. and Prakash S. V. [12] designed a small scale anaerobic digester for biodegradable solid waste and calculated sizing of digesters.Identification of significant environmental contributing elements was made possible via life cycle assessment. Emissions from feedstock supply had a very small influence on the whole life cycle. The ozone hole significantly worsened freshwater eco-toxicity and metal depletion, but emissions from construction materials like cement, steel, etc. had little effect on global warming. Leaks of CH4 and CO2 from the plant significantly reduced climate change, resulting in (net) negative output. There were two calculations on cow dung and domestic wastes. They calculated biogas yield of 0.264 m3/kg VS from cow dung and from domestic waste slurry the biogas yield of 0.425 m3/kg VS.

2.6 Bio-Waste management

Glivin et al., 2021 [13] reviewed on biowastes to biogas The status of different factors relating to the successful use of biogas as an energy source for wider use was addressed in this article. With appropriate technology connected to the kind of biowaste and its availability, the bio-source segregation should be enhanced. They discovered that adequate pre-treatment or co-digestion processes might enhance the production of biogas from microalgae. Although there are several digestors and technology for digestion, two-stage digesters have a higher methane production than single-stage digesters. The decision-makers will be assisted in meeting societal needs while preserving the environment by this comprehensive analysis of current technologies, the potential of biowastes, conversion strategies based on availability, upcoming technologies, government policies, and economic benefits.

Tumusiime et al., 2023 [15] intended to create a comprehensive energy recovery system that would allow for continuous feed digesters to produce biogas sustainably while also allowing for feedstock modification and operational management. A modern energy recovery system was prototyped and installed in a genuine working environment for pilot studies after a variety of system components were designed and integrated. The system was set up to measure the moisture level of the feedstock, determine how much water has to be injected to improve the substrate quality, and then show that information to the operator. In order to prevent any potential obstruction of the biogas production process, the system also monitors the operational parameters of the digester and suggests remedial action. The system may be used to replace traditional energy use for productive applications and is about 33% more efficient than the conventional one, according to the results. It also allows for the modification of feedstocks.

Xu et al., 2019 [19] studied on digested sewage sludge and cow dung biogas residue co-hydrothermally carbonised. When digested sewage sludge (DSS) and cowdung biogas residue (CDBR) were hydrothermally carbonised combined, the carbon content and high heating value(HHV) of the hydrochars were enhanced. According to the decreasing O/C and H/C atomic ratios, the co-hydrothermal carbonization's primary process was dehydration.By boosting the ignition temperature and the comprehensive devolatilization index, CDBR significantly enhanced the combustion attributes of hydrochar. Particularly for the hydrochar with 75% CDBR, the activation energy of the hydrochar from co-hydrothermal carbonization significantly increased. According to this study, co-hydrothermal carbonization of the mixed feedstocks was a viable method for producing high-quality hydrochar for energy recovery.

Singh A.D. et al., 2020 [27] studied the life cycle assesment of sewage sludge in large scale biogas plant.The findings showed that the repercussions of the whole life cycle were unaffected by the plant's design. When compared to coal-based electricity plants, biogas plants demonstrated lower GHG emissions (0.2385 kg CO_2 eq/m^3), and the digestate they generate may be a useful alternative to artificial fertiliser.Identification of significant environmental contributing elements was made possible via life cycle assessment. Emissions from feedstock supply had a very small influence on the whole life cycle. The ozone hole significantly worsened freshwater eco-toxicity and metal depletion, but emissions from construction materials like cement, steel, etc. had little effect on global warming. Leaks of CH_4 and CO_2 from the plant significantly reduced climate change, resulting in (net) negative output.

Gill-Wiehl A. et al., 2022 [29] They estimated that BPL policies had an overall 0.68 kilogramme per family increase in LPG use. For home delivery or cooking energy access tier, we observe no influence. Their research recommended that the strategy should be expanded in order to more effectively address consumption. In addition to better targeting of BPL households, this research recommended looking at consumption incentives and the quantity of the refill subsidy.The purpose of this study was to determine whether families in the comparison group—those who are marginally over the poverty line—would pay for the initial LPG connection as a result of the applicable BPL policy package.According to their findings, BPL rules are an effective push for families to use LPG, but the push is not strong enough to significantly raise households' clean fuel usage or their tier.

Leca E. et al., 2023 [33] found the greatest extent feasible, this literature study sought to address the impacts of the addition of different additives in co-digestion continuous or semi-continuous reactors. Analysis and discussion are provided on the addition of (i) microbial strains or consortia, (ii) enzymes, and (iii) inorganic additives (trace elements, carbon-based compounds) in the digester.However, there is little information on the application of additives as a tactic to overcome obstacles faced by collective territorial plants (inhibitions, foaming, complicated rheology). The majority of research have been done in batch reactors at the lab size, and there aren't nearly enough studies done in industrial settings or with long-term continuous reactor operation to generalise results to the scale of a large biogas plant.

Sawatdeenarunat et al., 2019 [3] suggested the potential of industrial effluents in biogas production. They offered the wastewater from eight significant industries with strong potential for producing biogas. Different feed require special precautions for anaerobic digestion. Common preferable choice for optimum biogas production will their high organic content but the lower concentration. Unwanted characteristics inherited from industrial effluents are present in the raw materials and specific processing of each industry, such as FOG(Fat, Oil, Grease) in palm oil mills and meat processing plants, salt and low temperatures in seafood processing plants, high sulphate in ethanol wastewater, high ammonia levels in animal feed, and high C/N and low pH levels in brewery and starch wastewaters. The higher-rate system is preferred by newer generations of industrial effluent AD because it reduces system footprint and is less sensitive to changes in hydraulic and organic loadings and toxicants. To fulfil authorised discharge standards, it is necessary to increase the organic conversion efficiency of these wastewaters to close to 100%, which will both increase the generation of bioenergy and significantly reduce the amount of aeration energy required in the subsequent treatment train. With advancements in biotechnology, material science, and process engineering, AD of industrial effluents may one day be able to not only convert almost all organic materials into bioenergy but also offer the most effective treatment to take the role of aerobic processes.

2.7 Study on Ultrasonication

Aylin Alagoz et al., 2018 [2] had done ultrasonication on agriculture wastes and wastewater sludge for biogas production and compare the result with microwave assisted biogas production from same feedstock. In their experiment they took olive pomace (OP) and grape pomace (GP), as agricultural wastes.They found in their experiment that ultrasonic assisted agricultural waste anaerobic co digested by waste water was much efficient than microwave assisted biogas production on same feedstock. Only 10-15% increases in biogas/methane yield were observed as a result of the microwave pre-treatment since the specific energy required was nearly 9 times greater than that utilised during ultrasonication.The rate-limiting "hydrolysis" stage was speed up by the ultrasonication and microwave pre-treatments for sludge, and the anaerobic biodegradability of organics in sludge samples was improved, increasing the yields of biogas and methane. Based on the applied specific energies, ultrasonication was shown to be a more effective sludge pre-treatment approach than microwave irradiation.

Quiroga et al., 2014 [11] identified the anaerobic co-digestion of bovine dung with food waste and sludge and the impact of ultrasound pre-treatment.Several studies were conducted in continuously stirred-tank reactors using 70% bovine manure, 20% food waste, and 10% sewage sludge under mesophilic and thermophilic conditions. When sewage sludge and bovine dung were sonicated, running at lower HRT resulted in greater volumetric methane outputs of 0.85 L CH4/L day at 36 °C and 0.82 CH4/L day at 55 °C. These figures reflect increases of up to 31% and 67% for mesophilic and thermophilic digestion, respectively, in comparison to the non-sonicated waste.

Lizama et al., 2017 [16] studied kinetic and solubilization of anaerobic biogas production from waste activated sludge. This study looked at the effects of WAS's ultrasonic pretreatment (USp) as a means of enhancing AD. The solubilization of macromolecules, behaviour of heavy metals, pathogen inactivation, and biogas generation were all assessed. A range of 5000–35000 kJ/kg TS (total solids) was used for USp. at 35000 kJ/kg TS, proteins were solubilized to a maximum degree of 22.9% and soluble chemical oxygen demand to a maximum of 26%. Even though the greatest USp only lowered the pathogens by 2 log units, a substantial level of inactivation was still achieved when the TS were dropped to 2% and continuous stirring was used. When the biochemical methane potential tests of the AD of raw and sonicated WAS were compared, the greatest USp resulted in a biogas overproduction of 31.43% (219.5 mL/g VS).An effective approach to increase the anaerobic digestion effectiveness of waste activated sludge (WAS) was found to be ultrasonic pretreatment. Over the examined range of Specific energy, sonication of WAS causes a rise in the solubilization of the organic components, primarily proteins.

Zou et al., 2016 [18] studied the effect of ultrasoncation on maize straw(MS) and dairy manure(DM) for anaerobic biogas production. They used ultrasonication time were 0,20,30,40 min at different power intensity and found that 30 min ultrasonication provide maximum yield of biogas of 240.32 mL/g Vs_{fed}. They also observed the surface structure of maize straw and dairy manure with the help of scanning electron microscopy. Ultrasonic pretreatment had an impact on the digester feed's cellulose activity (CA), reducing sugar (RS) content, volatile fatty acid (VFA) content, pH, and their maximum and lowest values throughout the anaerobic digestion (AD) process. The primary determinants of biogas generation varied across pre-treated samples, and it was shown that variations in the correlation between CA, RS, pH, and VFA concentration during the AD process made the digestive environment more conducive to AD.

[20] Azman et al., 2020 in their study on manure digestate assisted by ultrasonication(US) in anareobic digester for enhanced biogas production Disintegrated digestate was mixed with an equivalent volume of new manure feed to feed one of the digesters. According to the data, methane production rose by 18% following US-assisted digestate treatment at 1500 kJ/kg TS specific energy input with 30 days of hydraulic retention time. It was discovered that the applied specific energy and organic loading rate were associated to the enhanced methane generation rate. An elementary cost-benefit analysis revealed that the US disintegration at lab size required more energy than what could be recovered from the extra methane generated.

Deepanraj et al., 2017 [21] studied the effect of autoclave, microwave and ultrasonic pretreatment on anaerobic digestion of food waste with poultry manure and found that ultrasonication enhanced the biogas production cumulatively increased by 10.12%, which was maximum as compared to autoclave and microwave pretreatment.The biogas output and VS removal of ultrasonicated substrate rose from 8921 to 9926 ml and 41.96 to 46.52 g/l, respectively, as compared to non-treated substrate.

2.8 Research Gaps

- After analysis of several papers on anaerobic biogas production one things comes to highlight that the rate limiting stage of biogas production is hydrolysis,which is a first step of anaerobic digestion. In this stage polymeric organic compound like polysaccharides etc. to respective monomers like sugar, fatty acids etc, without pretreated substance this stage limit the rate of reaction and results lower yield of methane.

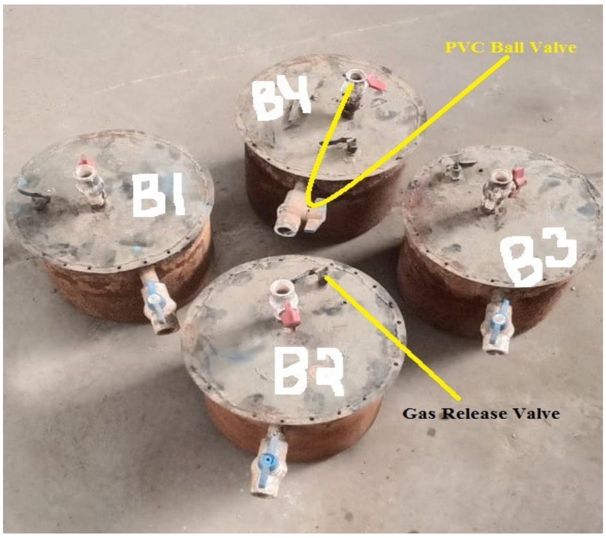
- Among all pretreatment method ultrasonic pretreatment is one of the promising pretreatment where it consumes less energy input for the certain energy output as compared to microwave and autoclave pretreatment method [2], [21].
- Along with optimizing the hydrolysis stage ultrasonic pretreatment advance the biogas production and improve the quality of methane in produced biogas. Ultrasonic pretreatment is much suitable for mass production of biogas.
- Proper feedstocks selections and their biogas formation potential,their pH value, Hydraulic retention time (HRT), ultrasonication time, temperatures,voltages,frequencies,use of suitable additives etc all these factors are to be kept in mind for optimum biogas production.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Experimental setup

Experiment was conducted on batch type lab scale anaerobic digesters. Four anaerobic digesters (Fig.1) of 10 L volume each were used to keep cow dung slurry and feed in different proportion in absence of air. Each digester filled with 75% of full capacity i.e., 7.5 L. For attaining anaerobic condition there were two PVC ball valves at two sepearate locations are attached to each digester from where feed can be poured into the digesters. There is one gas release valve are attached to each digester so that biogas formed can be easily taken out into bags through a pipe (Fig.2) which can be connected to gas release valve at time of collection of biogas.



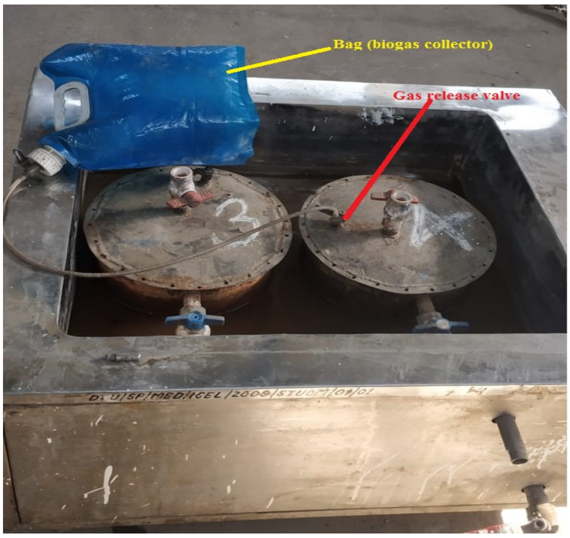


Fig.1 Anaerobic Digesters **Fig..2** Biogas Collector Bag

There is a biogas analyzer instrument(Fig.3) which can measure the content of methane (CH_4), carbon-di-oxide (CO_2), oxygen (O_2) and hydrogen sulphides (H_2S) present in the biogas obtained by anaerobic digestion. For pre-treatment of feedstock a ultrasonic cleaner machine (1.5kW,18kHz,230V) used with temperature control from 30 ºC to 120 ºC as shown in Fig.4.

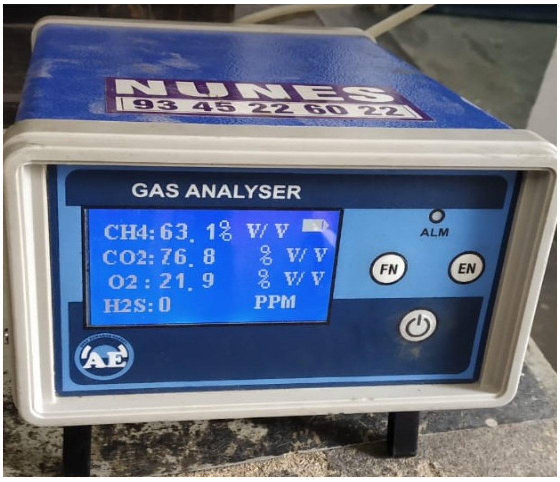


Fig.3 Gas Analyzer

Fig.4 Ultrasonic Cleaner

TABLE 3.1 Specification of Biogas Analyzer (Nunes Instruments)

DISPLAY	128 X 64 GRAPHICAL LCD
CALIBRATION	AUTOMATIC ZERO & SPAN WITH FRESH AIR SAMPLE CALIBRATION GASES
ACCURACY	+/- 1%
RESPONSE TIME	<60 SECONDS AT 95 % VARIANT
POWER SUPPLY	INTERNAL NI – CAD BATTERY
WORKING TEMPERATURE	-5 o TO 55 o C
STORAGE TEMPERATURE	-20 o TO 55 oC

TABLE 3.2 Parameters of Biogas Analyzer

PARAMETER	SENSOR	(min/max)	RESOLUTION	ACCURACY
CH4	NDIR	0-5%/100%	0.1%	+/- 2%
CO2	Semiconductor	350-1000PPM/ 100%	0.01%	+/- 1%
H 2S	Electrochemical	0 - 50/500PPM	1PPM	+/- 2%
O2	Electrochemical	0-100%	0.1%	+/- 2%

TABLE 3.3 Technical Specifications of Ultrasonic Cleaner

Voltage	220 Volt
Power	300-1500W
Frequency	18 kHz (low ultrasound)
Temperature control	30-110 oC

3.2 Feedstocks used

In this experiment food wastes are taken from canteen and mess of Delhi Technological University. The collected food wastes were blended with kitchen blender. Cow dung was collected from nearby Shahabad dairy, New delhi. Sludge water was collected from plant of biogas inside campus of Delhi Technological UniversityThe pH of Food waste measured was 7.8 with the help of pH electrode [10], [21]. Digester capacity was of 10 L while 2.5 L was kept vacant for gas formation, total 7.5 L Cowdung slurry was made. Slurry was made with the help of sludge water, the proportion of cowdung : sludge water was taken as 1:1.5 [10], [11], [22] with additive of jaggery was 10gm per kg of cowdung . The total solid (TS) with OLR was 6 kg TS $m^{-3}day^{-1}$ [5].Cow dung slurry was kept at HRT of 17 days at room temperature between 28ºC and 32ºC where methane yield was found 56% optimized from previous studies[1].

3.3 Ultrasonic Pre-treatment on substrate and feedstocks

After HRT within 10 hours B1 and B2 was pre-treated with ultrasound for 35 minutes at 50ºC and 60ºC on regular basis for 7 days and it was found that methane yield was 58- 63% which was optimized from [11], [16], [20]. The ultrasonic cleaner operates on 1.5kW power 18 kHz frequency (low ultrasound) with 230V supply. B3 and B4 was treated by coil inside it at 50ºC and 60ºC on regular basis for 7 days which yield methane was 43-45%. It was seen that at thermophilic condition without USp, the methane yield was lower. After that the cowdung slurry was pre-treated with food waste where proportion of cowdung:food waste:sludge water was 1:1:1.5. Ultrasonication was given for 35 minutes for 10 days on regular interval on food waste treated cowdung slurry and it was observed that the methane yield was 63-67%. The economic viability at the lab scale was better than the microwave assisted pre-treatment in terms of energy requirements for given energy produced [21]. However,the requirement of energy at lab scale biogas production was more which was negative energy [20].

3.4 Data Validation

The Central Composite Design (CCD) forecast was tested and confirmed when the ideal circumstances were attained. Utilising the expected values, this was done experimentally, and the proportion of methane output produced was recorded as "responses". To demonstrate the result viability, a comparison between experimental and anticipated values was done.

3.4.1 Optimization Methodology

RSM uses a range of mathematical, statistical, and graphical methodologies, techniques, and tools to develop, improve, and optimise a process. When our answer variables are impacted by a variety of independent factors, it may also be used to do modelling and analysis. Due to its advantages over conventional one-variable-at-a-time optimisation, such as the capacity to generate large amounts of data from a small number of experiments and the capacity to assess the interaction effect between the variables and the response surface, RSM is now widely used in the optimisation of analytical procedures. When using this method for experimental optimisation, you must first choose an experimental strategy, fit a suitable mathematical function, and then evaluate the fit of the model before generating predictions based on the experimental findings.

3.4.2 Design Expert software

RSM technique can be applied in "Design Expert" software, a statistical and mathematical tool. It provides test matrices for screening up to 50 variables. The statistical significance of these variables is assessed using analysis of variance (ANOVA). Graphical tools make it easier to see how each component affects the desired outcomes and spot data irregularities. The needed number of test runs may be determined with the help of a power calculator. An ANOVA is used to assess statistical significance. A numerical optimizer that is based on tested prediction models aids the user in choosing the best values for each of the experiment's variables."Design-Expert" provides 11 visuals in addition to text output for the residuals evaluation. RSM provides an estimate for the value of responses for any conceivable combination of the elements by altering the values of all variables simultaneously, which enables it to comprehend a multi-dimensional surface with non-linear shapes. The process' ideal solutions may be found using the optimisation function (*Stat-Ease Handbook for Experimenters*, n.d.).

CHAPTER 4
RESULTS AND DISCUSSIONS

Fig.5 indicates the methane quality in biogas as number of days increases after HRT of 17 days. Digesters B1 and B2 was pre-treated with ultrasonic cleaner at 50ºC and 60ºC respectively for 35 minutes for 10 days and found the result in increasing of methane yield of 63% and 65% as compared to B3 and B4 which was maintained at 50ºC and 60ºC respectively which yield methane of 44% and 44.7% at lower pace as compared to energy supplied and cost associated with it. Feed of food waste and sludge water in proportion of cow dung:sludge water:food waste is 1:1.5:1 shows the maximum yield of methane in biogas produced. From fig.5 and fig.6 it was clear that food waste leads to maximum methane yield of 69% with ultrasonic pre-treatment at thermophilic condition.

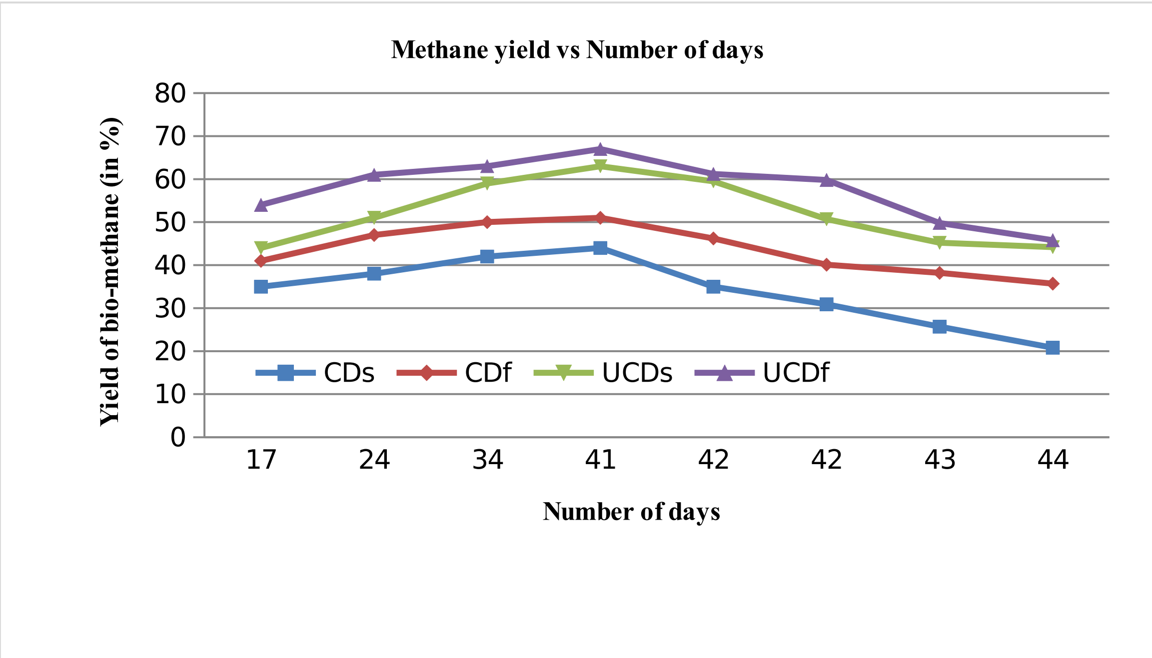


Fig.5 Percentage Bio-methane Yield vs Number of Days after HRT

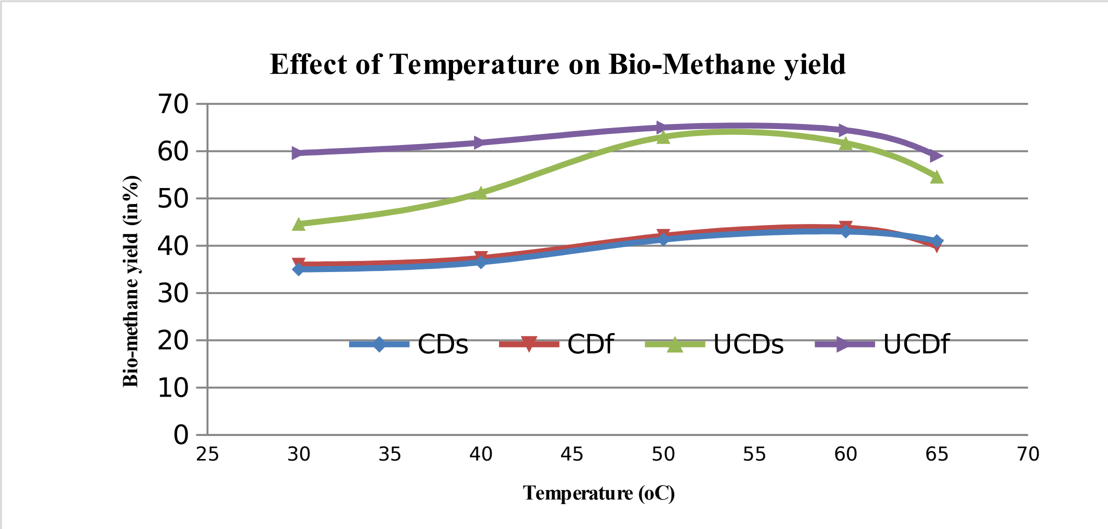


Fig.6 Temperature Variation on Bio-Methane Yield With or Without Treated Substrate

The pH value of CDs observed initially was 7.8 and finally it was 6.5 this pH was acidic not suitable for anaerobic digestion. At the end of 50^{th} day CDs slurry shows degradation of methane yield in biogas produced.

Different Slurry ratios (Cow dung:water) are indicated by

R1-1:0.75

R2-1:1

R3-1:1.5

R4-1:2

For these slurry ratio the pH value at first day and last day was observed in fig.7, it was obtained that for R1and R2 at first day the slurry was nearly 8 while at the last day (at 45^{th} day) was acidic. This shows how dilution play crucial role in decomposition reaction. While R4 shows pH value nearly same as first day as Last day which is nearly 7 and satisfy the digestion reaction.

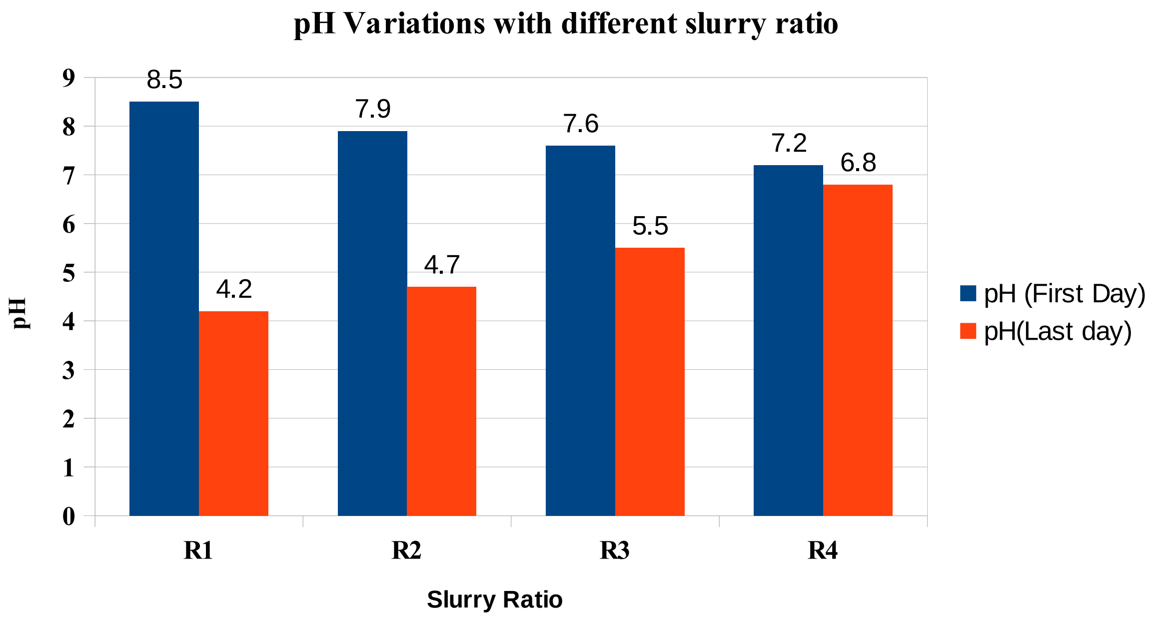


Fig.7 pH Variations at different Slurry ratio (Cowdung:water)

Since at the very first days there is sufficient presence of air in anaerobic digester from its porus medium and substrates show good respiratory and produce large amount of biogas while as after few weeks the biogas production reduced due to less substrate respiration since there is anaerobic condition.

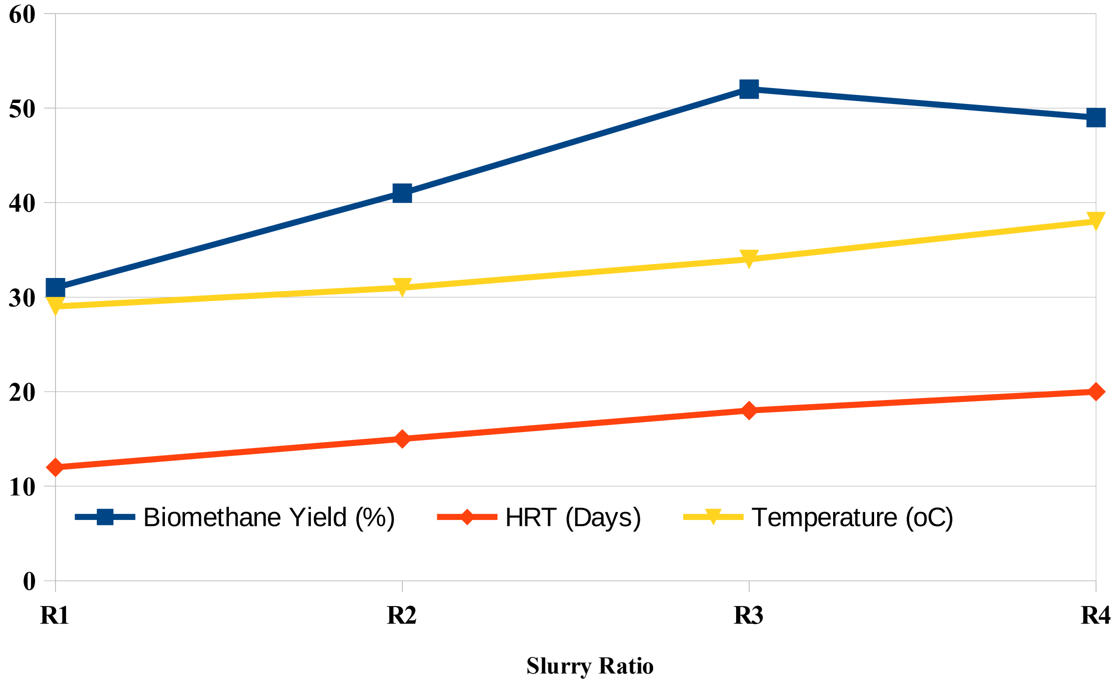


Fig.8 Parameter Variation on Bio-Methane Yield with different slurry ratios , HRT, Temperatures

Different Parameters have shown in fig.8 which further optimized with the help of RSM. This graph was taken while our anaerobic digesters was kept untreated with ultrasound, also the temperature variations was ambient and month was March-May. The optimum biomethane was obtained at R3 digester which contain slurry ratio of 1:1.5. Also this was seen that increasing temperature results in enhancing the biogas production. Also when HRT increased the biogas formation tendency also increases. Further there is treatment of feedstock and use of additive which further enhance the biogas production. The experimental results were compared to anticipated RSM techniques.

4.1 Result validation through RSM

The percentage of methane yield produced from UCDs under different sonication time, temperatures and the digestion time after HRT conditions set by Central composite design are presented in Table 1.The percentage of methane was obtained across 28 days after HRT and responses are recorded for 17,20,23,26,28 days are displayed. The highest methane yield percentage was found 65.63% in run #7 for 8 days after HRT while lowest was observed 24.27% in run #13 for 28 days after HRT.Different responses were caused by variations in the values of the manipulable variables (factors). This made stating the necessary link between the variables and answers, and as a result, result data equation 1 was created.

Table 4.1 Ranges of ultrasonication time and temperature input for design expert®(2 factors)

Factor	Name	Units	Type	SubType	Minimum	Maximum	Coded Low	Coded High	Mean	Std. Dev.
A	sonication time	minutes	Numeric	Continuous	10.00	60.00	-1 ↔ 10.00	+1 ↔ 60.00	35.00	17.68
B	temperature	degree celcius	Numeric	Continuous	20.00	100.00	-1 ↔ 20.00	+1 ↔ 100.00	60.00	28.28

Table 4.2 Ranges of ultrasonication time and temperature input for design expert®(3 factors)

Factor	Name	Units	Type	Sub Type	Minimum	Maximum	Coded Low	Coded High	Mean	Std.Dev.
A	Ultrasonic Temperature	degree celcius	Numeric	Continuous	25.00	60.00	-1H 25.00	+ 1H 60.00	42.50	12.70
B	Ultrasonic time	minutes	Numeric	Continuous	15.00	60.00	-1H 15.00	+ 1H 60.00	37.50	16.32
C	Number of days	days	Numeric	Continuous	17.00	45.00	-1H 17.00	+ 1H 45,00	31.00	10.16

4.2 Factors optimization

The effect of ultrasonication time and temperature on methane yield percentage is displayed on 3D plot as shown in Fig.6. The display shown a higher interaction between ultrasonication temperature and methane yield percentage, and a marginal interaction on ultrasonication time and methane yield percentage. The yield of methane grew as the temperature of the ultrasonication process rose, but it eventually started to fall as the process parameters departed from their ideal range. The sonication duration did have an impact on gas generation, however it had a little impact in comparison to the ultrasonication temperature.

Table 4.3 Methane yield % for various setup circumstances(2 factors)

Run	Factor 1 A:Sonication time (minutes)	Factor 2 B:Temperature degree (celcius)	Response 1 Methane yield %
1	10	20	29
2	35	60	55
3	60	100	25.6
4	35	60	59.8
5	60	60	45.3
6	10	60	50.1
7	35	60	63
8	35	60	59.8
9	35	60	56.4
10	10	100	27
11	35	20	44.6
12	60	20	53.7
13	35	100	20.2

The Central Composite Design forecasted the ideal circumstances for the highest methane output using numerical and point prediction optimisations. According to the forecast, the ideal parameters for the highest output methane yield were sonication duration of 35 minutes, ultrasonication temperature of 60°C, and anerobic digesting period of 8 days following HRT. The greatest methane output that could be expected under these circumstances was 63%.

As a result, the simplified quadratic result data for the methane yield produced from cow dung, which was determined for ultrasonication duration (A) and ultrasonication temperature (B), is presented as follows in 1:

Methane yield = 1.10762 + 0.514833*A+1.67218*B-0.006525*A*B-0.013924*B² (1)

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor.

Table 4.4 Methane yield % for various setup circumstances(3 factors)

Run	Factor 1 A:Ultrasonic Temperature (degree celcius)	Factor 2 B:Ultrasonic time (minutes)	Factor 3 C:Number of days (days)	Response 1 Methane yield (%)
1	42.5	37.5	31	62.1
2	60	60	17	21
3	42.5	37.5	45	63
4	25	60	45	38.6
5	42.5	15	31	41.8
6	60	60	45	23
7	60	15	45	44.9
8	25	37.5	31	40.1
9	25	15	17	38.9
10	42.5	37.5	31	49.2
11	42.5	37.5	17	44.5
12	42.5	37.5	31	62.1
13	42.5	60	31	43.5
14	60	37.5	31	40.2
15	25	15	45	45.9
16	42.5	37.5	31	62.1
17	60	15	17	31.3
18	25	60	17	36.8
19	42.5	37.5	31	62.1
20	42.5	37.5	31	62.1

Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space. The normal probability plot of residuals and the expected vs. actual methane output is shown in Figure 7(a) and (b). Plots demonstrate that the testing results are typical; as a result, the result data is successful in estimating methane yield output.

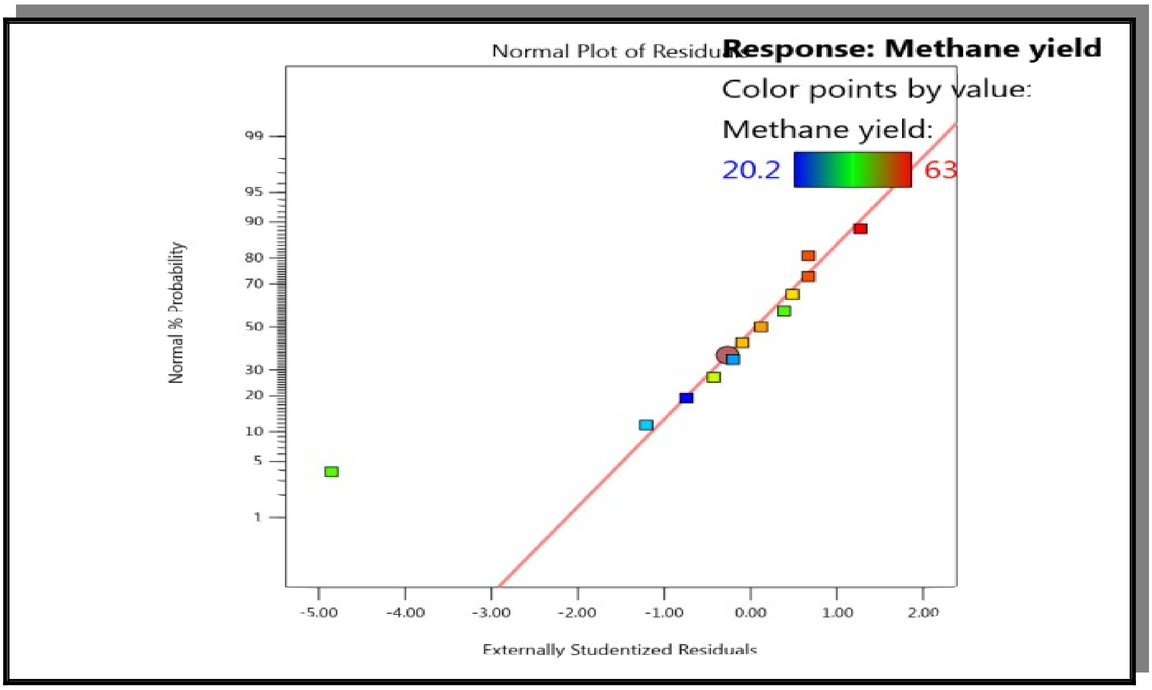


Fig.9 (a) Plot of Residuals vs Normal Probability

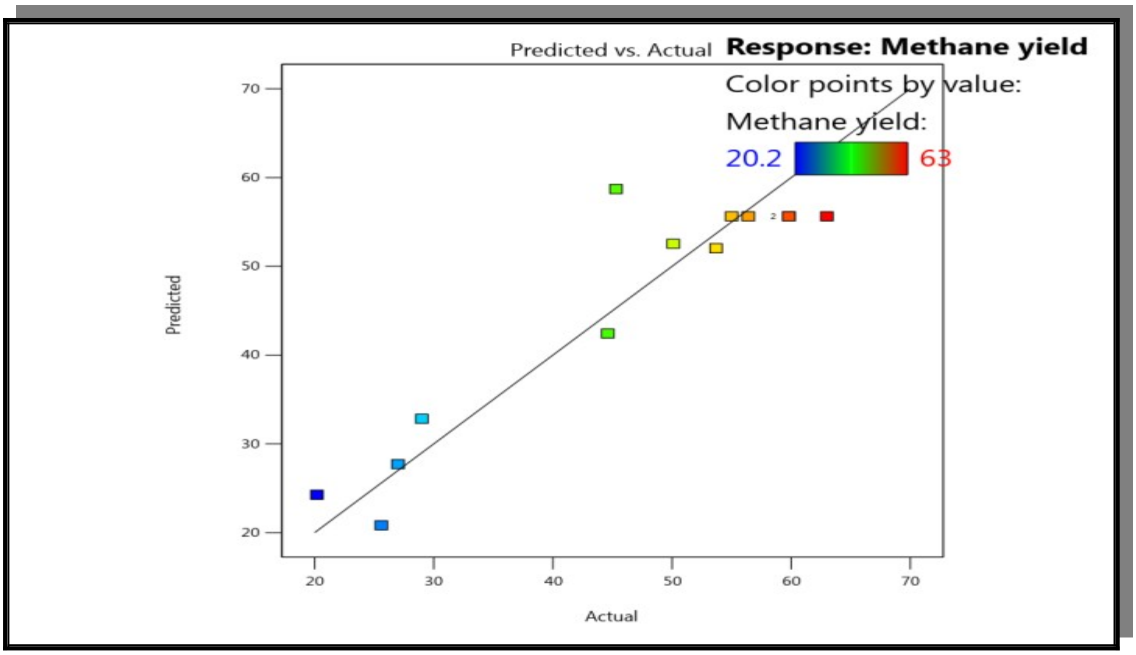


Fig.9 (**b**) Plot of Actual and Predicted values.

The regression equation's 3D response surface map (Fig. 8) revealed modest connections between the variables. The findings demonstrated that equation 1's result data was correct and satisfactory, and that the response result data was sufficient for representing the anticipated optimisations. Such interactions were noted in prior research (Ghaleb et al., 2020; Ibrahim et al., 2021) that used RSM for prediction in ultrasonicated biogas production and RSM for methane production optimisation. The prediction's validation indicated a 63% methane output. As 4% was the recorded percentage error, this result was quite near to the expected figure of 65.63%, confirming the sufficiency and validity of the predicted result datas. The percentage error should not be more than 30 % (Chun et al., 2015). In order to confirm the prediction and result dataling abilities of RSM, Analysis of Variance (ANOVA) (Table 3) for the response surface result data fit was performed.The ability was assessed using the coefficient of determination (R^2), enough precision, and lack of fit values for key result data parameters. The R^2, Adjusted R^2, Predicted R^2, and Adequate precision values were 0.8732, 0.8097, 0.5453, and 9.3999 respectively, indicating that the result data was highly significant according to the ANOVA, which had a low P-value of 0.0012 and a high F-value of 13.77. The regression result data's F-value demonstrated its importance, which is consistent with the findings of (Montingelli et al., 2016). It has been recommended that the value should be about 0.80 for the excellent fit of a result data when using the R^2 to assess the result data's goodness of fit (Pei et al., n.d.). The result data's high R^2 values attest to its consistency with the experimental data (Giwa et al., 2013)

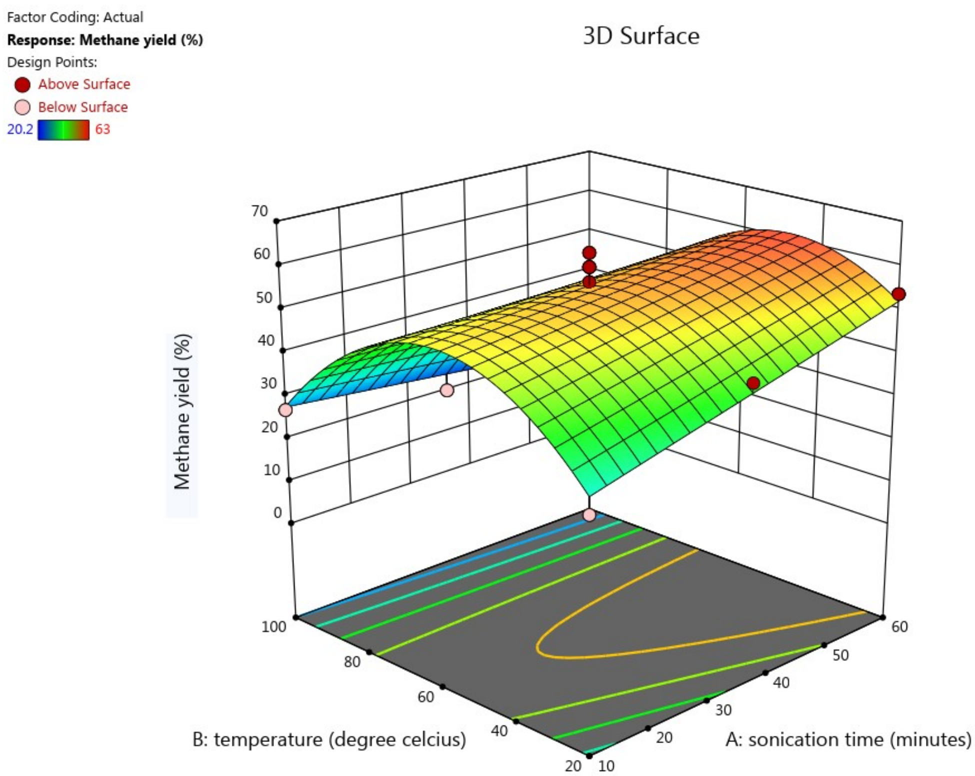


Fig.10 3d Surface Showing Interaction between Sonication Time, Ultrasonication Temperature and Bio-Methane Yield Percentage

Table 4.5 variance Analysis

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Result data	2325.93	4	581.48	13.77	0.0012	Significant
A-sonication time	57.04	1	57.04	1.35	0.2787	
B-temperature	495.04	1	495.04	11.72	0.0090	
AB	170.30	1	170.30	4.03	0.0795	
B^2	1603.54	1	1603.54	37.96	0.0003	
Residual	337.90	8	42.24			
Lack of Fit	298.06	4	74.52	7.48	0.0384	Significant
Pure Error	39.84	4	9.96			
Cor Total	2663.83	12				

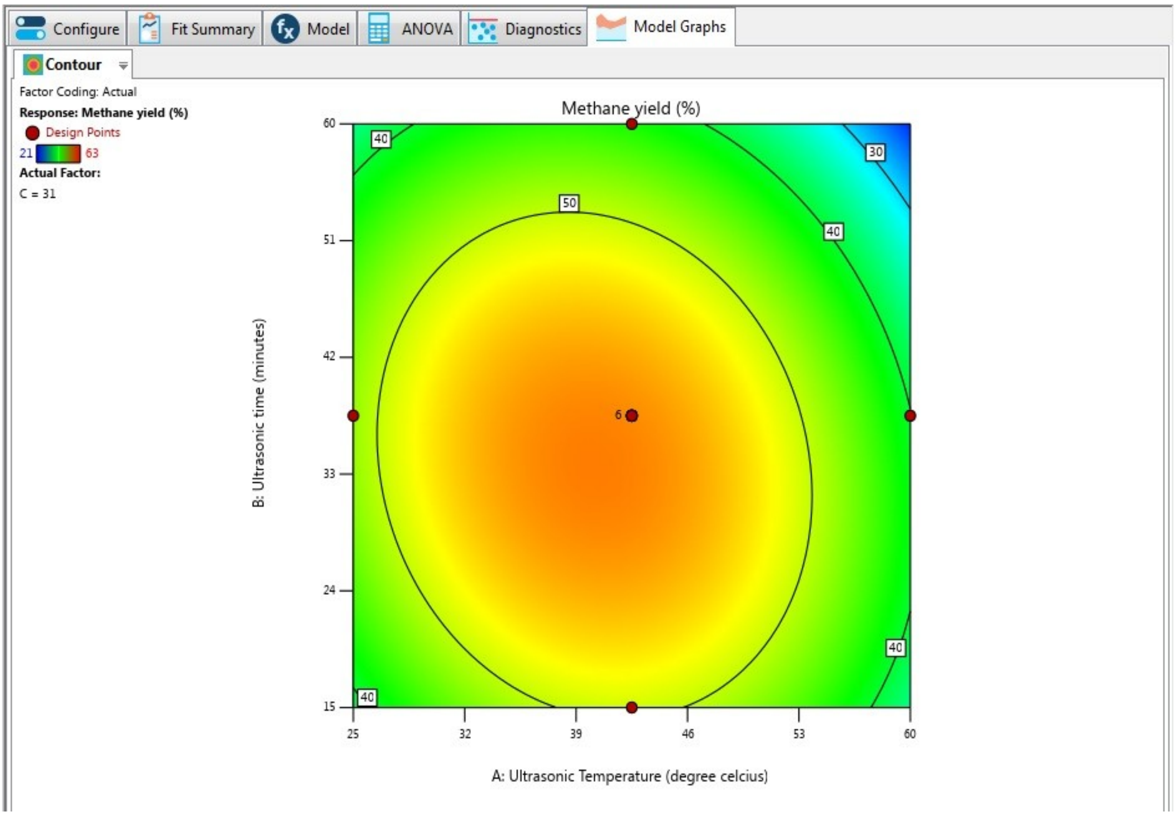


Fig.11 For Interactive Effect of Ultrasonic Time and Ultrasonic Temperature on Optimum Biogas Production

Result terms are significant when their p values are lower than 0.05. Result terms are not significant if the p value is higher than 0.10. The values suggested that the study's result was sufficient for the design of space navigation, according to (*Stat-Ease Handbook for Experimenters*, n.d.) The adjusted R^2 of 0.8097 was quite consistent with the predicted R^2 of 0.5453, and the square of the correlation coefficient (R^2) value was near to 1. The result was inferred to be significant by the result F-value in the F-test. Noise has a very little possibility (0.12%) of causing an F-value this significant. The result source's Sum of Squares was 2325.93. Each regression source's degrees of freedom (DF) was correspondingly one, giving the result source a total DF of 4. The sum of squares divided by the matching DF yielded the result's mean squares, which came to 581.48. The result in this case has a Lack of Fit F-value of 298.06 and an Adequate Precision of 9.3999. According to the Lack of Fit, the relative inaccuracy was considerable. There is a potential that this will happen as a result of the noise.

CHAPTER 5
CONCLUSIONS

An proven technique for creating biogas, a sustainable energy source, is anaerobic digestion. The method is constrained, nonetheless, by poor methane yields and sluggish hydrolysis rates. Anaerobic digestion has been proven to be more effective when ultrasonicated, however it is unclear what the ideal circumstances are for the procedure. Response surface methodology (RSM) will be used in this study to optimise the ultrasonication-assisted anaerobic digestion process for the generation of biogas. A central composite design (CCD) will be used to examine the effects of ultrasonication duration, ultrasonic power, and substrate concentration on the generation of biogas. In order to create a prediction model that may be utilised to improve the procedure, the findings will be analysed using RSM. The goal of this study is to use response surface methods to optimise the ultrasonication-assisted anaerobic digestion process for the production of biogas. The findings of this study will lead to the construction of a prediction model that can be used to optimise the procedure and will provide light on the impacts of ultrasonication duration, ultrasonic power, and substrate concentration on biogas generation. The results of this study may increase the effectiveness of biogas production, which might lead to the creation of a more ecologically friendly and sustainable energy source. An optimistic and growing technique for producing sustainable biogas from organic waste is anaerobic digestion. For both researchers and practitioners, increasing the effectiveness of anaerobic digestion systems has emerged as a major goal. By encouraging microbial activity and breaking down complicated substrates, ultrasonication has become recognised as a possible approach to enhance the efficiency of anaerobic digestion systems. This study uses Response Surface Methodology (RSM) as a statistical method to include ultrasonication into the anaerobic digestion process to improve the generation of biogas.

- The study technique entails carrying out studies to assess how ultrasonication affects the functionality of anaerobic digestion and identify the ideal operating settings. The experimental data will be designed and analysed using the RSM, enabling the identification of key process variables and their optimum values. The impacts of systematically varying variables on biogas generation, methane content, and process stability will be monitored and analysed. These variables include ultrasonication intensity, sonication time, substrate concentration, and temperature.

- RSM will be used to fit the data to a mathematical model, enabling the creation of a prediction model to enhance the anaerobic digestion procedure. The ideal circumstances for maximising biogas output and methane content while preserving process stability will be determined by the model by taking interactions between the input variables into account. A greater understanding of the underlying mechanisms will be made possible by the statistical analysis, which will offer insightful information on the individual and combined impacts of the process variables.

- The findings of this study are anticipated to develop anaerobic digestion technology and its use in the generation of biogas. This study will provide useful recommendations for increasing biogas outputs, promoting energy recovery, and lowering environmental effects related to the treatment of organic waste by optimising the process by ultrasonication and RSM.

Anaerobic digestion is a promising technology for the production of biogas from organic waste. However, the efficiency of the process is limited by the low solubility of substrates in the digester. Ultrasonication has been shown to improve the solubility of organic matter and can thus enhance biogas production. In this study, the effects of ultrasonication on biogas production were investigated using response surface methodology (RSM). The results showed that ultrasonication significantly improved biogas production, with an optimal sonication time of 35 minutes. The study demonstrated that ultrasonication can be a promising technology for improving biogas production in anaerobicdigestion. According to the study's findings, cow dung anaerobic digestion produced more methane when ultrasonic pre-treatment was applied. ideal ultrasonication period,Temperature and hydraulic retention time were shown to be crucial for maximising methane output. For the highest percentage of methane output from cow dung, numerical optimisation identified an ultrasonication period of 35 minutes, temperature of 60ºC, and retention time of 8 days following HRT.

These criteria are stated in a result data equation that was developed. Ultrasonic pre-treatment have an issue with its energy consumption as compared to biogas production at the lab scale. Further research on alternative energy source can be done for reducing energy demand for ultrasonication from conventional fuel.

Future Scopes:

- This research requires further improvement in energy input for ultrasonication, the renewable energy source must be integrated with ultrasonicator machine. This will make process energy positive.
- Further research on choosing of feedstocks and their pretreatment methods, use of suitable additives which enhance the rate of reaction and yield more methane content and optimized the process of waste management.
- Conventional energy source input limit the use of ultrasonication pretreatment at lab scale , but at large scale we can produce more sufficient energy whatever we used for. Research must be done on alternative sources of energy.

References

[1] K. Nand, S. Sumithra Devi, P. Viswanath, S. Deepak, and & R. Sarada, "Anaerobic Digestion of Canteen Wastes for Biogas Production : Process Optimisation," Process Biochemistry, 1991, pp. 1-5. doi: 10.0032j.deveng.1991.959291.

[2] B. Aylin Alagöz, O. Yenigün, and A. Erdinçler, "Ultrasound assisted biogas production from co-digestion of wastewater sludges and agricultural wastes: Comparison with microwave pre-treatment," *Ultrason. Sonochem.*, vol. 40, pp. 193–200, Jan. 2018, doi: 10.1016/j.ultsonch.2017.05.014.

[3] C. Sawatdeenarunat, C. Wangnai, W. Songkasiri, P. Panichnumsin, K. Saritpongteeraka, P. Boonsawang, S. K. Khanalk, S. Chaiprapat, "Biogas production from industrial effluents," in *Biomass, Biofuels, Biochemicals: Biofuels: Alternative Feedstocks and Conversion Processes for the Production of Liquid and Gaseous Biofuels*, Elsevier, 2019, pp. 779–816. doi: 10.1016/B978-0-12-816856-1.00032-4.

[4] P. Vijayakumar, S. Ayyadurai, K.D. Arunachalam, G. Mishra , W.H. Chen , J. C. Juan, S.R. Naqvi, "Current technologies of biochemical conversion of food waste into biogas production: A review," *Fuel*, vol. 323, Sep. 2022, doi: 10.1016/j.fuel.2022.124321.

[5] P. Viswanath, S. Sumithra Devi, and K. Nand, "Anaerobic Digestion of Fruit and Vegetable Processing Wastes for Biogas Production," 1992.

[6] F. Luca, "Number of biogas plants across India as of March 2021, by state," 2023. https://www.statista.com/statistics/941298/india-number-of-biogas-plants-by-state/#statisticContainer (accessed May 17, 2023).

[7] A. Sagastume Gutiérrez, J. M. Mendoza Fandiño, J. J. Cabello Eras, and S. J. Sofan German, "Potential of livestock manure and agricultural wastes to mitigate the use of firewood for cooking in rural areas. The case of the department of Cordoba (Colombia)," *Development Engineering*, vol. 7. Elsevier Ltd, Jan. 01, 2022. doi: 10.1016/j.deveng.2022.100093.

[8] L. R. C. Assunçao, P. A. S. Mendes, S. Matos, and S. Borschiver, "Technology roadmap of renewable natural gas: Identifying trends for research and development to improve biogas upgrading technology management," *Appl. Energy*, vol. 292, Jun. 2021, doi: 10.1016/j.apenergy.2021.116849.

[9] M. M. Habashy, E. S. Ong, O. M. Abdeldayem, E. G. Al-Sakkari, and E. R. Rene, "Food Waste: A Promising Source of Sustainable Biohydrogen Fuel," *Trends in*

Biotechnology, vol. 39, no. 12. Elsevier Ltd, pp. 1274–1288, Dec. 01, 2021. doi: 10.1016/j.tibtech.2021.04.001.

[10] S. Stephen Bernard, T. Srinivasan, G. Suresh, A. Ivon Paul, K. Mohideen Fowzan, and V. Ashwin Kishore, "Production of biogas from anaerobic digestion of vegetable waste and cow dung," in *Materials Today: Proceedings*, Elsevier Ltd, Jan. 2020, pp. 1104–1106. doi: 10.1016/j.matpr.2020.07.129.

[11] G. Quiroga, E. Maranon , L. Castrillon, Y. Fernandez-Nava, L. Gomez, M.M. Garcia , "Effect of ultrasound pre-treatment in the anaerobic co-digestion of cattle manure with food waste and sludge," *Bioresour. Technol.*, vol. 154, pp. 74–79, 2014, doi: 10.1016/j.biortech.2013.11.096.

[12] R. Jyothilakshmi and S. V. Prakash, "Design, Fabrication and Experimentation of a Small Scale Anaerobic Biodigester for Domestic Biodegradable Solid Waste with Energy Recovery and Sizing Calculations," *Procedia Environ. Sci.*, vol. 35, pp. 749–755, 2016, doi: 10.1016/j.proenv.2016.07.085.

[13] G. Glivin, N. Kalaiselvan, V. Mariappan, M. Premalatha, P. C. Murugan, and J. Sekhar, "Conversion of biowaste to biogas: A review of current status on techno-economic challenges, policies, technologies and mitigation to environmental impacts," *Fuel*, vol. 302, Oct. 2021, doi: 10.1016/j.fuel.2021.121153.

[14] P. Gupta, C. Kurien, and M. Mittal, "Biogas (a promising bioenergy source): A critical review on the potential of biogas as a sustainable energy source for gaseous fuelled spark ignition engines," *International Journal of Hydrogen Energy*, vol. 48, no. 21. Elsevier Ltd, pp. 7747–7769, Mar. 08, 2023. doi: 10.1016/j.ijhydene.2022.11.195.

[15] E. Tumusiime, J. B. Kirabira, and W. B. Musinguzi, "An integrated energy recovery system for productive biogas applications: Continuous mode operation and assessment," *Energy Reports*, vol. 9, pp. 4532–4546, Dec. 2023, doi: 10.1016/j.egyr.2023.03.097.

[16] A. C. Lizama, C. C. Figueiras, R. R. Herrera, A. Z. Pedreguera, and J. E. Ruiz Espinoza, "Effects of ultrasonic pretreatment on the solubilization and kinetic study of biogas production from anaerobic digestion of waste activated sludge," *Int. Biodeterior. Biodegrad.*, vol. 123, pp. 1–9, Sep. 2017, doi: 10.1016/j.ibiod.2017.05.020.

[17] R. Zeynali, M. Khojastehpour, and M. Ebrahimi-Nik, "Effect of ultrasonic pre-treatment on biogas yield and specific energy in anaerobic digestion of fruit and

vegetable wholesale market wastes," *Sustain. Environ. Res.*, vol. 27, no. 6, pp. 259–264, Nov. 2017, doi: 10.1016/j.serj.2017.07.001.

[18] S. Zou, X. Wang, Y. Chen, H. Wan, and Y. Feng, "Enhancement of biogas production in anaerobic co-digestion by ultrasonic pretreatment," *Energy Convers. Manag.*, vol. 112, pp. 226–235, Mar. 2016, doi: 10.1016/j.enconman.2015.12.087.

[19] Z. X. Xu, H. Song, S. Zhang, S.Q. Tong, Z.X. He, Q. Wang, B. Li a, X. Hue, "Co-hydrothermal carbonization of digested sewage sludge and cow dung biogas residue: Investigation of the reaction characteristics," *Energy*, vol. 187, Nov. 2019, doi: 10.1016/j.energy.2019.115972.

[20] S. Azman, H. Milh, M.H. Somers, H. Zhang, I. Huybrechts, E. Meers, B. Meesschaert, R. Dewil, L. Appels, "Ultrasound-assisted digestate treatment of manure digestate for increased biogas production in small pilot scale anaerobic digesters," *Renew. Energy*, vol. 152, pp. 664–673, Jun. 2020, doi: 10.1016/j.renene.2020.01.096.

[21] B. Deepanraj, V. Sivasubramanian, and S. Jayaraj, "Effect of substrate pretreatment on biogas production through anaerobic digestion of food waste," *Int. J. Hydrogen Energy*, vol. 42, no. 42, pp. 26522–26528, Oct. 2017, doi: 10.1016/j.ijhydene.2017.06.178.

[22] A. Ounnar, L. Benhabyles, and S. Igoud, "Energetic valorization of biomethane produced from cow-dung," in *Procedia Engineering*, 2012, pp. 330–334. doi: 10.1016/j.proeng.2012.01.1211.

[23] M. Karrabi, F. M. Ranjbar, B. Shahnavaz, and S. Seyedi, "A comprehensive review on biogas production from lignocellulosic wastes through anaerobic digestion: An insight into performance improvement strategies," *Fuel*, vol. 340. Elsevier Ltd, May 15, 2023. doi: 10.1016/j.fuel.2022.127239.

[24] A. Lahbab, M. Djaafri, S. Kalloum, A. Benatiallah, M. R. Atelge, and A. E. Atabani, "Co-digestion of vegetable peel with cow dung without external inoculum for biogas production: Experimental and a new modelling test in a batch mode," *Fuel*, vol. 306, Dec. 2021, doi: 10.1016/j.fuel.2021.121627.

[25] E. O. Otieno, R. Kiplimo, and U. Mutwiwa, "Optimization of anaerobic digestion parameters for biogas production from pineapple wastes co-digested with livestock wastes," *Heliyon*, vol. 9, no. 3, Mar. 2023, doi: 10.1016/j.heliyon.2023.e14041.

[26] A. S. Sambo, B. Garba, and B. G. Danshehu, “EFFECT OF SOME OPERATING PARAMETERS ON BIOGAS PRODUCTION RATE,” *Fuel*, vol. 329. Elsevier Ltd, May 14, 2022. doi: 10.1016/j.fuel.2022.127439..

[27] A. D. Singh, A. Upadhyay, S. Shrivastava, and V. Vivekanand, “Life-cycle assessment of sewage sludge-based large-scale biogas plant,” *Bioresour. Technol.*, vol. 309, Aug. 2020, doi: 10.1016/j.biortech.2020.123373.

[28] M. Jelínek, J. Mazancová, D. Van Dung, L. D. Phung, J. Banout, and H. Roubík, “Quantification of the impact of partial replacement of traditional cooking fuels by biogas on global warming: Evidence from Vietnam,” *J. Clean. Prod.*, vol. 292, Apr. 2021, doi: 10.1016/j.jclepro.2021.126007.

[29] A. Gill-Wiehl, T. Brown, and K. Smith, “The need to prioritize consumption: A difference-in-differences approach to analyze the total effect of India’s below-the-poverty-line policies on LPG use,” *Energy Policy*, vol. 164, May 2022, doi: 10.1016/j.enpol.2022.112915.

[30] S. A. Khan, T. C. D’ Silva, S. Kumar, R. Chandra, V. K. Vijay, and A. Misra, “Mutually trading off biochar and biogas sectors for broadening biomethane applications: A comprehensive review,” *Journal of Cleaner Production*, vol. 318. Elsevier Ltd, Oct. 10, 2021. doi: 10.1016/j.jclepro.2021.128593.

[31] S. Banik and R. Nandi, “Effect of supplementation of rice straw with biogas residual slurry manure on the yield, protein and mineral contents of oyster mushroom,” *Ind. Crops Prod.*, vol. 20, no. 3, pp. 311–319, Nov. 2004, doi: 10.1016/j.indcrop.2003.11.003.

[32] C. Linyi, Q. Yujie, C. Buqing, W. Chenglong, Z. Shaohong, C. Renglu, Y. Shaohua, Y. Lan, L. Zhiju, “Enhancing degradation and biogas production during anaerobic digestion of food waste using alkali pretreatment,” *Environ. Res.*, vol. 188, Sep. 2020, doi: 10.1016/j.envres.2020.109743.

[33] E. Leca, B. Zennaro, J. Hamelin, H. Carrère, and C. Sambusiti, “Use of additives to improve collective biogas plant performances: A comprehensive review,” *Biotechnol. Adv.*, p. 108129, Jul. 2023, doi: 10.1016/j.biotechadv.2023.108129.

[34] C. W. Chun, N. F. M. Jamaludin, and N. Zainol, “Optimization of biogas production from poultry manure wastewater in 250 ML flasks,” *J. Teknol.*, vol. 75, no. 1, pp. 275–285, 2015, doi: 10.11113/jt.v75.3981.

[35] V. Novotny, “From biogas-to hydrogen – Based integrated urban water, energy and

waste solids system - Quest towards decarbonization," *International Journal of Hydrogen Energy*, vol. 47, no. 19. Elsevier Ltd, pp. 10508–10530, Mar. 01, 2022. doi: 10.1016/j.ijhydene.2022.01.085.

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