

# Development of Two Stage Biogas Digester by Using Kitchen Waste for College Canteen

Nilima Vinayak Sonawane<sup>1</sup>, Niharika Sanjay Jagtap<sup>2</sup>, Shubham Prashant Tiwari<sup>3</sup>,  
Sushant Annaso Kattikar<sup>4</sup>, Saeedanwar S. Inamdar<sup>5</sup>, Sayali P. Mane<sup>6</sup>  
<sup>1,2,3</sup>Diploma student, Department of Civil Engineering, L.E.S.P Sangli  
<sup>4,5</sup>Lecturer, Department of Civil Engineering, L.E.S.P Sangli

**Abstract**—The present project focuses on the development of a two-stage biogas digester utilizing kitchen waste generated from the college canteen to produce clean and renewable energy in the form of biogas. With the growing concern over waste management and the need for sustainable energy sources, this project aims to convert biodegradable waste into useful energy while reducing environmental pollution. The two-stage biogas digester consists of a hydrolysis–Acidogenesis stage and a Methanogenesis stage, designed to improve the efficiency of biogas production compared to traditional single-stage digesters. In the first stage, complex organic matter in the kitchen waste is broken down into simpler compounds by hydrolytic and Acidogenic bacteria. In the second stage, these simpler compounds are converted into methane-rich biogas by Methanogenic bacteria under anaerobic conditions. The kitchen waste collected from the college canteen including vegetable peels, leftover food, and other biodegradable materials serves as the primary feedstock. The digester operates under controlled temperature and pH conditions, ensuring maximum gas yield and stable operation. The produced biogas can be utilized for cooking or heating purposes in the canteen, while the slurry byproduct can be used as an organic fertilizer for gardening or agricultural use. This project demonstrates a sustainable approach to waste management and energy recovery at the institutional level. It promotes environmental protection, reduces dependency on conventional fuels, and encourages the use of renewable energy within the college campus.

## I. INTRODUCTION

In recent years, the problem of waste management and the rising demand for renewable energy have become major global concerns. Large quantities of biodegradable waste are generated daily from domestic, commercial, and institutional sources such as canteens, hostels, and restaurants. Improper disposal of such waste leads to foul odor, unhygienic

conditions, and environmental pollution. At the same time, the increasing cost and depletion of conventional energy sources such as LPG and fossil fuels have encouraged the search for alternative, sustainable solutions. Biogas production through anaerobic digestion of organic waste provides a practical and eco-friendly solution to these challenges. Biogas is a clean and renewable fuel composed mainly of methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>), produced when microorganisms decompose organic matter in the absence of oxygen. It can be used for cooking, lighting, and even power generation. Additionally, the digestate, which remains after the digestion process, serves as an excellent organic fertilizer. Traditional single-stage digesters often face issues such as process instability, low gas yield, and incomplete digestion due to the complex biochemical reactions involved. To overcome these drawbacks, the two-stage biogas digester system has been developed. In this system, the digestion process is divided into two separate stages—acidogenesis (first stage) and methanogenesis (second stage). This separation allows better control over microbial activity, pH, and retention time, resulting in higher efficiency and methane yield. The present project, “Development of Two-Stage Biogas Digester by Using Kitchen Waste for College Canteen,” aims to utilize the kitchen waste generated in the college canteen as the main feedstock for biogas production. The project not only addresses waste management issues but also promotes sustainable energy use within the college premises.

## II. LITERATURE VIEW

I. Two-phase mesophilic kitchen-waste digestion (experimental). Name of Author: Mutegoa et al., Published Year - 2025 A recent pilot study comparing two-stage vs single-stage digestion of

kitchen waste found substantially higher methane yield and content in the two-stage system (reported methane content  $\approx 69.6\%$  and yield  $\approx 640$  L CH<sub>4</sub>/kg VS vs  $\sim 48\%$  and 356 L CH<sub>4</sub>/kg VS for single stage). The study attributes gain to separate optimization of hydrolysis/acidification (stable low pH for fast hydrolysis) and methanogenesis (neutral pH maintained in the methanogenic stage), which together allow higher organic loading rates and improved stability. Practical takeaways: keep acidogenic retention time short, monitor VFA export rate to the methanogenic stage, and apply moderate mixing to avoid VFA accumulation.

- II. Comprehensive review on AD of organic wastes (PMC). Name of Author: Kumar et al., Published year- 2024 This wide review contextualizes two-stage reactors among pretreatments (thermal, chemical, enzymatic) and co-digestion strategies. Key conclusions: pretreatments can boost hydrolysis rates (beneficial for the acidogenic stage), and co-digestion (e.g., with sludge or agricultural residues) often stabilizes C:N and improves methane yield from kitchen waste. It's a solid background source when justifying pretreatment or co-substrate inclusion.
- III. Two-stage meso/thermophilic digestion microbiology (MDPI Fermentation). Name of Author: Ohdoi et al., Published year -2024 This study compared mesophilic vs thermophilic staging combinations for food waste and examined microbial community shifts. Thermophilic acidogenesis increased hydrolysis but required stricter ammonia control in the methanogenic stage. For a college-canteen kitchen-waste digester, authors recommend mesophilic methanogenesis (more stable) combined with a slightly warmer acidogenic stage if faster hydrolysis is needed.
- IV. Pilot two-phase AD of deoiled food waste + WAS (Chemosphere). Name of Author: Jiang et al., Published year: 2023 In a pilot-scale two-phase system co-digesting deoiled food waste and waste-activated sludge, researchers showed that proper feed ratios and stage separation improved methane yield and functional microbial networks in the methanogenic reactor. The study emphasizes
  - feed homogenization, solids balancing, and nutrient C: N adjustments when using kitchen/food wastes with varying fat and moisture content
  - . Development of Two Stage Biogas Digester by Using Kitchen Waste for College Canteen L.E.S.P Pg.3 of 14
- V. Lactate-based two-stage AD for food waste (lab to pilot). Name of Author: García-Depraect et al., Published Year- 2022 This work tested a lactate-driven acidogenic stage to produce a stable, easily-consumable substrate for methanogens. Result: lactate-rich effluent increased methanogenesis rates and improved overall biogas productivity versus conventional acidogenic effluents. Design implication: targeted control of acidogenesis products (e.g., steering toward lactate/acetate) can simplify downstream methanogenic conversion and reduce buffering needs.
- VI. Study Of Biogas Production From Different Waste. Name of Author - S.R. Kalbande and V.P. Khambalkar Published Year – 2017 The focus of the research paper is the production of biogas from various feed stock and different waste. Feedstock composition is one of the major factors that affect the production of biogas. High yields of methane depend mainly on the substrates used as feeding material. However, the difference in total methane yield varies based on the type of interactions between different wastes that interfere with digestibility of wastes in the system. In this study percentage of methane content (the main constituent) in biogas produced from different fermentable materials is almost the same. In this paper the reviews on biogas production from different waste is studied and the different authors suggested that the poultry wastes produced more biogas than poultry droppings. Kitchen waste has high calorific value and nutritive value to microbes due to which efficiency of methane production can be increased by several orders of magnitude.
- VII. Biogas Compression and Storage System for Cooking Applications in Rural Households. Name of Author - M.K.Mohanty & R.C.Mohanty Published Year – 2016 To design and develop a biogas production, Purification, compression and storage system suitable for the use as a cooking

gas in rural household. The biogas is produced in a floating drum type digester by the anaerobic digestion of kitchen waste and collected by an elastic balloon. A foot lever compressor is designed, which allows the users to stand and compress using foot lever and a valve system. In addition to the compressor, container with biogas. The result showed that the system could compress biogas into a container, 4 bar pressure and operating time of 30 min. Development of Two Stage Biogas Digester by Using Kitchen Waste for College Canteen L.E.S.P Pg.4 of 14

- VIII. Development And Design of Biogas Plant for Treatment of Kitchen Waste. Name of Author - Dr. Nitin W. Ingole Published Year – 2015 Generation of biogas by using different types of biodegradable waste material is only the option to get relief from critical fuel crisis. In this study attempts were made to study the process of biogas generation critically by using food waste. The major biological reactions involved in anaerobic digestion as Hydrolysis, Acidification, Methanogenesis. Anaerobic digestion of food waste was carried out in the laboratory by developing a set-up of biogas plant to work as batch process. The measurement of biogas was done by water displacement method. Monitoring of the process was carried out daily. Sampling and its testing were done simultaneously. Based on the results obtained, design of digester for the village of known population was carried out
- IX. Production And Analysis of Biogas from Kitchen Waste Name of Author - Ziana Ziauddin and Rajesh P Published Year – 2015 A large amount of kitchen waste is obtained which can be utilized for better purposes. Biogas production requires anaerobic digestion. This project is to create an Organic Processing Facility to create biogas which will be more cost effective, eco-friendly, cutdown on landfill waste, generate a high-quality renewable fuel, and reduce carbon dioxide and methane emissions. Kitchen (food) waste will be collected from canteens for the reactor which works as anaerobic digester system to produce biogas energy. The anaerobic digestion of kitchen waste produces biogas, a valuable energy resource. Anaerobic digestion is a microbial process for production of biogas, which consists of primarily methane (CH<sub>4</sub>) and

carbon dioxide (CO<sub>2</sub>). Biogas can be used as energy source and also for numerous purposes. But, any possible applications requires knowledge and information about the composition and quantity of constituents in the biogas product

- X. BIOGAS PRODUCTION FROM KITCHEN WASTE Name of Author - Ravi Agrahari and Tiwari Published Year – 2013 The kitchen waste is the best alternative for biogas production in a community level biogas plant. It is produced when bacteria degrade organic matter in the absence of air. Biogas contains around 55- 65% of methane, 30- 40% of carbon dioxide. The calorific value of biogas is appreciably high (around 4700 kcal and 55% methane content). The gas can effectively be utilized for generation of power through a biogas based power- generation system after dewatering and cleaning of the gas. In addition, the slurry produced in the process provides valuable organic manure for farming and sustaining the soil fertility. In this paper, an attempt has been made to test the performance of different ratio of kitchen waste in a metal made portable floating type biogas plant. Development of Two Stage Biogas Digester by Using Kitchen Waste for College Canteen L.E.S.P Pg.5 of 14
- XI. Development Of Two Stage Anaerobic Digester for Biogas Production from Biodegradable Waste Name of Author - Pumisak Intanon & Wattanapong Rakwichian Published Year – 2007 The purpose of this research is to get more efficiency from a methane producing system using municipal biodegradable waste. This research built a pilot plant in a Phitsanulok municipal slaughter house with a treating capacity of 100 kilogram per day for biodegradable wastes from Phitsanulok city. For more improved efficiency, the pilot plant built a grinding machine, conveyor, added acid tank, two stage anaerobic digesters with pillows in each digester for promotion of methane productions. Gas volume was by a gas meter and methane content by gas chromatography. The result showed that the performance of the system Anaerobic Sequencing Batch Tank was high. The average biodegradable loading rate was 54.45 kg/d, in two-stage anaerobic digesters.

From these results, the two-stage anaerobic digesters showed high efficiency of methane producing about two times of the general fresh waste biogas system could produce about 20-30 % in general. This fundamental data was showed that, it is reasonable to expand to a large scale for municipal biodegradable waste treatment and is useful for the development of high methane producing

### III. SUMMARY

The reviewed studies collectively emphasize the effectiveness of two-stage anaerobic digestion (AD) systems for enhanced biogas and methane production from kitchen waste and other biodegradable feedstocks. Mutegoa et al. (2025) experimentally demonstrated that two-phase mesophilic digestion produces significantly higher methane yield (~640 L CH<sub>4</sub>/kg VS) and stability compared to single-stage systems, due to the optimized separation of hydrolysis/acidogenesis and methanogenesis. Similarly, Kumar et al. (2024) provided a comprehensive overview of AD processes, concluding that pretreatment and co-digestion methods effectively improve hydrolysis and methane yields. Ohdoi et al. (2024) highlighted the role of temperature regimes, suggesting mesophilic methanogenesis for operational stability in food-waste-based systems. Jiang et al. (2023) confirmed improved methane yield and nutrient balance in pilot-scale co-digestion of deoiled food waste and sludge, stressing feed homogenization and C: N optimization. García-Depraect et al. (2022) advanced the concept of lactate-based acidogenesis, which produces a stable substrate for efficient methanogenesis and enhanced biogas productivity. Earlier studies by Kalbande and Khambalkar (2017) established that methane yield depends on substrate type, noting that kitchen waste is rich in nutrients favorable for microbial activity. Mohanty and Mohanty (2016) explored biogas compression and storage systems for rural cooking applications, developing a low-cost purification and compression setup. Ingole (2015) focused on the design and laboratory analysis of biogas plants using Development of Two Stage Biogas Digester by Using Kitchen Waste for College Canteen L.E.S.P

Pg.6 of 14 food waste, detailing hydrolysis, acidification, and methanogenesis processes. Ziauddin and Rajesh (2015) examined the production and analysis of biogas from canteen-derived kitchen waste, emphasizing its potential as a renewable and eco-friendly energy source. Agrahari and Tiwari (2013) demonstrated that community-level kitchen-waste digesters yield 55–65% methane and produce useful organic slurry as a by-product. Finally, Intanon and Rakwichian (2007) provided early experimental evidence that two-stage digesters double methane productivity compared to single-stage systems, supporting their scalability for municipal biodegradable waste management.

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