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Optimization of Biogas Yield Via Anaerobic Process of Organic Kitchen Residues

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Abstract: Bioenergy is a renewable solution with the potential to address energy crises and waste management, promoting a circular economy. To unlock its benefits, optimizing biogas production becomes most important. Our study is focused on utilizing biogas from food waste produced at the Basaveshwar engineering college girls' hostel in Bagalkote through anaerobic digestion. In laboratory trials, 15.6 Kg of food waste yielded 293.38 cm^3 of biogas. This research also influenced the design of a digester for Basaveshwar engineering colleges girls hostel effectively tackling energy and waste challenges or its specific population.

Keywords: *Bio Energy, Biogas Production, Food Waste, Anaerobic Digestion.*

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I. INTRODUCTION

In the 21st century, humanity grapples with energy insecurities and environmental pollution. Biomass, a promising sustainable energy source, holds potential. India boasts 750 million MT biomass potential, meeting 30% caloric needs of 70% population. Biogas, compiled of methane and carbon dioxide from organic waste, offers scalable solutions for sustainable energy and waste management (MNRE, 2021).Food waste is a significant ecological issue, approximately one-third of food produced is lost. In India, households, perform an enormous part in causing this issue by squandering about waste 50 kg per person yearly. It contributes 8–10% GHG emissions and creates health risks, emphasizing proper waste management**.** Composting, incineration, landfilling, pyrolysis, gasification, and anaerobic digestion treat food waste. High moisture favors anaerobic digestion for efficient biodegradation and power generation. It produces methane without oxygen, requiring low energy, while temperature, pH, and feedstock influence biogas yield.

Methane, carbon dioxide, and associated gases, especially hydrogen sulfide and other sulfur compounds, are present in biogas. Anaerobic breakdown of organic substances by bacteria, a crucial component of the carbon cycle, yields biogas, beneficial for rural as well as urban environments. Methane (55–60%) and carbon dioxide (35–40%) are major components. Livestock waste, landfill gas, activated sludge, and industrial wastes are valuable substrates for biogas production, generating biomethane through controlled decomposition and providing a sustainable source of energy. Biogas possesses a calorific value of about 20–25 MJ/m³, burns with an LPG-like blue flame, and can be deployed in preference to firewood, diesel, and electricity. Production of biogas is impacted by feedstock, pH, temperature (25–40ºC), C: N ratio, solids, and retention time. Anaerobic digestion involves hydrolysis, acidogenesis, acetogenesis, and methanogenesis, producing methane and nutrient-rich effluents. Small scale digesters include floating gas holder and fixed dome type biogas plants.

Biogas, an alternative energy, contains methane and carbon dioxide, where removing carbon dioxide improves methane concentration and calorific value. Methane has high energy content, while excess carbon dioxide reduces efficiency. Biogas upgrading technologies include physical, chemical, and biological processes such as pressure swing adsorption, absorption, membrane separation, biological enrichment, and cryogenic separation.

II. MATERIALS AND METHODOLOGY

- *Selection and Assemblage of Organic Kitchen Residues*

The selection and assemblage of food waste from the girls' hostel at Basaveshwar Engineering College, Bagalkote, provides a sustainable solution by producing biogas for cooking, reducing waste disposal problems, promoting clean energy use, and supporting self-sufficiency."

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Fig 1 Assemblage of Food Waste Sample from Mess

➢ *Survey of Food and Kitchen Waste Produced at Girls' Hostel*

A 30-day waste survey was conducted at the Girls' Hostel of Basaveshwar Engineering College in Bagalkot with 900 residents. Mess and kitchen waste were collected separately and weighed daily. The recorded data showed kitchen waste ranged from 6.7 to 16 kg/day and mess waste from 43.5 to 87 kg/day, with averages of 12.06 kg/day and 65.79 kg/day."

Fig 2 Weighing of Food Waste

Fig 3 Kitchen Waste

➢ *Experimental Setup*

For the production of biogas, a 20 L HDPE digester was used. The carefully planned inlet, outlet, and gas collection systems resulted in a reactor with an effective volume of 15 L. Materials include PVC pipes, drip valves, funnels, M seals, and balloons. Feedstock was introduced via a PVC pipe inlet connected to the funnel; surplus feedstock was expelled via the outlet. A balloon that was tied to a drip valve served as a collection and storage vessel for the generated gas. This arrangement makes it possible to collect biogas and conduct controlled anaerobic digestion.

Fig 4 Experimental Setup of Anaerobic Digester

➢ *Preparation of Sample*

In the biogas production process at the Girls' Hostel of Basaveshwar Engineering College in Bagalkot, food waste was collected and initially placed in containers. To facilitate efficient digestion, the food waste was then mechanically smashed, reducing it to smaller, more manageable pieces. Water was added to create a slurry-like consistency, which is optimal for anaerobic digestion. Additionally, cow dung was utilized as a co-substrate. To prepare the cow dung for digestion, it was mixed with water to form a suspension as well. This combination of food waste and cow dung slurries served as the input material for the biogas digester, enhancing the microbial activity and biogas production efficiency within the system.

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Fig 5 Cow Dung Slurry

Fig 6 Injection of Sample in Digester

➢ *Biogas Production*

The biogas production process at Basaveshwar Engineering College in Bagalkot began with the introduction of cow dung slurry into the digester as an inoculum. This inoculum, rich in active anaerobic microbes, kick-started the digestion process. From the second day onwards, prepared food waste samples were introduced into the digester. These food waste samples were added daily in measured quantities to maintain a consistent feedstock. Regular stirring or agitation was an essential part of the process. It ensured proper mixing of the cow dung inoculum and the incoming food waste, promoting the uniform distribution of microbes and nutrients for effective anaerobic digestion. As the anaerobic microbes broke down the organic matter in the food waste, biogas is produced and was collected in a balloon and quantified through measurement, facilitating ongoing monitoring of the gas output.

➢ *Analysis of Biogas Produced in the Reactor*

A method for analysing the biogas produced and stored in a balloon by measuring its circumference and radius. Wrapping a cloth tape measure around the centre of the balloon to check its circumference is a practical way to estimate the volume of the balloon, which can give insights into the amount of biogas produced.

- *Circumference Measurement*

Gently wrap the cloth tape measure around the centre of the biogas-filled balloon. Make sure the tape is snug but not too tight as it doesn’t distort the shape of the balloon, and taking measurement in cm or inches.

- *Radius Calculation:*

The formula to calculate the radius © from the circumference © is: $C = 2\Pi r$

- *Volume Calculation:*

Once radius is calculated, then volume of the balloon can be measured using the formula for the volume of sphere.

$$V = (4/3) \times \Pi \times r^3$$

➢ *Characterization of Food Waste Sample*

- *Total Solids*

The process of determining total solids involves evaporating the water content of the sample by heating at 105 ºC until only solid components remain, including dissolved and suspended solids. Take empty weight of petri dish, pour 10 ml sample, heat, and take final weight to calculate total solids percentage.

Total solids % = (final wt. of petri dish-initial wt. of petri dish) × 100 Volume of sample

- *pH Analysis*

pH is a measure of hydrogen ion concentration’s negative logarithm. The scale ranges from 0 to 14; pH 7 is neutral, while below 7 is acidic and above is basic. A pH meter assesses hydrogen-ion activity to determine acidity/ alkalinity. It’s a “potentiometric pH meter” as it detects electricity potential difference between pH and reference electrodes due to solutions acidity.

- *TDS Analysis*

Total dissolved solids (TDS) refer to non-water substances like metals, minerals, and ions dissolved in water. The Hanna instruments Hl98301 Dist. 1 is a pocket-sized tester measuring up to 2000 ppm.

III. RESULT AND DISCUSSION

➢ *Findings from Girls Hostel Survey on Mess and Kitchen Waste Generation*

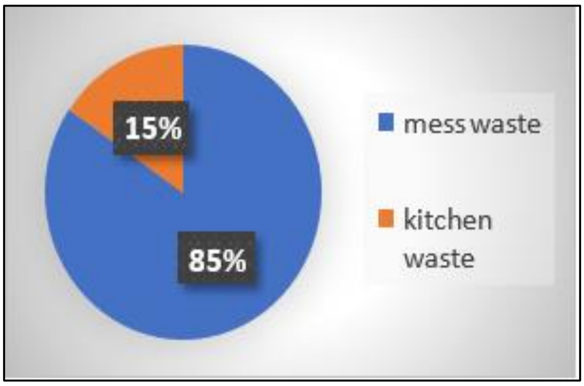

Fig 7 Chart Representing Amount of Mess and Kitchen Waste Generated

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In a 30-day survey, waste production showed 85% mess waste including rice, vegetables, and food-related items, while 15% kitchen waste consisted of uncooked vegetable scraps and peels.

- *Characterization of Food Waste Sample*

The analysis of biomass influent and effluent characteristics, before and after the digestion process the following tests were run. The results are shown in table given below.

Table 1 Characterization of Food Waste Sample

Sl.NO	Test	Before digestion	After digestion
1	pH	6.2	5.1
2	TDS	611.09 ppm	386 ppm
3	TS	836.5 mg/L	516 mg/L
4	SS	225.4 mg/L	130 /L

➢ *Biogas Production*

The experiment focused on utilizing food waste as a feedstock for biogas production. The study employed 15.6 kg of food waste for digestion. Over a 20-day period, the process yielded 293.38 cm^3 of biogas, as illustrated in the below table.

Table 2 Determination of Feedstock Loading for Biogas Generation

Sl. NO	Feed stock loaded in Kg	Biogas produced in cm^3
1	2.8	56.47
2	2.3	48
3	3.7	64.36
4	3.8	66.55
5	3	58

IV. CONCLUSION

The 30-day survey conducted at Basaveshwar Engineering College's girls' hostel provided valuable insights into the waste generation dynamics within the facility. It was observed that a significant majority, accounting for 85% of the waste, originated from the mess area, where food-related waste, including rice, vegetables, and other food items, played a substantial role. The remaining 15% was attributed to kitchen waste, primarily consisting of uncooked vegetable scraps and peels. Building upon these findings, an innovative biogas production project was initiated, employing a 20 L digester over a 20-day period. During this time, 15.6 kg of food waste yielded an impressive 293.38 cm^3 of biogas, showcasing the potential for sustainable energy generation.

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