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Performance Analysis of Biogas Production by Jatropha Curcas Leaves As Prime Biomass

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Abstract— This research investigates the utilization of Jatropha curcas biomass waste for efficient biogas production. After oil extraction, biomass residues such as leaves, stems from pruning, fruit hulls, seed husks, and oil cakes are repurposed rather than discarded. Traditionally used as fertilizers, briquettes, adsorbents, resin, or compost, Jatropha waste holds high potential for biofuel applications due to its hydrocarbon-rich nature. The study aims to harness these biomass components for biogas generation through anaerobic digestion. A custom-designed biogas digester was developed, where biomass was mixed with nontraditional digesters in fixed ratios to enhance breakdown and gas yield. Regular testing of gas pressure and methane concentration was conducted. On the 50th day of digestion, the methane percentage reached 76.7%, demonstrating a significant improvement in biogas quality. This highlights the viability of Jatropha leaves as a prime biomass feedstock. The results indicate a promising and eco-friendly approach to meet energy demands. It contributes to reducing dependency on fossil fuels while promoting sustainable waste management and renewable energy development.

Keywords— Jatropha waste, biomass, biogas, anaerobic digestion, waste management.

I. INTRODUCTION

The rapid industrialization and population growth across the globe have significantly increased the demand for energy, leading to the excessive consumption of fossil fuels. This dependence on non-renewable energy sources has contributed to critical environmental issues such as global warming, greenhouse gas emissions, and ecological degradation [1]. As a result, there is a pressing need to explore sustainable and environmentally friendly energy alternatives. Among the various renewable energy options, biogas production through anaerobic digestion of biomass has emerged as a viable and efficient solution to address energy and environmental challenges simultaneously [2].

Biogas is a clean, combustible gas primarily composed of methane (CH_4) and carbon dioxide (CO_2), produced from the microbial decomposition of organic matter under anaerobic conditions. It is a sustainable source of energy that can be utilized for electricity generation, cooking, and heating, especially in rural and semi-urban regions [3]. The feedstock used in biogas production plays a crucial role in determining the efficiency, yield, and overall economic feasibility of the process. Traditionally, biogas plants have used cattle dung, food waste, and municipal waste as substrates. However, the search for high-yield, low-cost, and readily available biomass feedstocks has led researchers to explore non-conventional sources such as agricultural and industrial residues[4].

Jatropha curcas, a drought-resistant shrub, has gained considerable attention in recent years due to its multifaceted benefits. It is widely cultivated for its non-edible oil-rich seeds, which are primarily used in biodiesel production. However, beyond oil extraction, various parts of the plant, such as leaves, stems, husks, and seed cakes, are often underutilized or discarded as waste[5]. These residual components are rich in lignocellulosic and organic matter, making them a promising substrate for biogas generation. Utilizing Jatropha biomass not only adds value to agricultural waste but also contributes to waste management and rural energy security[6].

In particular, the leaves of Jatropha curcas are abundant, especially during pruning seasons, and can serve as a potential feedstock due to their organic composition and biodegradability[7]. The strategic use of Jatropha leaves for biogas production opens up new avenues for integrating energy generation with sustainable agriculture. Moreover, leveraging such biomass for energy aligns with the principles of a circular economy, where waste is converted into valuable resources, thereby enhancing resource efficiency and reducing environmental impact[8].

This study focuses on the performance analysis of biogas production using Jatropha curcas leaves as the primary biomass. It aims to evaluate the potential of this specific biomass type in terms of gas yield, digestion

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efficiency, and energy output. The findings are expected to contribute to the broader understanding of biomass-based energy systems and encourage the adoption of alternative, renewable energy sources in regions where Jatropha is cultivated extensively.

II. RELATED WORK

Achten et al. [1] presented a comprehensive study on Jatropha curcas for biodiesel production, discussing its agronomic, economic, and environmental aspects. The authors emphasized the value of using both oil and biomass by-products to enhance energy generation in a sustainable manner.

Pacheco et al. [2] explored the nutritional evaluation of Jatropha curcas in relation to soil acidity correction, highlighting the importance of nutrient interaction on plant yield and biomass productivity.

Saturnino et al. [3] provided extensive agronomic information on Jatropha curcas, particularly its growth patterns, oil yield, and potential to generate by-products such as leaf and stem biomass suitable for energy production.

Wan et al. [4] supported the plant's inclusion in strategies aimed at improving water use efficiency, enhancing rural livelihoods, and reducing environmental degradation in semi-arid regions, indicating its relevance as a bioenergy crop.

Jingura et al. [5] evaluated Jatropha curcas as a multipurpose energy source, including its application in biogas, solid fuel, and biodiesel. Their work underlined the plant's suitability for decentralized energy production.

Ghosh et al. [6] investigated the effects of Jatropha de-oiled cake on plant growth under different spacing, reinforcing the dual-purpose benefit of the crop for both oil and biomass feedstock.

Openshaw et al. [7] critically reviewed Jatropha curcas, identifying its global potential while acknowledging challenges related to its agronomic and economic viability.

Gunaseelan et al. [8] conducted an in-depth analysis of Jatropha biomass, determining its methane potential and anaerobic digestion performance, which supports its application in biogas production systems.

Singh et al. [9] presented a holistic energy approach by utilizing all parts of the Jatropha fruit—oil, husk, and cake—thus promoting integrated energy resource utilization.

Patolia et al. [10] studied the crop's response to nitrogen and phosphorus fertilization on wastelands, demonstrating that optimized nutrient management can significantly increase biomass yield and, consequently, energy production potential.

III. EXPERIMENTAL SETUP

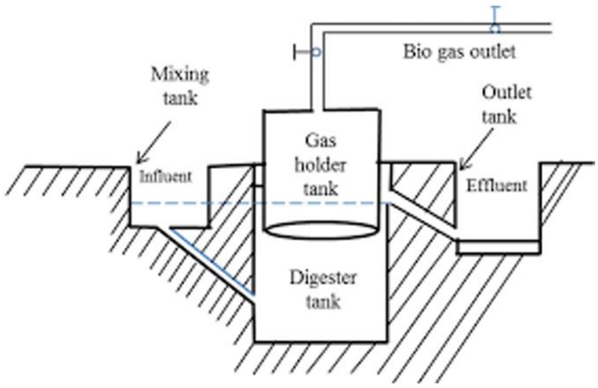

Figure 1: Biogas unit line diagram

Figure 2: Complete setup

The experimental setup for biogas production using *Jatropha curcas* leaves as the primary biomass involves the integration of several key components essential for anaerobic digestion, gas storage, and measurement. Each unit is designed to ensure ease of operation, manual intervention where necessary, and accuracy in data collection. The system is intended for small-scale laboratory or pilot testing to evaluate methane production efficiency over time.

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The digester tank is the central unit of the setup, where the anaerobic digestion process takes place. For this purpose, an open tank with a capacity of 50 liters is selected. The tank is designed to allow manual feeding and removal of biomass. Both the inlet and outlet for biomass input and digestate output are handled manually, providing control over the frequency and quantity of feedstock entering the digestion chamber. The tank must remain sealed during digestion to maintain anaerobic conditions, and measures are taken to ensure it is insulated from atmospheric interference.

The gas holder tank is an essential component used for storing the biogas produced during digestion. A 40-liter steel drum is selected for this purpose, equipped with arrangements for fitting necessary accessories such as valves, gauges, and outlet pipes. Prior to operation, the gas holder tank undergoes a thorough leak test to ensure gas-tight conditions. This precaution is critical in preventing methane leakage and ensuring safety during gas collection and storage.

For the gas outlet, a valve assembly is installed to control the release of biogas from the storage tank. This outlet is designed to remain sealed during the digestion process and is only opened when the collected gas is to be measured or utilized. The valve ensures smooth discharge of gas while maintaining the internal pressure of the gas holder tank. Accurate functioning of the gas outlet system is crucial for maintaining the consistency of gas sampling and usage.

A pressure gauge is mounted on the gas holder tank to monitor internal pressure and to assess the gas quality indirectly. A pressure gauge calibrated up to 30 bar is selected, although a pressure of 16 bar is generally adequate for evaluating gas properties. The higher calibration range ensures safety and allows for pressure build-up during peak gas generation. Regular monitoring of the gauge provides insights into the rate of gas production and the system's performance over time.

Finally, a methane analyzer is integrated into the system to assess the methane content of the produced biogas. The ACE gas analyzer, a specialized TDL (Tunable Diode Laser) spectrometer, is employed for this purpose. It is connected directly to the gas outlet from the digester, enabling real-time analysis of the methane concentration in the biogas. This device plays a crucial role in validating the effectiveness of *Jatropha curcas* biomass in generating high-quality biogas with substantial methane content.

With all components assembled, including the digester tank, gas holder, valve assemblies, pressure gauge, and methane analyzer, the complete setup is finalized. The system is tested for operational readiness and is then primed to initiate the anaerobic digestion process. This setup allows for controlled experimentation and data collection to evaluate the performance of *Jatropha* leaves in biogas production, providing a practical foundation for future scaling and optimization efforts.

Table 1: Biomass and catalysts

SNo	Material	Quantity	Type/ Purpose
1	Jatropha leaves (crushed)	5 KG	Prime Biomass
2	Cow dunk extract	1Liter	digestive
3	Butter milk	1 Liter	catalysts
4	water	8 Liter	To make solution

IV. Results and Discussion

The gas produced is checked for pressure by pressure gauge installed in gas tank and methane percentage is checked by methane gas analyzer as shown in following pictures.

Figure 3: Pressure readings taken on 3.12.23

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Figure 4: Gas analysis

Table 2: Shows increment in methane percentage on progressive dates

S.No.	Date	Methane Percentage (%)
1	03.12.2023	23.0
2	08.12.2023	27.5
3	13.12.2023	32.0
4	18.12.2023	40.6
5	22.12.2023	52.7
6	28.12.2023	58.8
7	06.01.2024	61.2
8	13.01.2024	71.1
9	22.01.2024	76.7

Table 2 presents the progressive increase in methane percentage recorded during the biogas production process using *Jatropha curcas* leaves as the primary biomass. The data reflects a consistent upward trend in methane concentration over time, starting from 23.0% on 3rd December 2023 and reaching 76.7% by 22nd January 2024. This steady rise indicates effective anaerobic digestion and highlights the suitability of *Jatropha* leaf biomass for sustained biogas generation. The significant increase, particularly after the fourth week, demonstrates the enhanced microbial activity and stabilization of the digestion process, ultimately leading to high-quality methane-rich biogas.

V. CONCLUSION

Producing biogas from waste can be a solution to waste but not to fuel. In the present study benefits of suggesting jatropha leaves as biomass are discussed also pressure readings and analyzer readings are taken. The quantity and type of decomposers selected to undergo anaerobic digestion is found optimal. It is found that the composition of methane from the process suggested is around 76.7% which is a great finding. The gas produced can be used directly as CBG in industries for using it as a fuel in IC engine; the methane can be separated by PSA technology. It can be then considered as BIO CNG.

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