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Design and Fabrication of Kitchen Waste Decomposer Device

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Abstract: *The increasing generation of kitchen waste in urban and semi-urban households presents a significant challenge to sustainable waste management. This research focuses on the design and fabrication of a compact, stationary kitchen waste decomposer system integrated with biogas generation capabilities. The system consists of a sealed plastic drum equipped with a temperature-regulated heating bulb and a biogas outlet. By maintaining optimal conditions for anaerobic digestion, the unit effectively converts organic waste into two valuable by-products: nutrient-rich compost and methane-rich biogas. The temperature control system accelerates the decomposition process, making it suitable for daily household use. Experimental trials indicate that the system can process up to 2 kg of waste per day, producing sufficient biogas for small-scale cooking applications while also reducing the burden on municipal waste systems. This project promotes an eco-friendly, low-cost, and energy- efficient solution for managing biodegradable waste at the source.*

Keywords: kitchen waste

I. INTRODUCTION

The rapid growth of urbanization and changing lifestyle patterns have led to a significant rise in the generation of household kitchen waste. In India alone, an estimated 50-60% of total municipal solid waste consists of biodegradable organic matter, primarily from kitchens. When not managed properly, this waste ends up in landfills, releasing harmful greenhouse gases such as methane and contributing to soil and water pollution.

Kitchen waste, however, is a rich source of organic material that can be converted into useful by-products such as compost and biogas. Compost improves soil fertility, while biogas serves as a clean, renewable energy source for cooking and heating. Despite the potential benefits, household-level waste-to-resource solutions are still limited due to lack of awareness, accessibility, or affordability.

This project aims to bridge that gap by designing and fabricating a compact, low-cost kitchen waste decomposer with an integrated biogas generation system. The decomposer uses a sealed plastic drum, fitted with a temperature-controlled heating element to maintain optimal conditions for anaerobic microbial activity. The system converts biodegradable kitchen waste into methane-rich biogas and organic compost, offering an efficient, eco-friendly waste management solution at the domestic level.

The project not only supports individual households in managing their waste sustainably but also contributes to broader environmental goals such as waste reduction, clean energy generation, and carbon footprint minimization.

In most urban households, kitchen waste is simply discarded along with other municipal waste, contributing to the overloading of landfill sites and resulting in serious environmental issues such as groundwater contamination, air pollution, and the emission of greenhouse gases. Yet, this same waste—when treated correctly—can serve as a valuable resource for both energy production and soil enhancement.

Traditional methods of handling kitchen waste either require high initial investments, large space, or regular maintenance, making them impractical for many families. Commercial biogas plants and large-scale composting units are often beyond the scope of individual households. To address this gap, the present study focuses on creating a

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compact and stationary system that not only treats kitchen waste at the source but also provides tangible outputs in the form of biogas for cooking and compost for gardening.

This innovation not only empowers households to manage their own waste responsibly but also supports the principles of circular economy and sustainable living. By integrating temperature regulation using a bulb and sensor, the system ensures that the decomposition process is fast, efficient, and active throughout the year, regardless of seasonal temperature fluctuations.

The overarching aim of this research is to develop a prototype that is technically feasible, economically viable, and environmentally beneficial, thereby encouraging widespread adoption and helping to reduce the ecological footprint of day-to-day human activities.

II. LITERATURE REVIEW

The effective management of kitchen waste has emerged as a critical component of modern sustainable development strategies, particularly in the context of rapidly urbanizing regions. Organic waste constitutes a significant portion of municipal solid waste (MSW) in India, and a considerable volume of it originates from household kitchens. Several research studies and experimental projects have laid the groundwork for small-scale, decentralized systems aimed at processing kitchen waste into useful by-products such as biogas and compost. This section presents a comprehensive review of existing technologies and methodologies relevant to the development of a temperature-controlled kitchen waste decomposer with biogas recovery capability.

Anaerobic Digestion for Biogas Generation

Anaerobic digestion (AD) has been widely accepted as a viable solution for the treatment of organic waste. The process involves the breakdown of biodegradable material by microorganisms in the absence of oxygen, resulting in the production of biogas—a mixture primarily composed of methane (CH_4) and carbon dioxide (CO_2). According to the GIZ Biogas Training Manual (2021), a standard household digester can yield between 0.03 to 0.05 cubic meters of biogas per kilogram of kitchen waste under controlled temperature and pH conditions. This form of waste-to-energy conversion not only reduces environmental pollution but also provides a renewable source of energy for cooking and heating.

Impact of Temperature on Microbial Activity

The efficiency of anaerobic digestion is highly dependent on temperature. Research conducted by Sharma et al. (2022) in the International Journal of Scientific Research and Publications (IJSRP) demonstrated that microbial activity reaches its peak within the mesophilic temperature range of 35°C to 45°C. At these temperatures, the digestion rate increases, leading to faster decomposition and higher biogas output. This finding has led to the incorporation of heating mechanisms such as incandescent bulbs, immersion heaters, or heating coils in modern biogas digesters to ensure process stability, especially in colder climates.

Small-Scale Domestic Biogas Systems in India

The Government of India, through the Ministry of New and Renewable Energy (MNRE), has supported numerous pilot projects promoting biogas production at the household level. Reports from MNRE (2019) highlight the success of fixed-dome and floating-drum models in rural and semi-urban areas. These models, although effective, often lack automated temperature control, making them less suitable for year-round operation in fluctuating climatic conditions. This gap presents an opportunity for innovation in compact, temperature-regulated decomposer systems.

Sensor-Based Composting and Smart Systems

The role of automation and smart technology in waste management has gained prominence in recent years. T. Panda and S. Ray (2021), in their research published in the International Journal of Engineering and Technology (IJET), proposed a composting system that integrates temperature and gas sensors with an IoT-based monitoring platform. Such systems can track internal conditions and notify users when compost is ready or when parameters deviate from optimal

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levels. While their focus was primarily on aerobic composting, the same principles can be applied to anaerobic systems with minor modifications.

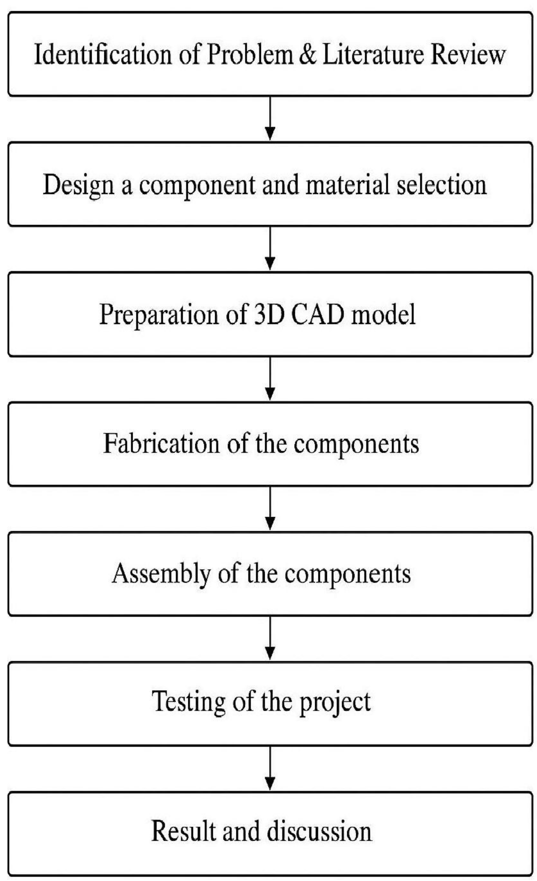
Design and Fabrication of Composting Units

In the study conducted by Aditya Arun Patil et al. (2022), a portable composting unit was designed using low- cost, locally available materials such as plastic drums, PVC pipes, and basic mechanical linkages. Their approach emphasized ease of use, low power consumption, and minimal maintenance. The findings underscored the importance of airtight seals, thermal insulation, and modularity in composting system design—concepts that have been incorporated into the current project.

Conclusion of Literature Review

From the above studies, it is evident that combining anaerobic digestion with effective temperature regulation and user-friendly design can significantly improve the performance and applicability of kitchen waste decomposer systems. While most existing systems are either manually operated or lack automation, this project introduces a hybrid design that utilizes a stationary sealed chamber, a temperature control sensor, and an integrated heating source to facilitate efficient decomposition and biogas recovery. By building upon proven principles and addressing key gaps, the proposed design aspires to make domestic waste management more accessible, efficient, and sustainable.

I.
Methodology



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II. WORKING PRINCLE

The kitchen waste decomposer system is based on the principle of anaerobic digestion, a natural biological process where microorganisms break down organic material in the absence of oxygen. The system utilizes a stationary plastic drum as a sealed chamber in which kitchen waste is decomposed under controlled temperature conditions to generate compost and biogas.

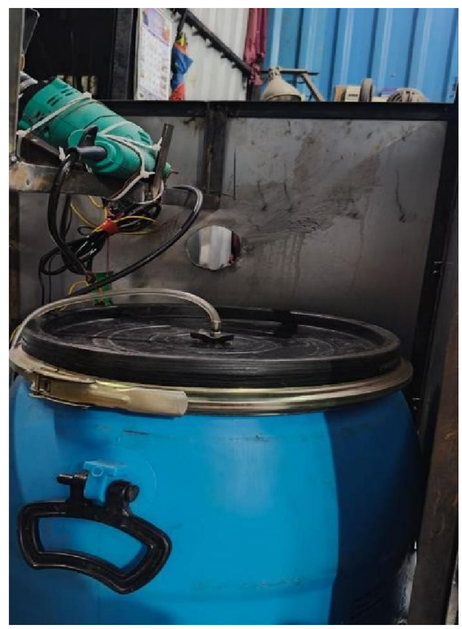
The process begins when organic kitchen waste—such as vegetable peels, leftover food, and fruit scraps—is introduced into the drum. Inside the sealed environment, anaerobic bacteria start breaking down the waste. To accelerate this process and maintain optimal conditions, a heating bulb with a temperature control sensor is installed inside the drum. This ensures the internal temperature remains within the optimal range (30°C–40°C), enhancing bacterial activity and increasing the rate of decomposition.

As decomposition progresses:

Biogas (mainly methane and carbon dioxide) is generated and can be collected through a gas outlet pipe.

The remaining solid waste gradually transforms into nutrient-rich compost, which can be used as an organic fertilizer.

The entire system operates passively once set up, requiring only periodic waste input and compost collection. The integrated sensor-based heating system ensures consistent thermal conditions, even in cooler environments, making the decomposer effective throughout the year. This eco-friendly process not only manages waste efficiently but also promotes sustainable energy production and organic farming by converting kitchen waste into valuable resources.



Decomposer Chamber :- It is used to store the waste which is cut from the cutter and the capacity of the drum is 75 liters.

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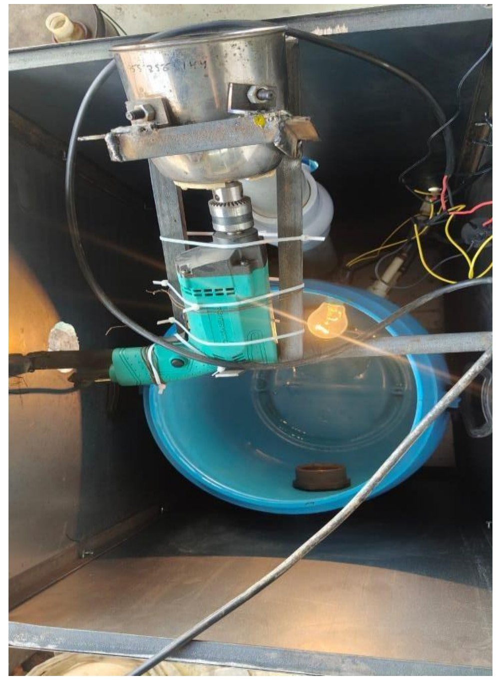

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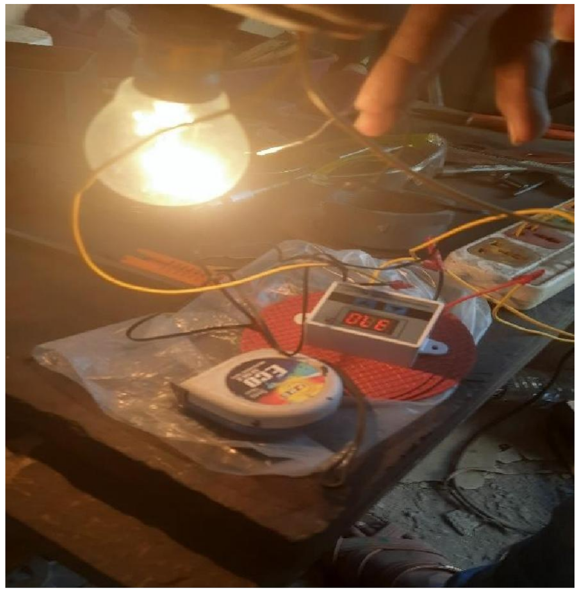
Temperature controller and bulb :- Temperature controller is use to control the temperature inside the chamber so therefore we have used bulb which can make temperature upto 30 to 40 degree.



Inlet and outlet valve :- It is used at the inlet and for outlet from inlet we put cut waste and from outlet we collect waste slurry fertilizer and its diameter is 75mm.

Frame:- It is make from 2*2*3 frame is size is make for household use its size is compact and can be placed in a corner
Mixer:- It rotates at the RPM of 2100 and it is use to cut the waste in small particals so that it can be passed to the storage chamber.

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Pressure gauge :- It is used to know the pressure created inside the chamber.

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CALCULATIONS
1. Volume Allocation of the Drum Total drum capacity: 75 liters Volume for solid waste: 45 liters
Volume reserved for biogas collection: 30 liters
This split ensures sufficient headspace for biogas accumulation without interfering with the waste decomposition process.

2. Heat Energy Required to Raise Temperature
Given: Mass of waste (approximate) = 3 kg (assuming ~45 liters solid organic waste, $\rho \approx 600$ kg/m³)
Specific heat capacity (c) $\approx$ 4.18 kJ/kg° C

Temperature rise (ΔT) = 15°C
Time to reach temperature = 27 minutes Formula:
Convert to kilowatt-hours (kWh): So, the system requires approx. 0.052 kWh of energy to heat the waste from ambient temperature to 40°C.

3. Power Usage of the Heating Element
Bulb Power: 100 W = 0.1 kW
Heating Time: 27 minutes = 0.45 hours Energy consumed:

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This confirms that the 100W bulb provides adequate heat for reaching the desired temperature.

4. Cooling Time and Insulation Efficiency

Cooling time = 40 minutes (to drop from 40°C to 25°C)

This indicates that the drum retains heat for a longer period, reducing power needs and improving energy efficiency.

5. Gas Pressure and Tank Safety

Gas chamber volume: 30 liters = 0.03 m³

Maximum safe pressure sustained by tank: 15 psi = 1.03 bar

Use Ideal Gas Law approximation for safety and release valve design.

This validates that the tank and pipes must be rated to at least 1.5 bar for safe biogas storage and operation.

III. FUTURE SCOPE

The kitchen waste decomposer prototype developed in this project serves as a foundational model for sustainable waste management at the household level. However, its potential reaches far beyond this initial scope. With further refinement and innovation, the system can be scaled, digitized, and commercialized to make a significant environmental and social impact. The following points outline its extended future potential:

1. Integration with IoT and Smart Technology:

The future development of the decomposer can involve the integration of IoT (Internet of Things) technology. Sensors can monitor temperature, humidity, gas levels, and compost readiness in real-time, while data can be transmitted to a mobile app. This would help users operate the system more efficiently and safely.

2. Automation of Mixing and Feeding Mechanisms:

Currently, the waste needs to be added and managed manually. In future versions, an automatic waste feeding system and mechanical agitator or stirring arm can be introduced. This would ensure uniform decomposition, eliminate manual effort, and make the system more user-friendly.

3. Solar-Powered Operation:

To enhance the sustainability of the system, the 100W bulb used for temperature regulation can be powered through a solar panel with a battery backup. This would make the decomposer fully independent of external energy sources and suitable for rural and off-grid locations.

4. Larger Community-Based Models:

By scaling the drum size and increasing capacity, similar systems can be deployed in schools, hostels, housing societies, canteens, and other semi-commercial settings. With little maintenance, these systems can manage large amounts of waste daily and reduce the dependency on municipal waste systems.

5. Advanced Gas Purification and Compression:

The biogas generated can be purified to increase its methane content and even compressed into cylinders for long- term storage. This would allow for wider applications such as running biogas stoves or heating systems in eco- friendly households.

6. Awareness and Education Integration:

These systems can be introduced in educational institutions as demonstration units to raise awareness among students and communities about the importance of waste segregation, renewable energy, and sustainable living.

7. Commercialization and Startup Potential:

With proper branding and mass production, this model can be turned into a startup idea or product kit that is easy to assemble and install in urban homes. It has the potential to become a green product that contributes to climate action goals.

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IV. CONCLUSION

This project successfully demonstrates the design, development, and working of a compact and efficient kitchen waste decomposer system. The increasing burden of organic waste in urban households demands a practical and sustainable solution. The prototype developed utilizes a stationary plastic drum, temperature-controlled bulb, sensor-based monitoring, and biogas outlet mechanism to achieve two primary goals—eco-friendly waste decomposition and renewable biogas production.

By maintaining an internal temperature range of 25–40°C, the system creates optimal conditions for anaerobic bacteria to thrive, accelerating the breakdown of organic matter. The integration of a 100W bulb and thermal sensor ensures controlled heating, while the biogas produced can be collected and used for cooking or lighting. The compost generated is nutrient-rich and beneficial for home gardening and agriculture.

The system was tested with real kitchen waste, and the results proved that the design is both feasible and effective for daily use. It requires minimal energy, has low operational costs, and contributes to reducing the household's carbon footprint. Moreover, it offers an immediate and impactful way to promote waste segregation and responsible disposal at the source. In conclusion, the kitchen waste decomposer aligns with the principles of the circular economy, zero-waste lifestyle, and clean energy generation. With further improvements, it holds the promise of transforming waste from a problem into a powerful, sustainable resource.

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