ADVANCED ROTARY IN-VESSEL COMPOSTING SYSTEM FOR BIODEGRADABLE WASTE

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ABSTRACT

Solid wastes are all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted. The organic waste, especially the food waste is a large menace while we deal with the solid waste management. Composting is one of the method for the decomposition of organic waste. This project aims at developing a rotary in-vessel aerobic composter for the food waste decomposition in College of Engineering, Trivandrum. While aerobic composting is commonly used for disposing of food waste, the use of suitable bulking agents is crucial to achieve optimal results. College campus face significant demands for disposal of fallen leaves, which have substantial potential as bulking agents for aerobic composting. This study explored the performance of fallen leaves and compared it with saw dust as bulking agent in composting. The findings revealed that while both reactors successfully degraded kitchen waste, composting with leaf bulking showed superiority over saw dust bulking in several aspects. Leaf bulking resulted in a longer thermophilic period, higher maximum temperature, increased humification and better degradation efficiency. And the comparison study also showed reasonable NPK value with dried leaves as bulking agent. The project finally used the best experimental combination in the rotary in-vessel aerobic reactor for the food waste decomposition in the college campus.

Keywords: In vessel composting, bulking agent, inoculum

1. INTRODUCTION

1.1 GENERAL

Solid waste management is a pressing global challenge, with organic waste, particularly food waste, contributing significantly to environmental degradation and depletion of the resources. [1] India, propelled by rapid urbanization and a expanding population, fight with the alarming challenge of solid waste management. As cities develop and consumption patterns evolve, the volume of waste generated increases, exacerbated by the prevalence of dry waste and wet waste.[2] Despite governmental efforts, the country's infrastructure for waste management remains inadequate, with many regions have no proper collection and disposal systems.

Food waste generation on campus is a significant issue that many educational institutions, including colleges and universities, facing nowadays. Within the campus environment, diverse factors contribute to food waste accumulation, ranging from overproduction and less consumption. Despite efforts to manage food waste, insufficient infrastructure and resources often hinder effective treatment. Improper treatment methods, such as landfill disposal or open dumping, further exacerbate the environmental impact of food waste by emitting methane, a potent greenhouse gas, and contaminating soil and water resources. Additionally,

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untreated food waste poses health risks, attracting pests and contributing to the spread of diseases. Composting is a natural process that involves converting organic waste materials into nutrient-rich compost through the action of aerobic bacteria.[1,2,3] This method is highly valued for its ability to efficiently manage organic waste while simultaneously producing a valuable resource for soil improvement and plant growth.[4] One such advancement is the In-vessel Rotary Drum Composting System, which offers a controlled environment for composting organic waste. The schematic diagram of the rotary in-vessel composter is given in Fig 1.1

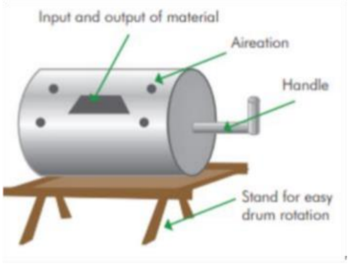

Fig 1.1 : Schematic diagram of Rotary In-vessel Composter

In-vessel rotary drum composting systems represent a significant advancement in composting technology, offering improved efficiency and product quality.[5] By providing a controlled environment, these systems accelerate the composting process, reduce environmental impact, and produce high-quality compost in less time compared to traditional methods. Incorporating invessel rotary drum systems into composting facilities can revolutionize organic waste management practices and contribute to sustainable waste diversion efforts.

1.2 NEED OF THE STUDY

College of Engineering Trivandrum (CET), established in 1939 by the Travancore monarch, Chithira Thirunal, stands as the oldest technical institution in the state The campus faces a growing challenge in managing solid waste, with organic waste, including fallen leaves and food waste from various sources, constituting a major portion of the waste generated. The primary contributors to Campus Food Waste (CFW) are identified as the Ladies Hostel (LH), Men's Hostel (MH), Main Canteen (MC), and Civil Canteen (CC). While the current practice of diverting Campus Food Waste (CFW) to a poultry farm and burning fallen leaves on campus addresses immediate disposal needs, a more sustainable approach is essential for long-term environmental health. Implementing a proper organic waste management system will not only minimize the environmental impact of waste disposal but also contribute to the creation of a more sustainable campus environment.[6] By exploring options such as composting for organic waste by utilizing fallen leaves, College of Engineering Trivandrum (CET) can enhance its commitment to environmental stewardship.

1.3 OBJECTIVE OF THE STUDY

- To conduct experimental investigations in laboratory compost reactors to arrive at suitable bulking agent.
- To design and develop an in vessel aerobic composting reactor for organic degradable waste generated in the campus based on the experimental results.

2. METHODOLOGY

2.1 GENERAL

The study designed an in-vessel aerobic composter for decomposing the organic waste produced in the campus of College of Engineering Trivandrum. The study also focused on accelerating the composting process by the addition of bulking agents. The dried leaves menace in the college is also taken in to consideration and these leaves are used in the compost as bulking agents. The comparative study of fallen dried leaves with sawdust was done to understand the suitability of fallen dried leaves as bulking agent in food waste composting.

2.2 MATERIALS

2.2.1 Campus Food waste

Food waste can be described as the food which get wasted during the production, transportation and consumption. Campus Food Waste (CFW) was gathered from various sources within the college premises, including the men's hostel, ladies hostel, main canteen, and civil canteen, to conduct experimentation. To facilitate the collection process, a designated collection bin was installed on the college campus. This bin served as a central point for depositing food waste, allowing for efficient segregation and management of CFW. The sample of collected food waste is shown in the fig 2.1

Fig 2.1 Collection of food waste

2.2.2 Bulking Agents

For the experimentation, two different bulking agents were chosen:

Fallen dry leaves: Leaves that had naturally fallen from trees on the college campus were collected. These leaves were then subjected to a sun-drying process, allowing them to dry out thoroughly for a period of three days. Once dried, the leaves were finely ground into a powder like consistency.[7]

Sawdust: Sawdust was sourced from a local sawmill located near the College of Engineering Trivandrum. This sawdust, a byproduct of wood processing, was readily available and obtained directly from the mill. Sawdust is often used as a bulking agent in composting due to its absorbent properties and ability to maintain proper aeration within compost piles. [8]

2.2.3 Inoculum

This inoculum comprised Actinomycetes and Lactobacillus, two bacterial species known for their ability to facilitate the decomposition process and produce high-quality compost efficiently within a relatively short period. The commercial inoculum was sourced externally and incorporated into the composting process to enhance microbial activity and accelerate decomposition rates.

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2.3 METHODS

2.3.1 Preparation of matured compost for experimental study

For the experiment, matured compost was prepared according to a specific protocol. The preparation involved combining food waste, inoculum, and sawdust in predetermined weight ratios. Specifically, a mixture consisting of 1.5 kg of food waste, 15 mg of inoculum, and 100 mg of sawdust was prepared. [9] To facilitate the composting process, the mixture was turned daily to promote adequate mixing and aeration, essential for microbial activity and decomposition.[10] After a period of 45 days, samples of the matured compost were collected for quality analysis. This analysis aimed to assess various parameters such as nutrient content, microbial activity, and compost stability, providing valuable insights into the effectiveness of the composting process and the quality of the final product. The fig 2.2 shows the conversion of food waste to compost.

Fig 2.2 Conversion of food waste to compost

2.3.2 Food waste collection and quantification in CET

In the waste management initiative at the College of Engineering Trivandrum (CET), the collection and quantification of Campus Food Waste (CFW) were systematically undertaken. CFW was collected from various sources within the college premises, encompassing waste generated on Mondays, Wednesdays, and Fridays. Each collection day served as a representative sample of the typical waste generation pattern observed during different intervals of the week. To ensure accurate measurement, the quantity of CFW generated on each of these days was meticulously quantified. Following the collection and quantification process, a 3-day average was computed, incorporating data from Monday, Wednesday, and Friday.[11] This average served as a reliable indicator of the average daily CFW generation rate within CET.

2.3.3 Characterization of Campus Food Waste

In the characterization process of Campus Food Waste (CFW), a thorough examination was conducted to assess its diverse properties. The aim was to gain insight into key characteristics crucial for effective waste management strategies. Several parameters were analyzed, including pH levels, temperature, moisture content, and bulk density.[12] pH measurements provided information on the acidity or alkalinity of the waste, aiding in understanding its potential impact on composting processes and environmental conditions. Temperature assessments helped gauge the thermophilic activity within the waste, indicative of microbial activity and decomposition rates. Moisture content analysis offered insights into the water content of the waste, influencing composting efficiency and microbial activity. Additionally, bulk density measurements provided data on the compactness of the waste, guiding decisions related to storage, handling, and transportation. By comprehensively characterizing CFW through these parameters, a deeper understanding of its composition and properties was attained, facilitating informed decision making in waste management practices. The instruments and methods used for finding the characteristics of food waste is shown in table no. 2.1

Tab 2.1 Instrument and methods used for finding the characteristics of food waste

Parameter	Instrument	Method
pH	pH meter	Potentiometric method
Temperature	Thermometer	Thermometric method
Moisture content	Oven, small container	Oven dry method
Bulk density	Container of known volume	Mass-Volume method

2.3.4 Experimental investigation in laboratory

Selection of bulking agent and its quantification: For the study, two bulking agents, namely sawdust and fallen dried leaves, were selected to assess their efficacy in composting. Different quantities of these bulking agents, specifically 10 gm, 15 gm, and 20 gm, were used in combination with 200 gm of food waste and 5 gm of inoculum for analysis. This variation in bulking agent quantity allowed for the examination of their impact on composting efficiency and final compost quality. Throughout the experiment, temperature, moisture content, and pH levels were continuously monitored at 25-day intervals.

Experimental setup for lab scale study: For finding out the best substrate combination for composting, various combination of bulking agent and inoculum study were carried out in the laboratory.[11] The bulking agent used in the study includes saw dust and dried leaves. A total of 6 combinations were made for the study. Here the food waste (200gm) and inoculum (5gm) were same for all the 6 combination. The varying factor was the bulking agent and its quantity. Saw dust with 10%, 15%, 20% and dried leaves 10%, 15%, 20% were used as the bulking agent in this study.

2.3.5 Designing and Development of Rotary In-vessel Composter

The process of composting was studied using the indigenously developed rotating drum in-vessel compost reactor. The reactor (Fig. 2.3) consists of horizontally placed, fully enclosed perforated vessel with a loading capacity of 50 kg. Comparison study of bulking agent with saw dust and dried leaves were also carried out in the lab scale study. The collected Campus Food Waste (CFW) was then inserted in to the rotary in vessel with best substrate from the lab scale study and monitored for 25 days. [13]

The substrate consist of 10 kg of Campus Food Waste, 250 gm commercial inoculum and 500 gm of dried leaves. Rotation was given twice in a day and after 25 days the various parameters such as the NPK values and C:N ratio were tested and compared it with lab scale study.

This approach not only addresses the specific requirements of processing 50kg of waste per reactor but also maximizes compost quality and production efficiency.

Fig 2.3 Rotary In-vessel Composter

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3. RESULTS AND DISCUSSION

3.1 GENERAL

The results of the food waste quantification, characteristics and the lab scale study of composting using various inoculums and bulking agent along with the comparison of best substrate combination in rotary in-vessel composter are discussed in this chapter.

3.2 WASTE GENERATION QUALITY AND QUANTITY OF CET CAMPUS

3.2.1Characteristics of food waste

The Campus Food Waste (CFW) was collected and checked its characteristics such as temperature, moisture content, pH and density are shown in Tab 3.1

Table 3.1 : Characterization of food waste

Sl. No	Parameters	Value
1	Temperature (℃)	32
2	Moisture content (%)	87.5
3	pH	8.01
4	Density	360 kg/m³

The data from the table indicates several key characteristics of the food waste generated at CET campus, which will influence the composting process.

3.2.2Average food waste generation in CET campus

The total daily food waste generation across all CET campus establishments listed in the table 3.2 is 405 kg. This is a significant amount of organic waste produced each day.

Table 3.2 : Quantity of food waste generated in CET Campus

Establishment	Average daily food waste generation (kg/day)
Men's hostel mess	120
Ladies hostel mess	190
Main canteen	90
Civil canteen	3
Other food waste in campus	2
Total	405

This data from CET campus provides a snapshot of the daily food waste generation, highlighting the potential environmental and economic consequences if not addressed properly.

3.3 CHARACTERISATION OF THE MATURED COMPOST USED FOR THE STUDY

Nitrogen: The compost has 0.6% nitrogen, which is within the permissible range of 0.3-1.5%. Phosphorous: The compost has 0.2% phosphorous, which is within the permissible range of 0.11%. Potassium: The compost has 0.5% potassium, which is within the permissible range of 0.31%. PH: The compost has a PH of 7.2, which is within the permissible range of 6-8.5. Moisture content: The compost has a moisture content of 32%, which is within the permissible range of 3040%. This suggests that the compost is a good source of nutrients for plants. The characteristics of matured compost used for experiment is shown in the Table 3.3

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Table 3.3 : Characteristics of the matured compost used for experiment Source: Food and Agricultural organization Report of United Nation

Parameter	Nutrient in compost	Ideal value
Nitrogen	0.6 %	0.3 – 1.5 %
Phosphorous	0.2 %	0.1 – 1 %
Potassium	0.5 %	0.3 – 1 %
pH	7.2	6 – 8.5
Moisture content	32 %	30 – 40 %

3.4 STUDY OF TEMPERATURE ON COMPOSTING

The temperature of both saw dust bulked and leaves bulked compost while using commercial inoculum within a interval of 5 days up to 25th day is depicted in the below table 3.4

Table 3.4: Temperature on compost while using commercial inoculum

	Saw dust			Leaves		
Days	Temp with Sawdust 10g (°C)	Temp with Sawdust 15g (°C)	Temp with Sawdust 20g (°C)	Temp with Leaves 10g (°C)	Temp with Leaves 15g (°C)	Temp with Leaves 20 g (°C)
5	30	30	30	33	32	30
10	40	38	36	47	45	43
15	55	52	50	62	60	58
20	50	48	45	57	55	52
25	40	38	35	47	45	42

The table clearly depicts the compost with leaves bulked shows the highest temperature and the compost with 10gm of leaves bulked attained a temperature of 62 ˚C. Also the leaves bulked compost reached the mesophilic stage (FAO Report : 45-70 °C) in lesser no of days which accelerates the composting process.

3.5 STUDY OF MOISTURE CONTENT ON COMPOSTING

The moisture content of both saw dust bulked and leaves bulked compost while using commercial inoculum within a interval of 5 days up to 25th day is depicted in the below table 3.5

Table 3.5: Moisture content on compost while using commercial inoculum

	Saw dust			Leaves		
Days	MC with Sawdust 10g (%)	MC with Sawdust 15g (%)	MC with Sawdust 20g (%)	MC with Leaves 10g (%)	MC with Leaves 15g (%)	MC with Leaves 20g (%)
5	55	53	51	58	57	56
10	50	48	46	53	52	51
15	45	43	41	48	47	46
20	40	38	36	43	42	41
25	35	33	31	38	37	36

The table clearly depicts the moisture content of saw dust bulked and leaves bulked compost and the values obtained are within the range as per FAO report of United Nations. (Moisture content range as per FAO Report : 30 – 40 %)

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3.6 STUDY OF pH ON COMPOSTING

The pH of both saw dust bulked and leaves bulked compost while using commercial inoculum within a interval of 5 days up to 25th day is depicted in the below table 3.6

Table 3.6: pH on compost while using commercial inoculum

	Saw dust			Leaves		
Days	10g	15g	20g	10g	15g	20g
5	7.2	7.1	7	6.8	6.7	6.6
10	6.3 6.3		6.4	6.1	5.8	5.6
15	5.5	5.5	5.5	5.3	5.2	5
20	6.7	6.7	6.7	6.7	6.4	6.3
25	7	7.3	7.1	6.8	6.7	6.7

The table clearly depicts that the pH of saw dust bulked and leaves bulked compost and the values obtained are within the range as per FAO report of United Nations. (pH range as per FAO Report : 6 – 8.5)

3.7 CHARACTERIZATION OF COMPOST COMBINATIONS

The parameters such as Nitrogen, Phosphorous, Potassium and Carbon : Nitrogen of all the 6 combinations were carried out.

Table 3.7 : Characteristics of the compost with commercial inoculum used for experimental study

Combination	Nitrogen (%) Ideal range [0.3-1.5]	Phosphorous (%) Ideal range [0.1-1]	Pottassium (%) Ideal range [0.3-1]	Total Organic Carbon (%) Ideal range [30-40]	Carbon : Nitrogen Ideal range [20-40]
FW+SD(10)+CI	1.3	0.5	1	41	31.5
FW+SD(15)+CI	1.4	0.5	1	41.5	29.6
FW+SD(20)+CI	1.2	0.5	1	42	35
FW+DL(10)+CI	1.3	0.5	1	40	30.7
FW+DL(15)+CI	1.3	0.5	1	41	31.5
FW+DL(120)+CI	1.2	0.5	1	41.5	34.5

The results obtained from the testing confirms that leaves bulked compost is more suitable than saw dust bulked compost. Additionally it also depicts it is better to use commercial inoculum.

3.8 CHARACTERIZATION OF THE MATURED COMPOST FROM ROTARY IN-VESSEL COMPOSTER

The compost from the rotary in-vessel composter was tested for NPK values and C:N ratio and compared with the lab scale study. The values are depicted in the table 3.8

Table 3.8 : Characteristics of the matured compost from rotary in-vessel composter

Parameter	Nutrient in in-vessel composter	Nutrient in experiment	Permissible value
Nitrogen	1.3 %	1.5 %	0.3 – 1.5 %
Phosphorous	0.5 %	0.5 %	0.1 – 1 %
Potassium	0.95 %	1.1 %	0.3 – 1 %
pH	6.5	6.9	6 – 8.5
Moisture content	39 %	37 %	30 – 40 %

The values tested confirms that the composting parameters after rotary in-vessel composting is almost similar with the lab study values. And both the values obtained are within the permissible limit as per the United Nation Food and Agriculture Organization.

4. CONCLUSION

The study reveals that, the compost with fallen dried leaves as bulking agent shows superior composting properties when compared with saw dust while analyzing the parameters such as temperature, moisture content and pH for 25 days with 5 day interval and testing the NPK value and C:N ratio after 25 days. The scaled up study of composting using rotary in-vessel composter shows similar results as that of the lab scale study and thus infers that the rotary in-vessel can be used in composting to reduce the composting time and improves the composting properties. The decentralized method of composting using rotary in-vessel composter can reduce the effort and cost of composting and its future scope extends to the agglomeration of AI tools in order to make it more compactible and more efficient. The future study also needs to look in to varieties of bulking agent and inoculums which can accelerate the composting with little effort and money.

5. CONFLICT OF INTEREST

I declare that there is no known competing financial interests or personal relationships that could have appeared to influence the work reported here.

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