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DESIGN AND DEVELOPMENT OF COMPACT AEROBIC HOUSEHOLD COMPOSTER

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Abstract : The design, development, and evaluation of a compact household aerobic composter optimize airflow through controlled aeration to promote composting. After 24 h, 12 h, 6 h, and no aeration, composting rate, efficiency, nutrient content (NPK), temperature profile, moisture content, and secondary physical qualities like color and biological activity were examined. Each composter received 0.5 kg of organic waste and was monitored for 8 days. Statistical analyses assessed the homemade aeration system. Temperature data was non-normal ($p = 0.0031–0.018$), but compost mass and percentage conversion were normal ($p = 0.363$). According to Kruskal–Wallis tests, aeration treatments did not substantially impact compost mass, % conversion ($p = 0.368$), or median temperature ($p \approx 0.1115$ In one-way ANOVA, mean nitrogen, phosphorus, and potassium concentrations did not change across treatments ($p = 0.754$, 0.381, and 0.837). Researchers found that the makeshift aeration composting system reliably converted organic waste regardless of aeration duration. Compact aerobic composters can manage residential garbage, according to the findings. Shredding may improve composting efficiency and system mobility, according to the findings.

1. INTRODUCTION

Global municipal solid waste generation is projected to increase by nearly 70% by 2050, reaching 3.4 billion metric tons (Alves, 2023). This surge is driven by factors including population growth, urbanization, economic development, and consumption patterns. Effective waste management is thus critical to mitigate environmental impacts. In the Philippines, with over 100 million people, annual waste production exceeds 21 million metric tons, averaging approximately 0.4 kg per capita per day (DENR, 2021). This highlights a pressing need for sustainable waste practices. Composting emerges as a viable alternative to reduce organic waste in landfills and greenhouse gas emissions.

In Zamboanga City, limited access to compact, affordable household composters restricts adoption of composting practices. Current commercial composters are often expensive and bulky, unsuitable for urban households with limited space. Furthermore, conventional composting methods typically require extended decomposition times, limiting their usability and acceptance.
This study aims to address these gaps by developing a compact aerobic household composter with fan-assisted aeration to accelerate composting processes within urban constraints.

1.1 BACKGROUND OF THE STUDY

Zamboanga City faces a critical gap in accessible, small-scale household composting solutions. Despite growing awareness of environmental issues and the urgent need for sustainable waste management, residents have limited access to space-efficient and practical composting systems. This constraint hinders community efforts to divert organic waste from landfills, reduce greenhouse gas emissions, and foster environmentally responsible practices at the household level.

Compounding this issue is the slow and inefficient nature of conventional composting methods, which often require extended decomposition periods before producing usable compost. Such delays limit the timely application of compost for gardening and soil improvement, thereby reducing the potential benefits of composting for urban agriculture and waste reduction. Addressing these challenges requires the development of a compact, user-friendly composting system capable of accelerating the decomposition process while maintaining efficiency and ease of operation.

1.3 OBJECTIVES

This study aims to design and develop a compact household aerobic composter equipped with a fan-assisted aeration system to optimize airflow and accelerate the composting process. Specifically, it seeks to:

- To determine the composting rate (in days), analyze the nitrogen, phosphorus, and potassium (NPK) content of the compost, and evaluate overall composting efficiency.
- To examine the effects of varying aeration durations (24 hours, 12 hours, and 6 hours) on composting performance.

1.4 SIGNIFICANCE OF THE STUDY

The study proposes an effective solution to urgent environmental issues by offering families an efficient composting system that minimizes landfill waste and decreases greenhouse gas emissions. Furthermore, it possesses educational merit by advocating for sustainable waste management techniques and fostering environmentally conscious behaviors among the general population. The project demonstrates significant multidisciplinary collaboration, uniting the fields of engineering, environmental science, and waste management to collaboratively tackle pressing environmental issues.

1.5 Scope and Delimitation

The study focused on the design, development, and optimization of a compact household aerobic composter that utilized fans for efficient composting; in this study, the researcher designed only one unit of composter with four variations in aeration supply duration: 24 hours, 12 hours, 6 hours, and with no aeration. The study lasted for 1-2 months and utilized shredded vegetable waste from Sta. Cruz Bagsakan Center as a sample for the composter.

2. METHODOLOGY

2.1 Secondary Data Gathering

The data necessary for the study were obtained from various sources. This includes Academic journals and research papers related to composting, waste management, and sustainable practices that can provide valuable secondary data.

2.2 Location of the Experimental Study

The study was conducted in a residential property located in Buenagatas, Boalan, Zamboanga City.

2.3 Research Design

An experimental design was employed to compare the treatment efficiency of two packed-cage RBC setups. The first setup used bio balls with foam as the filter media, while the second setup used bio balls with coconut coir. Both setups were evaluated for their ability to reduce biochemical oxygen demand (BOD_5), total suspended solids (TSS), and oil and grease (O&G) over a three- week operational period.

2.4 Theoretical Considerations and Designs

Composting involved various environmental and design factors that required consideration. However, in this study, the focus was exclusively on these design parameters for equipment development. This decision was made because other parameters primarily aimed to optimize the composting process and, in turn, influenced the equipment's design.

2.5 Sizing

The size of the equipment was determined based on the projected volume of solid waste generated per person in the Philippines, which is estimated to be approximately 0.40 kg/person/day (DENR News Alerts 2021) Out of this total, it is expected that around 45% will constitute food waste (World Bank, 2015). According to the Philippine Statistics Authority (2020) the household population of the Philippines in 2020 was 108,667,043 persons dividing the household population by the number of households in the country, which was 26,393,906 in 2020, yields an average household size of 4.11 persons per household this translates to 0.738 kg of food waste. According to available literature, food waste typically has a density of 300 kg/cu.m (Tchobanoglous et al., 1977). The effective volume was calculated using the mass density formula.

$$V = \frac{M}{\rho} \qquad \text{-----eq. 1}$$

where V = volume

M = mass

ρ = density

Thus, the composter dimension is 0.135m x 0.135m x 0.235m
A fixed freeboard of 0.181m was added on the side lengths and 0.444m on the height for extra allowance and air space

2.6 AIR REQUIREMENT

Theoretical air requirements for composting were determined by applying the stoichiometric reaction principles of waste oxidation, as documented in Polprasert (1989).

$$C_{16}H_{27}O_8N + 18O_2 \longrightarrow 16CO_2 + 12\,H_2O + NH_3$$

Theoretical air requirement = 7741.533kg

2.7 PARTICLE SIZE

According to Philippine Agricultural Engineering Standard (PAES 2002) the particle size of waste should range from 5 mm to 50 mm. In cases where the compost materials are extremely compact, a bulking agent or additive must be included. This agent should be blended or processed to achieve the necessary size before introducing it to the compost pile. In this study the size was 5mm

2.8 MOISTURE CONTENT AND C: N RATIO

A moisture content ranging from 50 to 70 (with an average of 60%) will be the most suitable, as recommended by Polprasert in 1989. No attempt was made to adjust the moisture content of the selected organic wastes because the commonly reported moisture content for vegetable waste in the literature is 48-95%

As for the C: N ratio, based on the table below, the C: N ratio of the selected organic waste which (Garbage) is only 16:1, which is less than the optimum value of 25:1. There will be no attempt to adjust the C: N ratio in this study since a low ratio would result in the loss of N as NH3 during the composting process in a forced aeration system, elevated temperature, and high pH (Polprasert, 1989).

2.9 SECONDARY OBSERVATION

Observations were done during the course of the experiment on the appearance of the compost such as its color, or if it was earthlike. Additionally, life forms visible to the naked eye, such as worms, molds, beetlemites, and ants, were observed from the fifth day onward.

3.0 LAYERING

The composter was equipped with seven layers of compartments where one should pull the base platform of each individual layer so that the waste at top compartment will fall under the next compartment

3. RESULTS AND DISCUSSION

3.1 Fabricated Composter

The fabricated household aerobic composter measured 12.60" × 12.60" × 20" and consisted of seven layered compartments with a pull-out base platform for staged composting. Aeration was provided by CPU fans controlled via a microcontroller, which also monitored temperature using thermistors. An emergency shutdown feature was integrated to prevent overheating.

Figure 3.1

Schematic Diagram of the Composter

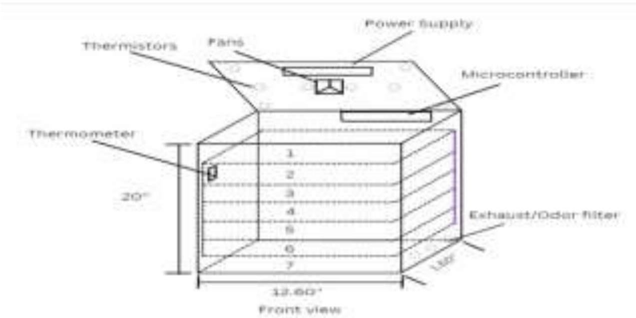


Figure 4.1

The fabricated Composter

3.2 Composting Rate and Conversion

Table 4.1

Result tabulation of Composting rate and conversion

Composter Number	Duration (d)	Initial Mass (Kg)	Compost Mass (Kg)	Percentage Conversion (%)
C1	7	0.5	0.19	38%
C2	7	0.5	0.185	37%
C3	8	0.5	0.165	33%

Initial compostable material mass was **0.5 kg** for all treatments. Aeration significantly influenced compost formation:

- **C1 (24 hrs)** — 38% conversion after 7 days
- **C2 (12 hrs)** — 37% conversion after 7 days
- **C3 (6 hrs)** — 33% conversion after 8 days
- **C4 (No aeration)** — No compost formation

Statistical analysis (Shapiro–Wilk and Kruskal–Wallis tests) showed no significant differences among treatments, likely due to small sample size. Results confirm aeration's critical role in accelerating decomposition.

Table 4.2

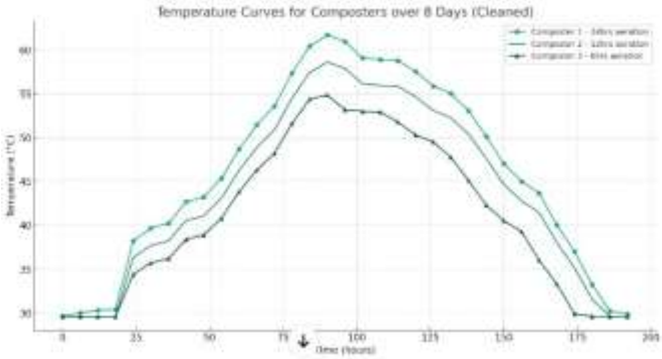
Measures of central tendency for Composting rate and conversion

	Duration (in days)	Compost Mass (in Kg)	Percentage Conversion
Mean	7.5	0.180 Kg	36%
Median	7.5	0.180 Kg	37%
Mode	7,8	0.165, 0.185, 0.19 Kg	33%, 37%, 38% (multimodal)
Range	1	0.025 Kg	5%
Standard Deviation	0.557	0.0132 Kg	2.646%

Table 4.2 displays the Shapiro-Wilk test for normality was performed to assess the distribution of compost mass and percentage conversion. With p-values of 0.363 for both variables, the test did not indicate a significant departure from normality. This suggests that the assumption of normal distribution in the dataset is not violated. However, it's important to note that the validity of normality tests is questionable with such a small number of observations

3.3 Temperature Profile

The observed temperature curves in the graph provided a retrospective view of the composting process under various aeration regimens.



Longer aeration resulted in higher peak temperatures and sustained thermophilic phases:

- **C1:** 45.47 °C
- **C2:** 42.79 °C
- **C3:** 40.74 °C
- **C4:** No thermophilic phase

Kruskal–Wallis analysis indicated no statistically significant difference in median temperatures ($p > 0.05$), though trends aligned with composting theory emphasizing oxygen availability for microbial activity.

Table 4.3

Measures of central tendency for temperature profile

	C1	C2	C3
Mean	45.47	43.47	40.74
Median	45.18	42.91	39.90
Mode	28.01	29.62	29.62

Table 4.3 shows the normality of the temperature distribution within each dataset was assessed using the Shapiro-Wilk test. The findings of the study revealed that the likelihood of the data conforming to a normal distribution was minimal for each of the three composters, as evidenced by p-values of 0.018, 0.0077, and 0.0031 for the aeration durations of 24, 12, and 6 hours, respectively. The non-normality of the data distributions required the application of the Kruskal-Wallis test, a non-parametric approach, to assess the statistical significance of differences between the groups.

Table 4.4

Summary statistics for temperature profile

Test	Statistic	P-value	Conclusion
Shapiro – Wilk (composter 1)	0.922	0.0182	Non-normal distribution
Shapiro – Wilk (composter 2)	0.908	0.0077	Non-normal distribution
Shapiro – Wilk (composter 3)	0.894	0.0031	Non-normal distribution
Kruskal-Wallis	4.388	0.1115	No significant difference

Table 4.4 displays the Kruskal-Wallis test yielded a p-value of 0.1115, indicating that there was no statistically significant difference in the median temperatures between the different aeration times. In academic terms, this p-value suggested that the observed variations in median temperatures across the composters could reasonably occur by chance, with an approximate 11.15% likelihood. Therefore, it was concluded that the different aeration times did not significantly affect the composting process as measured by the temperatures observed in this study.

3.4 Nutrient Content (NPK)

Based on the data from the study, the effects of aeration time on the nutrient composition (Ammonia Nitrogen, Phosphorus, Potassium) of the compost produced in three different composters. The data indicated varied concentrations of nutrients depending on the aeration time, which was critical in composting processes for optimizing the nutritional content of the resulting compost.

Table 4.5

Nitrogen, Phosphorus and Potassium (N,P,K) contents of composts by each trials in mg/L

Trial	C1 (N)	C1 (P)	C1 (K)	C2 (N)	C2 (P)	C2 (K)	C3 (N)	C3 (P)	C3 (K)
1	20	50	50	100	20	240	200	50	120
2	340	120	20	500	230	200	290	240	140
3	270	140	180	70	130	40	40	150	160
4	500	60	200	270	60	40	100	130	20
5	300	180	240	280	220	80	90	150	20
6	50	50	110	280	240	230	490	70	90
7	100	110	150	440	80	80	260	100	40
8	320	140	40	140	80	70	240	110	240
9	200	40	10	80	150	110	40	200	240
10	470	230	230	70	80	80	10	10	20
11	60	220	130	20	210	130	320	150	90
12	230	230	150	30	170	90	440	150	170
13	20	210	80	430	200	60	80	140	160
14	120	30	240	250	210	90	340	120	150
15	500	230	210	320	220	230	90	10	30
16	500	180	60	360	220	180	280	180	180

Table 4.6

Measures of central tendency for NPK content

Statistic	C1 (N)	C1 (P)	C1 (K)	C2 (N)	C2 (P)	C2 (K)	C3 (N)	C3 (P)	C3 (K)
Mean	250.0	138.75	131.25	227.5	157.5	121.25	206.875	122.5	115.625
Median	250.0	140.0	140.0	260.0	185.0	90.0	220.0	135.0	130.0
Mode	500.0	230.0	150.0	70.0	80.0	80.0	40.0	150.0	20.0

Table 4.6 shows statistics reflect the central tendencies and distributions of the nutrient contents in the compost trials. The means indicate the average concentration, while the medians provide a sense of the middle value of the data set, and modes reflect the most common values. The data's variability, particularly with modes that have multiple values, suggest that the composting process can yield different nutrient profiles across different batches.

Table 4.7

ANOVA test results for NPK content

Nutrient	Shapiro wilk test p- value	ANOVA F value	ANOVA P value
Nitrogen	C1: 0.085 C2: 0.197 C3: 0.255	0.284	0.754

Phosphorus	C1: 0.051 C2: 0.032 C3: 0.567	0.987	0.381
Potassium	C1: 0.215 C2: 0.026 C3:0.104	0.178	0.837

Table 4.7 displays The ANOVA test results indicate no significant differences in the mean concentrations of nitrogen, phosphorus, and potassium across the three composters:

The p-values for nitrogen (0.754), phosphorus (0.381), and potassium (0.837) are all well above the conventional significance level (0.05). This suggests that the variability observed in nutrient content across the different composters does not statistically differ from each other, implying similar compost quality and nutrient recovery effectiveness across the three setups. Analysis showed that aeration duration did not significantly affect nitrogen, phosphorus, and potassium content (ANOVA, $p > 0.05$). Nutrient values remained within acceptable ranges for organic fertilizers, suggesting that aeration primarily impacts composting speed rather than nutrient retention.

3.5 Observations

From day 4 onwards, compost exhibited a dark color, earthy odor, and visible decomposer organisms (molds, beetle mites, ants), indicating active microbial activity and compost maturation.

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