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Study on Kitchen Waste Composting Using Microbial Cultures and Biochar

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Abstract: Kitchen waste has long contributed significantly to environmental pollution. The experiment titled "Study on kitchen waste composting using microbial cultures and biochar", conducted at Nepal Academy of Science and Technology, Lalitpur, was meant to find the possible ways to shorten the composting period. Seven treatments were arranged in a completely randomized design (CRD): T1 (Control), T2 (EM-1), T3 (Prarhamva Decomposer), T4 (Biofertilizer KM), T5 (Biochar 400 g + Biofertilizer KM), T6 (Biochar 800 g + Biofertilizer KM), and T7 (Biochar 200 g). The decomposition period ranged from 14 to 33 days across treatments. The key finding was a significant reduction in composting duration, with T6 (800 g Biochar + Biofertilizer KM) achieving the fastest decomposition in just 14 days ($p < 0.05$), effectively reducing the composting time by more than half compared with the control (T1) and EM-1 (T2), both of which required 33 days. Chemical analysis revealed that T2 (EM-1) produced the highest nitrogen (0.55%) and organic matter (30.09%) content, whereas the highest phosphorus content (2.17%) was found in T3 (Prarhamva Decomposer), and the highest potassium (4.77%) was recorded in T5 (Biochar 400 g + Biofertilizer KM). Although temperature fluctuations were observed during different phases of decomposition, the integration of biochar and Biofertilizer KM consistently enhanced the composting process. These results demonstrate that biochar enrichment can significantly shorten the composting cycle, offering a robust platform for sustainable solid waste management.

Keywords: *Biochar, Biofertilizers, Compost, Kitchen Waste*

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1. Introduction

Food waste refers to leftover food that is not consumed and residues generated during food preparation from households, commercial establishments (e.g., restaurants), institutions (such as schools, colleges, and hospitals), and some industrial sources (e.g., workplace cafeterias) (Hartono et al., 2015). Kitchen waste, which may contain up to 74.5% moisture, poses significant environmental risks, including leachate generation and foul odor emission if not properly managed (Zhang et al., 2008). Composting offers a simple and effective biological approach for managing such organic waste, with optimization efforts focused on accelerating decomposition, minimizing odor, and producing nutrient-rich soil amendments. Composting typically requires one to three months but can extend up to six to twelve months, depending upon the management practices and waste composition. Therefore, ensuring efficient organic matter breakdown is crucial for successful composting.

Microorganisms play a vital role in the degradation of organic matter, with various microbial species working together and synergistically to break down complex substrates. The study by Barthod et al. (2018) found that mesophilic and thermophilic microbial populations influence ammonia emissions and temperature dynamics during the composting process. The introduction of external microbial cultures, such as effective microorganisms (EM), has been shown to enhance waste degradation rates and improve the nutrient content of the resulting compost (Jusoh et al., 2013; Saad et al., 2013). Microbial populations also respond dynamically to temperature changes, which correspond to different stages of the decomposition process (Rich & Bharti, 2015). Several studies have demonstrated that the addition of efficient microbial inoculants to composting mixtures accelerates waste degradation by increasing enzymatic activity and reducing the initial lag phase of the biological process (Karnchanawong & Nissaikla, 2014; Manu et al., 2017; Onwosi et al., 2017).

Biochar, a carbonaceous material produced through the pyrolysis of biomass, has attracted increasing attention in waste management due to its unique physicochemical properties (Xiao et al., 2014). Its high porosity, large surface area, and substantial cation exchange capacity (CEC) enable it to sequester carbon, remediate pollutants, and provide a stable and favorable habitat for microbial communities (Ahmad et al., 2014; Czekała et al., 2016; Lehmann & Joseph, 2015). Owing to these characteristics, biochar has been proposed by many researchers as a potential amendment to accelerate the composting process. A review of the literature indicates that biochar can enhance composting efficiency, even in livestock and poultry waste, when applied at rates of approximately 5–10%. This improvement is attributed to its ability to prolong the thermophilic phase, reduce leachate formation, regulate substrate pH, and minimize the emission of harmful gases such as ammonia, nitrous oxide, and methane (Akdeniz, 2019). From a farmer’s perspective, both compost and biochar serve as environmentally friendly soil amendments that are also effective and economically feasible (Karim et al., 2022). Therefore, incorporating biochar into composting systems may enhance microbial activity, improve aeration, and stabilize nutrients within the compost matrix. The overall findings of this research contribute to the expanding literature on climate–health interactions and offer actionable insights for public health practitioners, policymakers, and community organizations working to enhance resilience in climate-vulnerable coastal settings.

2. Materials and Methods:

2.1. Description of study

The experiment was carried out on pots (bags) at Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur, from April 2022 to July 2022. The study site is located at 27º39'22"N and 85º19'39" E, at an altitude of 1350 meters above sea level, with a subtropical climate.

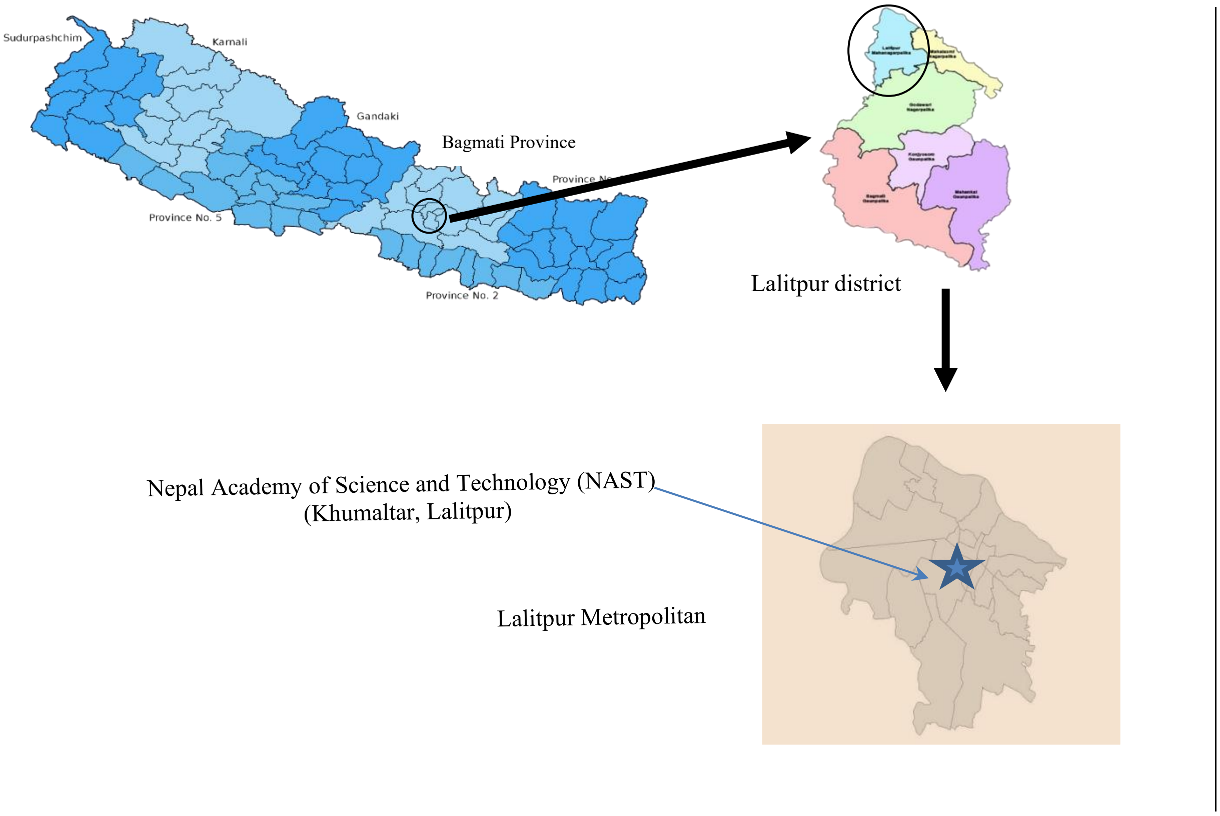

Figure 1. Location of the experimental site, Nepal Academy of Science and Technology (NAST)

2.2. Experimental details

Experimental design and Variables

The experiment design was laid out in a completely randomized design (CRD) with 7 treatments, each replicated 3 times. The details of the treatments used in the study are shown in Table 1, and the layout of the experiment is presented in Figure 2. Three types of variables were considered in this study: independent, dependent, and control variables. The treatments involving additive microorganisms represented independent variables, while homogeneous compost parameters such as water content, temperature, NPK (Nitrogen-Phosphorus-Potassium), organic matter (OM), and C/N ratio represented the dependent variables.

Table 1: Composition of treatments

Treatments	Composition	Details
T_1	Control	5 kg of kitchen waste without the use of cultures
T_2	Kitchen waste + EM-1	250 ml of activated EM-1 in the top, bottom, and middle layers of 5 kg of kitchen waste
T_3	Kitchen waste + Prarhamva Decomposer	5 kg of waste treated with 100 g of Prarhamva Decomposer layer by layer
T_4	Kitchen waste + Biofertilizer KM	Kitchen waste (5 kg) +250 ml of activated Biofertilizer KM at each layer of compost
T_5	Kitchen waste+ Biochar+ Biofertilizer KM	Kitchen waste (5 kg) +400 g biochar + 250 ml of activated micro inoculant
T_6	Kitchen waste + Biochar + Biofertilizer KM	Kitchen waste (5 kg) +800 g biochar + 550 ml of activated micro inoculant
T_7	Kitchen waste+ Biochar	Kitchen waste (5 kg) + 200 g biochar

EM-1 and Prarhamva Decomposer, used in this experiment, are commercial microbial products. EM-1 contains a consortium of lactic acid bacteria, photosynthetic bacteria, yeasts, actinomycetes, and beneficial fungi. Prarhamva Decomposer, prepared on cocopeat and vermicompost as substrate and available in solid form, includes primarily cellulose-degrading fungi (*Trichoderma viride* and *Rhizopus* spp.) along with phosphate-solubilizing bacteria (PSB), two to three strains of lactic acid bacteria (*Lactobacillus* spp.) adapted to different temperature ranges, nitrogen-fixing bacteria (*Azotobacter* spp., etc.), photosynthetic bacteria, yeasts, and actinomycetes.

2.3. Details of the composting process

Preparation of Black plastic bags for composting

Black plastic bags measuring 5 x 4 feet (1.52 x 1.22 meters) were used. Holes were made in bags with the help of a punching machine, spaced 1-2 inches apart. Holes were made at the top, bottom, and sides to ensure adequate aeration.

Activation of Effective Microorganism (EM-1) and Biofertilizer KM (microbial cultures)

An EM-1 solution was prepared by mixing 50 ml with 910 ml of water and 40 g of jaggery in a closed container. The solution was then stirred 2-3 times daily to release gas and was left for 7 days in a shady, cool place away from direct sunlight. After 7 days, the solution was ready for use, with a pH of 3.8 indicating maturity. For Biofertilizer KM, 950 ml of water, 40 g of jaggery, and 10 g of biofertilizer were mixed and fermented for 5–7 days.

Collection of waste for composting

Food waste was collected before being placed in bags. Green vegetable waste was collected from the Balkhu wholesale vegetable market, while brown waste, primarily tree leaves, was collected from Gundu, Bhaktapur.

Preparation of materials for kitchen waste:

Food waste was manually cut into 1–2 inch pieces to increase the surface area for decomposition. All collected waste was prepared accordingly for the composting process.

Composting of Kitchen Waste

Each bag was filled with alternating layers of chopped food waste and an equal amount of brown material, with a total weight of 5 kg per bag. Between each layer, the EM-1 solution was sprayed at the recommended dose. For biochar-treated compost, the recommended dose of biochar was placed and the EM-1 solution was sprayed between the layers of green matter and brown matter. Temperature and moisture were measured every second day, using a compost thermometer and the fist test method, respectively. The pile was left unturned until the fourth day, after which it was turned every second day. No additional waste was added to the pile once the composting started, as any new material would require the same breakdown time, thereby extending the overall decomposition period. Water was added frequently to maintain moisture. Indicators of rapid decomposition included a pleasant odor, visible heat (in the form of water vapor while turning pile), colonization of white fungal mycelium on the decomposing organic material, a drop in temperature, and a reduction in volume.

Once the compost was ready, it was screened and air-dried for 24 hours before being taken to the laboratory for further analysis.

Nutrient analysis of compost

For the nutrient analysis of compost, various parameters were analyzed in the laboratory. All the analyses were performed using a standard lab manual for soil and fertilizer analysis published by the Department of Agriculture Soil Management Directorate, Hariharbhawan, Lalitpur. Total Nitrogen, Total Phosphorus, Total Potassium, pH, and Organic matter percentage were analyzed using the Kjeldahl method, the Olsen sodium bicarbonate method, the Flame photometer method, the pH meter method (1:2), and the Walkey-Black method, respectively. Moisture percentage was also calculated.

The biochar used in the compost was derived from *Pteridium aquilinum* and *Eupatorium cannabinum* Linn, commonly known as Banmara. It was produced at Bhibo Jaibik Urja in Dhulikhel, through the pyrolysis of locally available materials.

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Table 2: Properties of the biochar used

S.N.	Parameter	Method	value
1	Nitrogen %	Kjeldahl digestion and distillation	0.77 %
2	Organic carbon %	Walkley – Black	13.50 %
3	CEC	Neutral ammonium acetate	19.08 meq/100g

3. Results

Statistical analysis was performed using SPSS and GenStat software. One-way Analysis of Variance (ANOVA) was used to determine significant differences among treatment means. Mean separation was conducted using the least significance difference (LSD) test at a 5% significance level ($p < 0.05$). The results obtained during the study are presented under different subheadings. The experimental and laboratory analyses are presented in Tables 3-5.

3.1. Effect of treatments on days of completion

The treatments significantly influenced the time required for compost maturity ($p < 0.05$). Composting duration ranged from 14 to 33 days (Table 3). Treatment T6 (800 g biochar + Biofertilizer KM) achieved the fastest decomposition in 14 days, followed by T3 (16 days) and T5 (19 days). In contrast, both the control (T1) and EM-1 (T2) required 33 days. This indicates that the higher biochar concentration in T6 effectively reduced the composting duration by more than half compared with the control.

Table 3. Effect of treatments on decomposition of compost

Treatments	Mean (Days of completion)
Control	33^{d}
EM-1	33^{d}
Prarhamva Decomposer	16^{a}
Biofertilizer KM	24^{c}
Biofertilizer KM + Biochar 400 g	19^{b}
Biofertilizer KM + Biochar 800 g	14^{a}
Biochar 200 g	22^{c}
Grand mean	23.52
CV%	6.6
LSD	2.729
P value	0.01

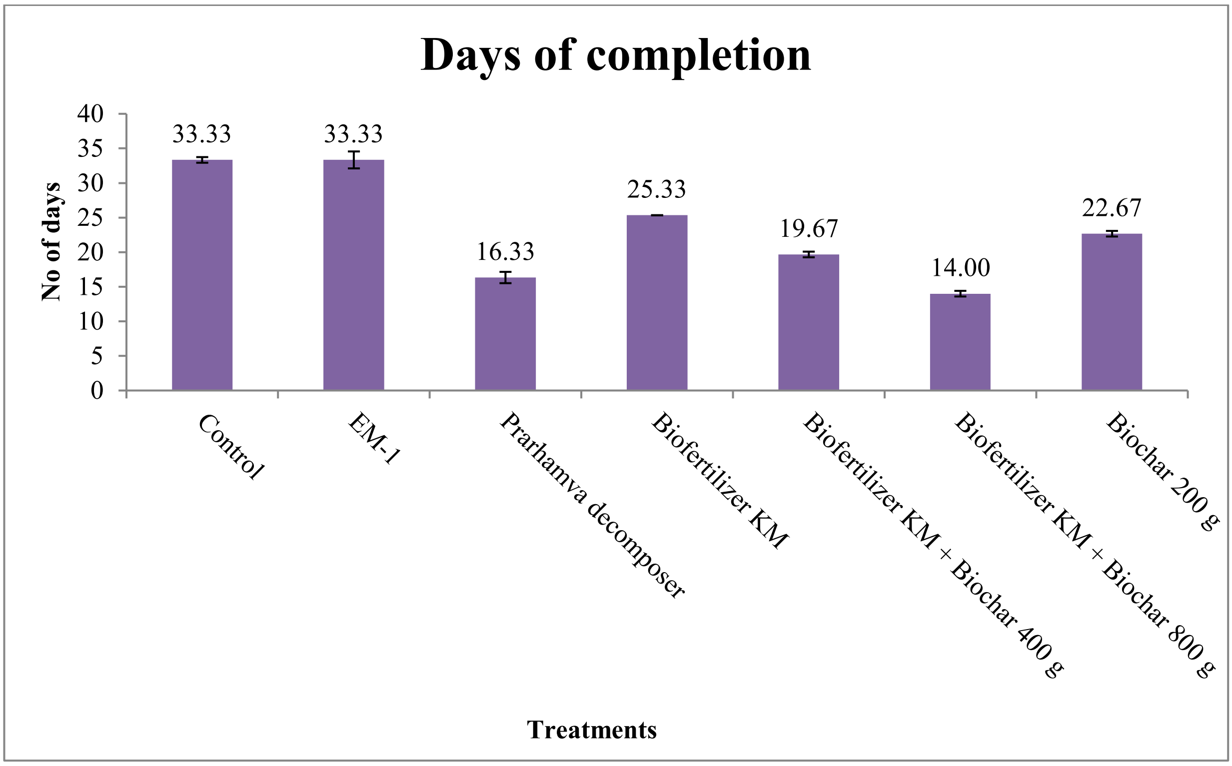

Figure 2. Days of completion for Compost

3.2. Effect of treatments on physical properties of compost

The physical properties analyzed included compost weight, temperature, and moisture content. Weight and moisture were measured after composting was completed, while temperature was recorded at 10-day intervals for 40 days. There was a significant difference in compost weight among the treatments (p=0.005), with T4 and T6 having the highest final weight.

Table 4. Effect of treatments on physical properties of compost

Treatments	Mean (Moisture percentage dry wt. basis)	Mean compost weight (kg)	Mean temperature (10-20 days)	Mean temperature (20-30 days)	Mean temperature (30-40 days)
Control	64.46^{a}	1.74^{bc}	41.77^{a}	51.083^{a}	37.07^{c}
EM-1	57.05^{a}	1.53^{ab}	52.95^{e}	54.167^{a}	36.03^{bc}
Prarhamva Decomposer	60.27^{a}	0.55^{a}	48.76^{bc}	46.750^{a}	33.07^{a}
Biofertilizer KM	70.16^{a}	2.7^{c}	50.19^{cd}	46.583^{a}	35.20^{b}
Biofertilizer KM + Biochar 400 g	72.18^{a}	2.5^{bc}	52.32^{e}	47.333^{a}	36.47^{bc}
Biofertilizer KM + Biochar 800 g	65.07^{a}	2.63^{bc}	47.09^{b}	46.333^{a}	31.70^{a}
Biochar 200 g	67.11^{a}	2.13^{bc}	51.31^{de}	47.333^{a}	35.96^{bc}
Statistical analysis					
Grand mean	65.19	1.97	49.20	48.51	35.07
CV (%)	14.33	29.2	2.0	20.56	2.9
LSD	16.62	1.007	1.7630.2729	17.47	1.798
P-value	0.49	0.005	0.010.702	0.944	0.01

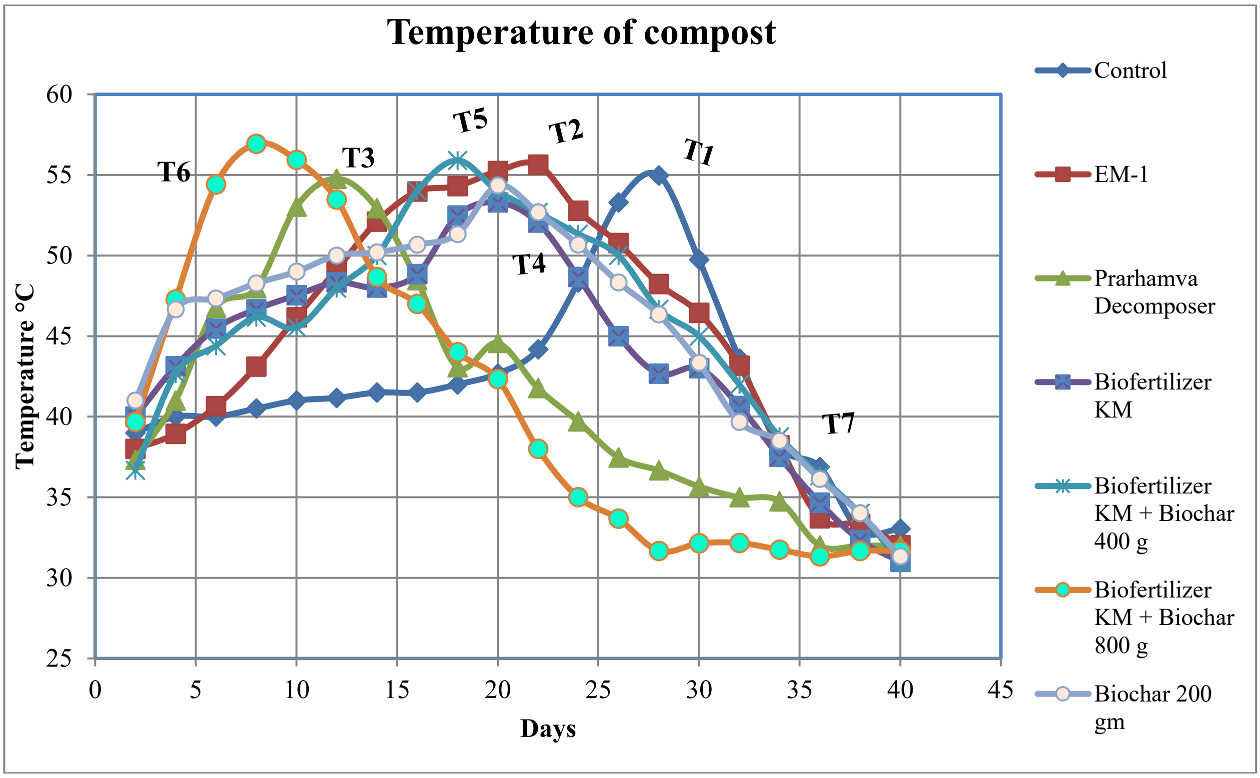

Figure 3. Temperature changes during composting

The temperature of the compost was significantly influenced by the treatments. In Treatment 6 (Biochar 800 g + Biofertilizer KM), the temperature increased from days 5 to 10, while the other treatments had temperatures lower than average. This result indicates that the thermophilic stage began for Treatment 6 by the 10th day of composting, whereas the other treatments remained in the mesophilic stage. Consequently, Treatment 6 experienced a temperature rise, while the others stayed within a normal range. The data revealed significant differences in temperature among the treatments during the composting process. The lowest temperatures were recorded for Treatments 6 (31.70°C), 3 (33.07°C), and 2 (36.03°C), while the highest temperatures were recorded in Treatments 1 (37.07°C) and 5 (36.47°C). The maximum average temperature was quiet consistently recorded in Treatment 2. In contrast, Treatment 6 exhibited the lowest temperatures overall, except for an initial steep rise during the early phase.

3.3 Effect of treatments on chemical properties of compost

For the chemical properties of compost, different parameters such as compost organic matter, total nitrogen (N), total phosphorus (P), total potassium (K), and pH were analyzed, and results were summarized in Table 5.

Table 5. Effect of treatments on chemical properties of compost

Treatments	**Mean (pH)**	**Mean**			
		(Total Nitrogen (%)	**(Total Phosphorous (%)**	**(Total Potassium (%)**	**(OM (%)**
Control	8.1^{a}	0.35	1.59^{ab}	4.32^{abc}	28.07^{ab}
EM-1	7.9^{a}	0.55	1.66^{ab}	3.37^{abc}	30.09^{b}
Prarhamva Decomposer	8^{a}	0.49	2.17^{b}	2.67^{a}	29.87^{ab}
Biofertilizer KM	8.1^{a}	0.19	1.91^{ab}	3.02^{ab}	28.69^{ab}
Biofertilizer KM +Biochar 400 g	8.03^{a}	0.25	1.61^{ab}	4.77^{c}	26.43^{a}
Biofertilizer KM +Biochar 800 g	7.97^{a}	0.19	1.9^{ab}	3.77^{abc}	27.14^{ab}
Biochar 200 g	8.03^{a}	0.32	1.31^{a}	4.67^{bc}	28.16^{ab}
Grand mean	8.019	0.333	1.736	3.80	28.47
CV (%)	1.9	74.4	21.5	23.5	7.8

LSD	0.2729	0.4336	0.6521	1.564	3.900
P-value	0.702	0.453	0.196	0.071	0.268

The pH of the final compost was similar across all treatments, ranging from 7.9 to 8.1, with no significant differences observed ($p > 0.05$). Regarding chemical composition, no significant differences were found among treatments for nitrogen, phosphorus, potassium, and organic matter content at the 5% level ($p > 0.05$). Despite the lack of statistical significance, T2 (EM-1) had the highest nitrogen (0.55%) and organic matter (30.09%) contents. Phosphorus levels were highest in T3 (2.17%), while T5 achieved the maximum potassium level (4.77%). Organic matter ranged from 26.43% to 30.09% across treatments (Table 5).

4. Discussion

The accelerated composting observed can be attributed to biochar's high porosity and surface area, which provide a stable habitat for microbial colonization and enhance aeration within the compost pile (Lehmann & Joseph, 2015). This porous structure promotes the growth of thermophilic bacteria, as shown by the earlier temperature increase in T6, leading to a quicker breakdown of complex organic matter. Additionally, biochar's high adsorption capacity helps retain nutrients and sequester inhibitory compounds such as ammonia, which could otherwise restrict microbial activity during the initial stages of decomposition (Chowdhury et al., 2014; Czekała et al., 2016). When biochar is added to organic waste for composting, it creates favorable conditions such as high cation exchange capacity, large porosity and surface area, adequate microbial growth in the compost pile, increased plant nutrient retention, reduced greenhouse gas emissions, and immobilization of heavy metals. Therefore, biochar serves as an effective amendment to shorten the composting process and enhance the quality of the finished compost (Sanchez-Monedero et al., 2018).

The significant reduction in composting duration to 14 days in biochar-amended treatments highlights its potential as an effective bulking agent, as well as the role of microbial cultures. Biochar also minimized mass loss through leachate flow by stabilizing the compost structure (Breitenbeck & Schellinger, 2004). This is particularly important for kitchen waste, which typically suffers from high volume reduction due to its moisture content. The study by Mirdamadian et al. (2011) mentioned if suitable microbial inoculants are used during the process of composting, we can reduce the composting time significantly. According to Keener et al. (2000), mature and stable compost can serve as a source of microorganisms to accelerate the decomposition process, which also explains why the composting time of T3 was reduced to 16 days.

The integration of microbial inoculants further influenced the nutrient content of the final product. While differences were not statistically significant, treatments with EM-1 (T2) and Prarhamva Decomposer (T3) showed slightly higher levels of nitrogen and phosphorus, respectively. This aligns with the findings by Manu et al. (2017) and Jusoh et al. (2013), suggesting that specialized microbial cultures can enhance nutrient transformation during the aerobic process. However, the alkaline nature of biochar resulted in slightly higher pH values across the treated composts, which may further promote protein mineralization.

It is important to note that commercial products like EM-1 and Prarhamva Decomposer may have inconsistent constituents, and users should exercise caution regarding product performance from batch to batch. Overall, the use of biochar (800 g) in combination with microbial cultures provides a practical solution for rapidly converting kitchen waste into high-quality organic fertilizer

5. Conclusion

The application of biochar (800 g) combined with biofertilizer KM significantly accelerated the composting process, reducing the composting period to under 20 days. This method not only shortens composting time but also ssssenhances the nutrient profile, particularly nitrogen, phosphorus, and potassium. Microbial inoculants like EM-1, which contains lactic acid bacteria, photosynthetic bacteria, fungi and yeasts, and Prarhamva Decomposer, which contains *Trichoderma viridae, Rhizopus* spp., and other essential groups of microorganisms, also contributed to composting efficiency. While different concentrations of biochar primarily affect composting speed, their impact on chemical properties is minimal. It should be noted, however, that other factors also affect the effectiveness of the waste composting process and the maturation of compost. Overall, this approach presents an effective and sustainable solution for managing kitchen waste and converting it into nutrient-rich compost suitable for improving soil fertility.

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