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Research Article

Comparative Analysis of Household Composting Methods for Organic Waste Management

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Abstract

Solid waste management remains a major environmental challenge in Nepal, particularly in urban centers like the Kathmandu Valley, where organic waste makes up over 50% of municipal solid waste. This study compares the effectiveness of three household-level composting methods—vermicomposting, Takakura composting, and plastic bag composting—by evaluating their decomposition rates, nutrient yields, and key physicochemical properties. Using 700g of vegetable and fruit peels per method, composting was carried out in cardboard boxes, and final composts were analyzed for temperature, pH, moisture content, electrical conductivity, water-holding capacity, organic matter, nitrogen content, and carbon-to-nitrogen (C:N) ratio. Statistical analysis (Kruskal-Wallis H test and Tukey's Post Hoc test) revealed significant differences in several parameters, including moisture, water-holding capacity, and nitrogen content. Takakura composting yielded the fastest decomposition time (51 days) and highest organic matter content (41.60%), while vermicomposting produced the highest nitrogen content (2.83%), water-holding capacity (82%), and overall yield (391g). Box composting performed least effectively across most parameters. The findings suggest Takakura composting is best suited for rapid, small-scale household composting, whereas vermicomposting is ideal for high-yield, nutrient-rich compost production on a household or commercial scale. Overall, the study underscores the potential of decentralized composting as a sustainable solution for organic waste management in Nepal.

INTRODUCTION

Waste is the leftovers from usual household or industrial processes. To reduce waste, different methods, such as reducing, reusing, recycling, and composting are used. Much household and commercial waste can be converted into compost or vermicompost. Composting is a biological process where microorganisms decompose organic matter such as food scraps, leaves, and agricultural waste into a nutrient-rich, soil-like material called compost. It is a natural recycling method that transforms biodegradable waste into organic manure, which can enrich soil and support sustainable agriculture. Composting reduces landfill waste and methane emissions, improves soil health and fertility, and promotes circular economy and resource efficiency (EPA, 2025). These are rich in nutrients and can help sustainably restore land (Baruah, 2024). Composting makes solid waste management effective, which helps the government more efficient as the necessity to build new landfill sites is reduced.

The mismanagement of solid waste is a pressing global concern, as it affects environmental quality, economic sustainability, and social well-being. Rapid and unplanned urbanization in Nepal has significantly intensified the challenges associated with solid waste management, particularly in urban centers like Kathmandu. Lack of proper waste segregation, lack of source segregation and recycling practices, limited institutional capacity and weak enforcement, public awareness and behavior issues, overdependence on landfills and unsustainable practices, are general issues related to solid waste management particularly in urban areas like Kathmandu Valley (Pokhrel, et.al (2005); Allevato, et.al, (2019). In the Kathmandu Valley, common practices such as open dumping of waste in landfills and rivers have not only led to widespread contamination of air, land, and water, but also pose severe risks to wildlife and human health. Addressing this complex issue demands integrated assessments and holistic solutions (Ferronato & Torretta, 2019). Various technical, institutional, financial, environmental, and social challenges arise while managing these wastes.

Among the various waste types, organic waste constitutes the majority share, with national data indicating that over 50% of municipal solid waste is biodegradable in nature (CBS, 2020; Ojha, 2021). While traditional composting practices have been prevalent in Nepal for centuries, their use has declined over time. Nonetheless, local governments continue to promote household-level composting as a viable means of managing organic waste at the source. Urban growth and limited infrastructure have strained municipal waste systems. To solve the issue, decentralized waste management practices such as composting, have become increasingly important.

Different types of composting are used to convert the organic waste to manure. For instances, bin composting, vermicomposting, box composting, and the Takakura method. These methods have their own strengths and weakness and their suitability differs according to feedstock, environmental conditions, and operational scale. Several studies conducted in countries such as China and Spain have examined the effectiveness, decomposition rates, and yield of various composting methods at both household and community levels (Cheng *et al*., 2022; Barrena. *et al*., 2022). However, in Nepal, such rigorous analyses remain scarce. In particular, composting of specific organic waste types, such as fruit and vegetable peels, has not yet been systematically explored. Therefore, identifying the most effective composting method for household-level application is both timely and relevant. Comprehensive comparative analyses that consider Nepal's unique climatic, social, and infrastructural conditions are still very limited.

In this study, we have determined the effectiveness of different composting techniques for management of organic waste at household level, the rate of decomposition and yield of compost manure among different composting techniques.

MATERIALS AND METHODS

The study was carried out in Dhobighat, Lalitpur. The area lies between a latitude of 27.67819º N, a longitude of 85.30182º E, and an elevation of 1,301 meters above sea level.

Methodology

The research was conducted through experimental methods to compare the three composting methods. Cardboard boxes of same size were used for all the three methods of composting. For each composting sample, 700 gm of vegetable (400 gm) and fruit peel (300 gm) wastes were taken.

Composting Methods Used

Three different composting techniques have been used:

a. **Box composting**: The box composting involves layering organic waste—typically kitchen scraps and garden debris—inside a box made of biodegradable or breathable material (like cardboard or wood). The box acts as a containment unit while allowing for aeration and microbial activity (Sharma *et al.*, 2024)

b. **Vermicomposting**: Vermicomposting involves using earthworms to decompose biodegradable organic materials (Arumugam *et al*., 2017). These worms consume a wide variety of organic matter, and their excreta-known as casting, are enriched with nitrates and plant-available nutrients such as phosphorus, potassium, calcium, and magnesium, all of which contribute to enhanced soil fertility (Bhat, 2018).

c. Takakura Composting: The Takakura composting method is considered an appropriate approach for organic waste management at the individual or household level, owing to its simplicity, practicality, and ease of implementation (Wikurendra *et al*., 2022; Farumi *et al.,* 2020).

Composting process

Box Composting

A layer of soaked cardboard, litter was placed at the bottom of the cardboard box (18×10×7.5cm) Thereafter, organic waste was placed. Some amount of water was sprinkled to maintain moisture content of the compost. Then the cardboard box was covered with cardboard with small holes to ensure sufficient circulation of air.

Vermicomposting

Vermicomposting was carried out using kitchen waste as the primary substrate. 100 g of *Eisenia fetida* were introduced in a perforated cardboard box with a base as bedding layer of soaked cardboard, hay, and litter, followed by layers of vegetable and fruit scraps. The pile was covered with perforated cardboard to retain moisture and prevent light and pests. Moisture was monitored daily. Citrus, onions, garlic, meat, and dairy were excluded due to their harmful effects on earthworms (Gayani et al., 2024).

Takakura Composting (TC)

Takakura composting was initiated by preparing a fermenting liquid from tap water, sugar, and chopped fruits and vegetables. After 3–5 days of fermentation, the liquid developed a sour odor, indicating microbial activity. A fermenting bed was then prepared using a 1:1 mix of rice bran and rice husk in a cardboard box. The liquid was added, and moisture was adjusted to form a lump without dripping. The bed was covered with breathable cardboard to promote fungal growth. Subsequently, 700 g of chopped organic waste were added and the mixture was placed in a cardboard box, loosely covered with perforated cardboard to maintain aeration.

Compost samples were analyzed for quality and yield. Parameters measured included pH, temperature, moisture, carbon content, and C:N ratio. Temperature was recorded every four days using a ±1 °C accurate glass thermometer until compost maturity. For the Takakura method, additional readings were taken after the first and second steps.

Physical and chemical analysis of the compost prepared

Compost yield was assessed by weighing the first fully decomposed sample. Moisture content was determined by oven-drying at 105 °C for 24 hours and calculating weight loss. For pH and electrical conductivity, compost was mixed with water (1:5), stirred for 10 minutes, and measured using digital meters (HI98107U for pH; HI98197 for EC).

Water-holding capacity was determined by mixing 10 g of compost with 40 mL of water and measuring retained moisture (Reddy *et al.*, 2021). Organic carbon was analyzed using the Walkley and Black method, while nitrogen content was measured via the Kjeldahl method. The C:N ratio was then calculated accordingly.

The results from the experiment were analyzed using JASP software (version 0.16.4.0) and Microsoft Excel 2013. The normality of the data was checked using Shapiro-wilks test and as data were not normal, Kruskal-Wallis H Test was used to compare the median of the parameters soil moisture, pH, nitrogen content, and C:N ratio of the compost samples. To find out what the differences were, a Tukey Post Hoc test was also used.

RESULTS

Physical and Chemical Analysis involved monitoring changes in temperature, pH, moisture content, and electrical conductivity, whereas the nutrient analysis include organic matter content, Nitrogen content, C: N ratio, duration of compost, yield.

Temperature

The temperature was found to be higher in TC (32.02 ˚C) in the 32nd day of composting process. Lowest temperature was attained in vermi-compost among all the compost.

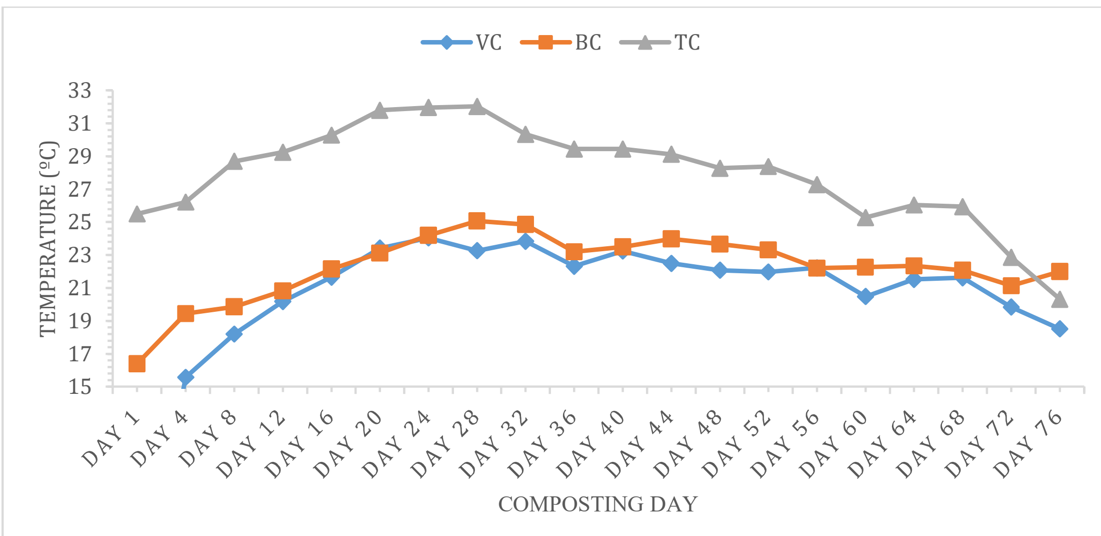

Figure 1: Temporal variation in temperature in different composting methods (The temperature of VC was not recorded on day 1)

Table 1: Physicochemical Properties of Compost Produced by Different Methods

Methods	Parameters	pH	EC (µS/cm)	OM (%)	Nitrogen (%)
Box Composting	Min - Max	7.5 - 7.9	0.9 - 1.7	2.84 - 5.19	2.6 - 2.62
	Mean (SD)	7.68 (0.16)	1.36 (0.3)	3.77 (0.88)	2.61 (0.008)
	Median (IQR)	7.6 (0.2)	1.4 (0.2)	3.69 (0.49)	2.62 (0.01)
Takakura Composting	Min - Max	6.8 - 7.5	0.7 -1.7	4.07 - 7.72	2.64 - 2.68
	Mean (SD)	7.2 (0.32)	1.22 (0.37)	6.38 (1.51)	2.65 (0.02)
	Median (IQR)	7.4 (0.5)	1.2 (0.3)	7.13 (1.71)	2.64 (0.03)
Vermicomposting	Min - Max	6.6 - 7.7	1.2 - 2.2	5.84 - 8.68	2.8 - 2.84
	Mean (SD)	7.16 (0.48)	1.7 (0.38)	6.89 (1.1)	2.83 (0.02)
	Median (IQR)	7.1 (0.8)	1.7 (0.4)	6.49 (0.81)	2.83 (0.01)

Moisture Content

The moisture content of matured compost of VC, BC, TC were found to be 61.61%, 54.3% and 46.19% respectively. Vermicomposting was found to have comparatively higher moisture content than other composts. Moisture content of the material determines the decomposition rate of the organic matter. There is no significant difference between BC and TC (df= 2, p = 0.008), but significant differences were found between BC and VC, and TC and VC (df= 2, p = 0.266)

pH

Maximum pH was obtained in box compost (7.68) while minimum was observed in TC (Table 1). There is no significant difference in pH among the compost samples (x^2= 5.88, df=2, p=0.053).

Electrical Conductivity

VC has the highest electrical conductivity among the three compost formed 1.7mS/cm. TC had the lowest electrical conductivity among all the compost formed 1.2mS/cm while BC had 1.4mS/cm value of EC (Table 1). (x^2= 3.83, df= 2, p=0.15), indicating no significant differences in EC among compost types.

Water Holding Capacity

Among the three mature compost formed at the end of composting VC had the highest water holding capacity (WHC) (82%). BC had the lowest water holding capacity (66%) and the value of water holding capacity for TC was (72%). There is significant difference in WHC among compost types (df = 2, p = 0.046).

Organic Matter

The organic matter of matured composts ranged from 20% to 45%. The highest value of organic matter content was found in Takakura compost (41.602%) followed by vermi-compost (33.874%) and box compost (29.060%) (Figure 1). There is significant differences in organic matter across compost types (x^2= 8.70, df= 2, p = 0.01).

Nitrogen Content

The mean nitrogen content was found to be 2.83%, 2.64%, and 2.62% for VC, TC, and BC respectively (Table 1) and differed significantly according to composting type (x^2=12.73, df = 2, p<0.05). There was significant difference in nitrogen content in three different compost types (Table 2).

Table 2: Post Hoc Comparisons of N content

Samples		Mean Difference	SE	T	p_{tukey}
BC	TC	-0.040	0.010	-4.054	0.004
BC	VC	-0.214	0.010	-21.691	< .001
TC	VC	-0.174	0.010	-17.637	< .001

The KW test showed that there are significant differences in nitrogen content among the different samples (df=2, p=0.002). All the compost showed significant differences when compared to BC with TC, BC with VC, and TC with VC in terms of nitrogen (Table 2).

C: N ratio of composts

The C: N ratio for TC was found to be (9.112), which was the highest among all three composts formed. BC had the lowest value of C: N ratio (6.462), whereas the value of C: N ratio for VC was found to be (6.962).

Table 3 : Post Hoc comparisons of C:N ratio

	Samples	Mean Difference	SE	T	p-tukey
BC	TC	-2.650	0.505	-5.251	< .001
BC	VC	-0.500	0.505	-0.991	0.596
TC	VC	2.150	0.505	4.261	0.003

The Kruskal-Wallis test showed a significant difference in C:N ratio among the compost types (df = 2, p = 0.006). Tukey's test confirmed significant differences between BC and TC, and TC and VC, but not between BC and VC (Table 3).

Time period required for composting

The duration of the composting process plays a significant role in assessing the rate of organic decomposition. Among the three methods examined, Takakura composting required just 51 days for completion, while box composting took 92 days. Vermicomposting reached maturity in 62 days. Box composting took the longest time to produce compost in this study—92 days in total.

Discussion

Through this study, we have explored the comparative assessment of three commonly used composting methods to determine their suitability based on effectiveness, rate of composting and manure yield yielding. A comparative study of composting techniques is conducted to evaluate and identify the most efficient, quality of final compost.

Period required for composting

Takakura composting (TC) was the fastest method in this study, completing in 51 days. This was 5 days longer than reported by Neupane (2020). Jiménez-Antillón *et al*. (2018) noted a 42-day composting period for food waste. The variation may be due to waste type, composting system, and climate. TC likely benefited from native microorganisms in fermented materials, which accelerate decomposition (Aziz *et al.,* 2025), unlike box composting (BC) and vermicomposting (VC).

Temperature

The highest temperature in the vermicomposting unit was 24.04°C, within the suitable range of 0–35°C (Edwards, 2010). Temperatures during vermicomposting ranged from 14°C to 24°C, lower than in traditional composting but suitable for *Eisenia fetida*. The thermophilic phase was absent, consistent with mesophilic conditions due to earthworm sensitivity (Zhou *et al*., 2021). Temperature patterns matched those reported by Neupane (2020). In Takakura composting, the peak temperature was 32.02°C in the fourth week, within the mesophilic range. No thermophilic phase was observed; temperatures remained between 25°C and 32.02°C (Aslanzadeh *et al*., 2020). Early temperature increases of 1–7°C indicated modest microbial activity, similar to Neupane (2020).

Moisture Content

The final compost moisture content ranged from 30% to 70%. Vermicomposting showed comparatively higher moisture levels, attributed to mucus secretion by earthworms. Takakura method yielded the lowest final moisture content (46.19%), likely due to elevated temperatures that accelerated evaporation. This aligns with previous findings indicating reduced moisture in Takakura composting to intensified microbial activity and heat generation (Borrero *et al*., 2018). Conversely, box composting retained higher moisture (54.3%), consistent with the typical range reported for aerobic systems (47.9–55.4%) (Guo *et al*., 2021).

pH

Compost pH serves as a key indicator of decomposition and stabilization, reflecting microbial succession and organic matter mineralization. In this study, the final pH values ranged from 7.16 in vermicompost to 7.7 in box compost, with Takakura compost registering 7.2. The near-neutral pH in vermicompost (7.16) may result from ammonium ion release and carbonic anhydrase activity in earthworms, which neutralize acidity (Rahman *et al*., 2024). These findings align with previous studies reporting pH shifts from acidic to neutral due to microbial activity and ammonium accumulation (Pérez *et al.*, 2023; Oueld Lhaj *et al*., 2024).

Electrical conductivity

Electrical conductivity (EC) is a widely accepted indicator for compost salinity, with values below 4.0 mS/cm considered suitable for agricultural use (Ebrahimi *et al*., 2024). In this study, all compost types remained within this threshold, with vermicompost showing the highest EC at 1.7 mS/cm. These findings are consistent with previous reports, including Toor *et al*. (2024), who documented EC values between 2.02 and 4.44 mS/cm in vermicomposts, and Gebeyehu & Kibret (2013), who observed EC increases during composting.

Water Holding Capacity

Water holding capacity (WHC) varied across compost types, with vermicompost (82%; 4.1 g/g), Takakura compost (72%; 3.6 g/g), and box compost (66%; 3.3 g/g) showing distinct moisture-retention profiles. These values align with previous findings in composts derived from diverse organic materials (Khater, 2015; Govindaraju et al., 2021), while lower WHC ranges reported in brewery waste composts (57–62%) highlight the influence of feedstock composition (Demeke & Gabbiye, 2020; Paradelo *et al.*, 2019).

Organic Matter Content

All compost samples in this study exceeded the recommended organic matter range of 35–65% for high-quality soil amendments (DeepRoot, 2021). Vermicompost showed values comparable to those reported by Pereira *et al*. (2022). Variations in organic content are largely influenced by the carbon composition of feedstock (Xie *et al*., 2023), with materials like fruit and vegetable peels contributing to humus formation (Jakubus, 2020). The Takakura and box composts yielded results consistent with those reported by Neupane (2020), while vermicompost values were slightly lower than those found by Aloka (2011) and Sharma *et al*. (2022).

Nitrogen Content

Nitrogen plays a vital role in composting by balancing the carbon-to-nitrogen (C:N) ratio and enhancing microbial activity (Sun *et al*., 2025). In this study, vermicompost exhibited the highest nitrogen content (2.83%), exceeding values reported by Dube *et al.* (2025), Sharma *et al*. (2022), and Aryal & Tamrakar (2013), and surpassing the minimum standard of 1.5% set by the Ministry of Agriculture and Livestock Development (2021). Compared to Neupane (2020) and Chaulagain *et al*. (2018), the nitrogen content was higher by 0.7% and 2.39%, respectively, though lower than the 3.5% reported by Sharma, *et al*. (2025). In contrast, reduced nitrogen in box compost may result from microbial assimilation and conversion into bacterial proteins during decomposition (Sun *et al*., 2025).

C:N ratio of composts

The C:N ratios of all the three composts observed in this study fall well within the recommended range of 10:1 to 20:1 for mature and agriculturally safe composts (European Compost Network, 2021; Hargreaves *et al*., 2022). The relatively lower C:N ratio in vermicompost reflects its higher nitrogen content, consistent with findings by Maharjan *et al.* (2022). The Takakura compost ratio was lower than values reported by Jiménez-Antillón *et al*. (2018), likely due to differences in feedstock and process conditions. Overall, the low C:N ratios across all compost types support their suitability as soil amendments, particularly for enhancing nutrient availability in the root zone (Gabhane *et al*., 2020).

Conclusions

This comparative study emphasizes the importance of selecting composting methods that match household needs, urban conditions, and available resources. By assessing decomposition efficiency, yield, and nutrient content across three approaches, the findings provide understanding for improving organic waste management at the local level. The results guide data-driven approaches to organic waste management in household composting and can help guide community initiatives, policy development, and future research focused on sustainable and socially appropriate waste treatment strategies.

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BA: Conceptualization, Formal analysis, Writing-Original Draft, Writing- Review & Editing, Supervision**;** **ND:** Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Data Curation, Validation, Writing- Original Draft, Writing- Review & Editing, Project administration.

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