SSRG International Journal of Industrial Engineering
ISSN: 2349 – 9362 / https://doi.org/10.14445/23499362/IJIE-V11I3P103

Volume 11 Issue 3, 11-17, Sep-Dec 2024

Original Article

The Effect of Turning on Home Composting

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Received: 11 October 2024 Revised: 23 November 2024 Accepted: 12 December 2024 Published: 29 December 2024

Abstract - *The improper handling of waste generation ultimately harms living organisms and their environment. It is evident from the analysis that Municipal Solid Waste (MSW) has a high percentage of biodegradable waste; thus, composting could be considered a sustainable and systematic approach. Composting yard waste helps reduce the load on the disposal site and improves crop productivity by providing nutrient-rich compost. Aeration speeds up the degradation process. Two identical composting bins were designed to assess the effect of turning on composting, and the various controlling factors, such as temperature, moisture content, pH, organic carbon content, etc, were observed for 4 weeks. The pH gradually increases over time. The moisture content drops from 68.28% to 53.3% and 56.67%. The temperature for turning the thermophilic phase twice weekly was seen on the 6th day. After the 12th day, the temperature fluctuated within the mesophilic range for a turning interval of once a week. The thermophilic phase was observed between the 10th day and the 20th day. By observing the variation in controlling parameters, it was figured out that turning the composting bin once a week is the ideal frequency for turning for home composting, compared to twice a week. However, turning twice a week is also up to the harmless standard.*

Keywords - *Solid waste management, Composting, Turning, Yard waste, Temperature, Emission.*

1. Introduction

Solid waste is an unintended but unavoidable by-product of urbanization. The problem of Municipal Solid Waste Management (MSWM) is no different when it comes to dumping and unsanitary landfills of solid waste compared to the rest of the globe approach [22, 26]. The impact on an environment's important components and human health can be observed due to the improper management of solid waste [5, 18, 19, 21, 31, 35, 36]. For a sustainable environment, the management/disposal of MSW is essential as the existing disposal methods adopted by the urban local bodies have been unsuccessful in tackling the issue adequately [35]. It is very significant to know the details of the waste concerning the overall characteristics (biological, physical, chemical) as it reflects the proposed treatment and will help better understand the diverse stages of the composting process and nutrients of the final product [11, 30].

The typical waste composition comprises a high percentage of biodegradable organic waste [2, 3, 8, 22, 27, 30, 35]. As per the observation, more than 50 percent of the average MSW of an urban area can be easily composted, and the rate of decomposition of solid waste can be increased by proper optimization [2, 30]. The decentralized home composting method can be viewed as a sustainable strategy for managing organic waste. This approach alleviates the burden on landfill sites and minimizes overall environmental pollution. Additionally, it reduces transportation costs and the expenses associated with establishing a decentralized composting plant, which is often seen as a more efficient and promising technique [24, 27]. While it is true that many composting plants face challenges and end up failing [6, 28, 33, 40], numerous small-scale decentralized composting plants in other countries are thriving and gaining popularity [9, 14, 35].

Some of the best-maintained facilities in India, particularly in places like Indore city [16, 24]. Pointed out that the in-vessel composter is an adequate technique for managing waste; however, many aspects have not been considered to improve the performance of existing composting facilities. [27] conducted an experimental setup to evaluate the efficiency of Air-Blown Reactors (ABR) and Rotary Drum Reactors (RDR).

The analysis revealed that the ABR outperformed the RDR in efficiency. Additionally, the waste's Total Organic Carbon (TOC) was assessed using the fertilizing index of Municipal Solid Waste (MSW) compost, indicating that the ABR had superior results than RDR. The composting technique relies heavily on oxygen, making it crucial for successful composting processes. Proper ventilation and adequate turning frequency are implemented in large composting facilities to ensure enough oxygen supply. When oxygen is insufficient, both temperature and microbial activity decline. This highlights the need to optimize the drum's turning frequency or develop an effective regimen to enhance the rotary drum's pathogen reduction and nutrient retention [24, 27, 37].

Lack of oxygen lowers temperatures and can lead to an anaerobic process, which ultimately exhausts oxygen levels [13, 20, 29, 39, 43]. Conversely, turning the compost too frequently during the initial stages can result in nutrient loss, decreased efficiency, and increased operation and maintenance costs [39, 43].

Striking a balance with appropriate turning frequency enhances degradation rates, improves compost quality, and reduces greenhouse gas emissions, particularly methane [23, 41, 43]. [43] evaluated the effects of turning frequency (0 days, 2 days, 4 days, and 8 days) in a co-composting process involving manure from pigs and fungus residue. The result shows that turning frequency significantly influenced temperature, moisture content, and nitrogen mass losses. Moreover, notable nitrogen losses were linked to ammonia gas emissions during biodegradation.

[15] determined through their analysis that non-covered compost, when managed with a turning frequency of once every two weeks, yielded the most effective results for manure-straw composting. Investigated the impact of turning frequency on agro-forestry and restaurant waste, finding that turning the compost material every four days yielded the best maturity results.

Similarly, [42] conducted experiments to explore the relationship between composter rotation and the stability of waste composting. They established four treatment variations with different turning frequencies: twice a week, once a week, once every 14 days, and no turning. The results indicated that all treatments, except for the one with no turning, met the standards set by Chinese sanitation regulations.

Composting, as a biodegradation process, yields compost-a nutrient-rich product that significantly enhances crop productivity [7, 34]. Several factors influence the quality of the compost produced, including the design of composting facilities, the source of feedstock, the proportions used, and the procedures adopted throughout the composting process [22].

While the composting process is known to be time-consuming, recent studies suggest that co-composting organic waste can considerably improve both the process's efficiency and the compost's quality by combining the diverse properties of different waste materials, co-composting leverages the strengths of each type of waste, resulting in a more effective and higher-quality compost product.

A laboratory experiment was conducted using actual field samples to implement the composting system effectively. The results from this experiment will offer valuable insights for planning and developing a sustainable waste management approach. This information will aid in decision-making and assessing the current waste management practices, as well as provide details about the various physicochemical changes involved and the nutrient content quality of the compost.

2. Materials and Methods

For the experimental studies, the mixed waste consisting of straw, twigs, and garden prune, along with food waste and kitchen waste, was randomly collected from the house yard and shredded (<3 cm) manually with a machete and with the help of a mechanical shredder. The initial characteristics of mixed material are noted in Table 1.

Table 1. Initial characteristics of the material

Initial Moisture Content (%)	pH	Size (cm)	C: N Ratio	Weight of the Organic Waste in (kg)	Initial Total Nitrogen (%)	Initial Total Organic Carbon (%)
68.28	6.7	3cm	29.54:1	30	1.38	40.77

3. Experimental Design and Set-Up

The experiment was conducted indoors. The room fluctuated with natural atmospheric conditions since temperature and humidity were not controlled. For the study, two identical composting bins were designed and fabricated in a 50-litre capacity plastic bucket with a lid, as shown in Figure 1.

The materials used in designing the composting bin are a 50-litre capacity plastic bucket with lid, steel rod, PVC bibcock, and gas collection chamber. Each bin has a single compartment. To fulfil the oxygen requirement and for drainage purposes, the bottom portion of the bin was holed at suitable intervals with the help of a driller. The top portion of the bin was provided with the gas collection chamber, which was made airtight to prevent gas leakage from the composting bin. The gas measurement outlet was provided near the gas collection chamber to escape gas production. The PVC bibcock was provided at one end of the bin, which was open after each monitoring session. For the proper mixing, the composting bins were provided with the centrally placed vertical rod with several spikes at suitable intervals. The mixing was done manually by rotating the handle provided at the central top. The whole setup was supported on a stand. The composting bins were filled until they were two-thirds full, as carried out by other researchers [25], and aeration was achieved by turning the bin e once a week and twice a week, respectively, for 30 days.

Fig. 1 Composting bins

4. Sampling and Monitoring

The triplicate samples collected carefully were labeled as I, II, and III. The composting sample was grabbed by opening the top portion of composting bins without disturbing the adjacent layer for determination of pH, moisture content, and carbon content, temperature, oxygen, respectively, for the time interval of 3 days (green color composting bin) and 5 days (blue color composting bin) respectively for 30 days just before the overturning each time till 30 days.

5. Analytical Method

The oven drying method determined moisture content (mc) as per IS code 2720 part 2. A portable pH Meter was taken. The pH determination sample was carefully mixed with water in a 1:10 ratio and kept untouched for 2 hours [26]. The sample's nitrogen content (%) was estimated by an automatic nitrogen and protein estimation system (KEL PLUS, ISO 9001:2008 Certified & CE Certified). The various gas emissions (O_2, CH_4, CO_2, others) during the composting period were measured by inserting the tube of Biogas analyzer (gas board 3800E, 5000 Geotech). The total organic carbon content (%) was determined using the methods outlined by sources [1, 38]. The temperature was measured simply by inserting the thermometer. Three consecutive readings were taken from the sample, and their average was considered the overall reading.

6. Statistical Analysis

All the correlation equations and variations of control parameters were obtained using Microsoft Excel.

7. Result and Discussion

Variation in temperature, pH, oxygen (%), and organic carbon content is shown in Figure 2 (a), (b), (c), (d), and (e). The temperature is an important component that improves the composting process. The composting process generally occurs between the mesophilic range (25°C to 35°C) and the thermophilic range (40°C to 60°C). The microbes become inactive at the psychrophilic range [7], and the elevated temperature helps the substrate compound chemical bond to break down in composting. The last stage is the cooling phase, where the temperature drops due to the stabilization of microbes [37]. The temperature in the reactor occurs due to biochemical activities and microbial metabolism during the composting period. For the interval of turning for 3 days, the thermophilic phase was seen on the 6th day, and after the 12th day, the temperature fluctuated within the mesophilic range.

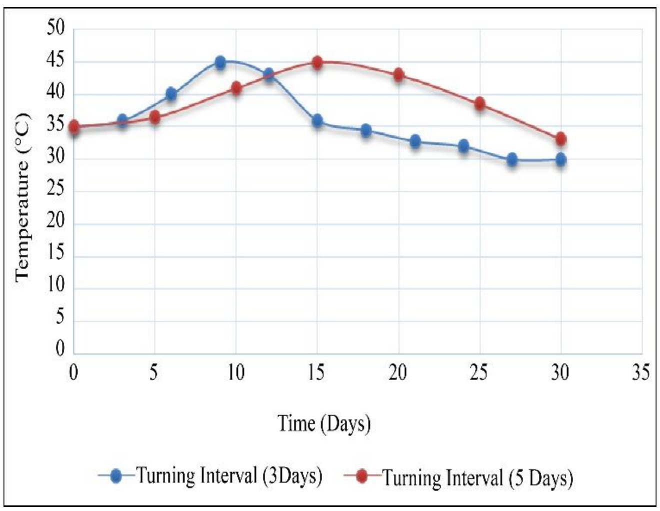
For a turning interval of 5 days, the thermophilic phase was between the 10th and 20th days, respectively, i.e., it lasted for 10 days. Turning frequency helps with compost material's degradation and gives rise to temperature. Moreover, such a turning frequency results in lesser heat loss and makes the phase of thermophilic temperature longer.

The pH affects microorganisms' respiration rate and compost material's degradation rate. It is the significant index during composting. The finished compost may have a pH above 7, preferably between 7 and 8.5, and a slightly alkaline or neutral pH is important for the survival of microbes during the composting period [17]. Generally, the pH level drops below 5 at the beginning of the composting process due to acid production by the acid-producing bacteria.

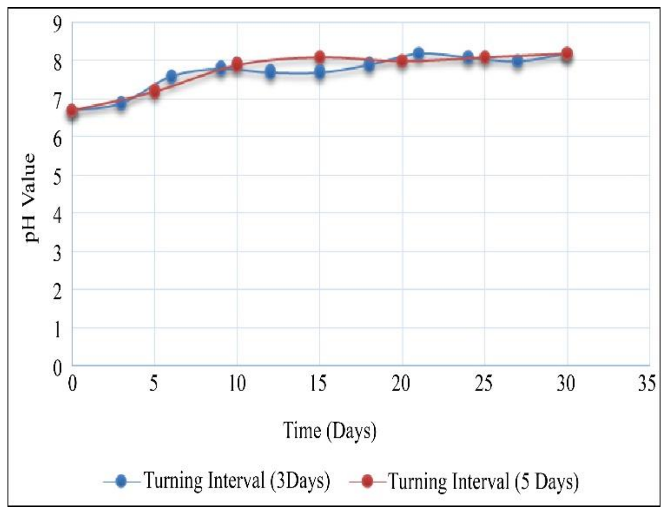
pH gradually increases due to NH_3 production by the breakdown of complex bonds in the feedstock [27, 43], and the final product maturity can be ascertained with the 7-8 value by the end of the process [4, 42]. As per the observation, the pH was low at the initial phase for both 3 days and 5 days turning intervals; however, it was gradually increased due to the conversion of acid to carbon dioxide as the result of the biological activity of microorganisms. For the interval of turning for 3 days, the oxygen concentration seemed to be the lowest (10.88%) on the 12th day and the highest (17.91%) on the 30th day. For 5 days turning interval after the 10th day, the oxygen concentration was seen to increase from 12.82% to 18.32%.

The decrease in oxygen concentration percentage during turning indicates the active decomposition of compost matter [42]. Moisture Content (MC) supports the activities of microorganisms, and the measurement of MC represents critical factors like water availability in samples, as low moisture range tends to limit microbial activity. [17, 37] mentioned that MC is more effective than temperature in composting. [12, 20] pointed out that for the easy movement of nutrients in a dissolved state and without anaerobic conditions to prevail, removing waste moisture content should be maintained between 50 percent to 70 percent on a wet to weight base.

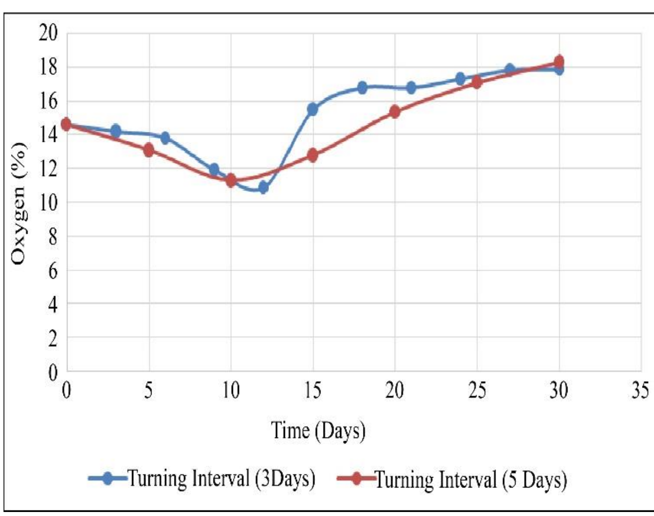
The composting material should have 40% to 60% moisture but may vary with different mixtures and composting feedstock [43]. [24] explained that the aerobic nature is established in the process, due to which oxygen drifts in composting when the MC is more than 60 percent. The loss in moisture content can be considered as the index of the rate of decomposition, which happens due to the generation of heat by the activity of microorganisms. The moisture content was elevated at the initial stage, i.e. 68.28%. By the 30 days, i.e. the end period of composting, it dropped to 53.3% and 56.67% for the interval of turning of 3 days and 5 days, respectively, which is within acceptable limits. The cause of the high percentage of moisture content at the beginning is a high proportion of food waste. Organic carbon content is formed by the breaking down of biodegradable organic matter. The increased amount of organic waste increases the total amount of carbon content. Determining total carbon content is significant in ascertaining the capabilities of releasing GHG from organic waste.



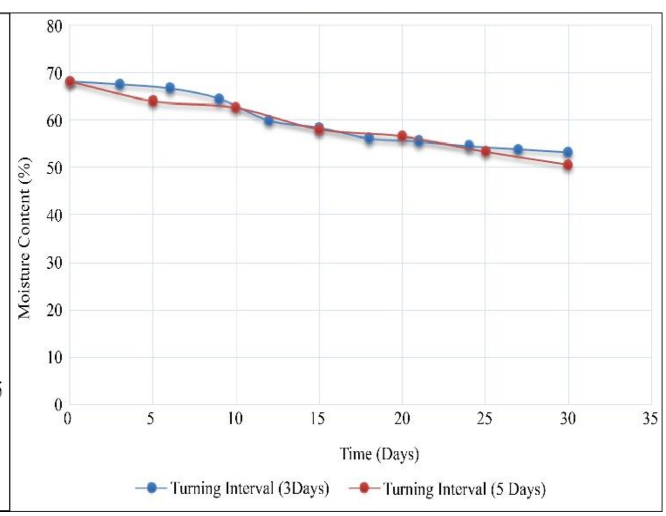
(a) Temperature



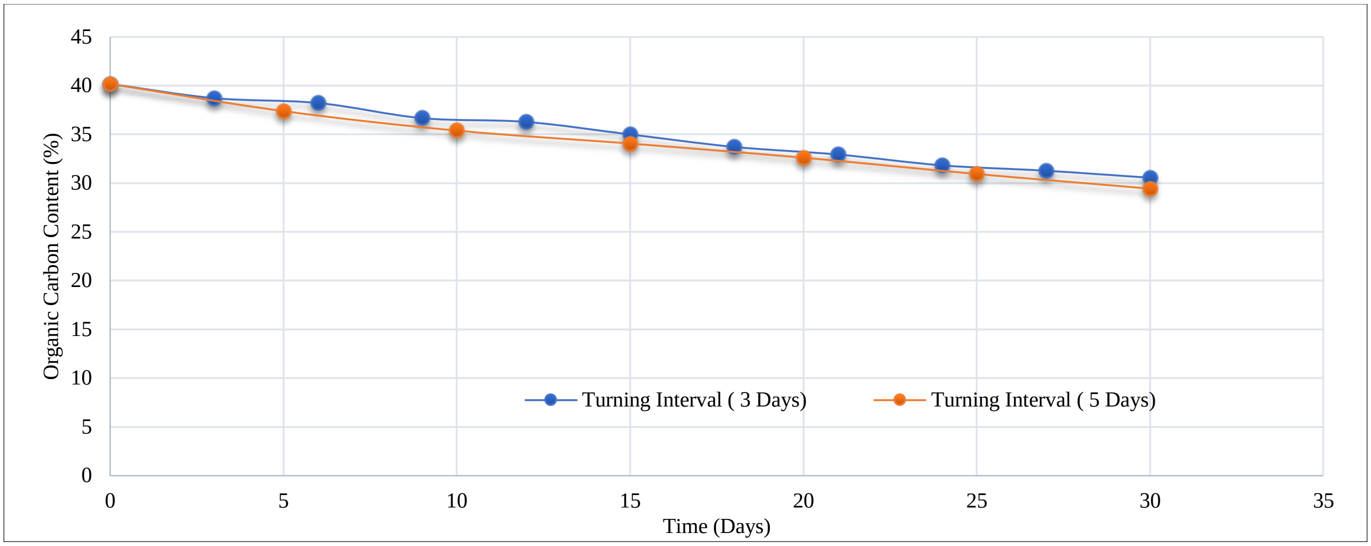
(b) pH value



(c) Oxygen



(d) Moisture content



(e) Organic carbon content

Fig. 2 Variation in (a) Temperature, (b) pH value, (c) Oxygen (%), (d) Moisture, and (e) organic carbon content (%).

Table 2. Overall compost characteristics

Sl. No.	Parameters	Initial Characteristics of the Waste Sample	Characteristics of Compost after 30 Days (3-day Turning Interval)	Characteristics of Compost after 30 Days (5 Days Intervals)
1	Particle Size (cm)	3	-	-
2	Moisture Content (%)	68.28	53.33	50.67
3	Temperature (°C)	35	30	33.5
4	pH	6.7	8.2	8.2
5	Oxygen (%)	14.62	17.19	18.32
6	Organic Carbon Content (%)	40.77	30.56	29.44
7	Total Nitrogen (%)	1.38	1.26	1.28
8	Volatile Solid (%)	72.33	55.00	53.00
9	C/N Ratio	29.54	24.3:1	23:1

Overall, the findings indicate that an optimal turning frequency is essential for maximizing the efficiency and quality of the composting process [25, 42, 43]. It was found from the experimental analysis for 30 days that the interval of 5 days is an ideal frequency for turning yard waste into home composting. However, turning composting material at 3 days is also up to the harmless standard. Moreover, turning the composting bin has little to no effect on compost quality. The overall characteristics of the compost can be summarized in Table 2.

8. Conclusion

The results indicate that turning composting material enhances the composting process, a finding supported by various researchers. By analyzing the variations in controlling parameters, it was determined that turning the composting material every 5 days is the most effective frequency for home composting of yard waste over 30 days, while turning every 3 days also remains within acceptable standards. Additionally, the turning frequency has minimal impact on the overall quality of the compost.

The experimental setup further demonstrated the feasibility of decentralized in-vessel composting for on-site solid waste management, confirming that yard waste can be effectively managed using composting bins. Home composting is a sustainable solution for managing Municipal Solid Waste (MSW), helping alleviate pressure on landfill sites and reducing environmental pollution.

This approach not only cuts down transportation costs but also extends the lifespan of landfill facilities. Moreover, it supports agricultural productivity by recycling organic matter into the soil, ultimately improving crop yields.

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