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Comparative Analysis of Large-scale Composting and Home-scale Composting in Lucknow, Uttar Pradesh, India

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***Abstract*: This study presents a comparative analysis of home composting and large-scale composting for organic waste management, aiming to assess their efficacy, feasibility, and environmental implications. Using a mixed-methods approach that combines qualitative evaluations with quantitative data analysis, the study looks at important factors such as compost quality, waste diversion rates, resource inputs, prices, environmental effects, and community involvement. Based on extant literature, official reports, and case studies, the comparative analysis offers valuable insights into the respective benefits and drawbacks of the two composting techniques**

***Keywords*: community involvement, compost quality, environmental implications, expenses, , large-scale composting, organic waste management, resource inputs, waste diversion**

I. Introduction

Composting involves a natural process that creates compost by breaking down naturally occurring substances such as grass, foliage, and kitchen scraps (Xiao et al., 2009). It is a sustainable method of reusing garbage and improving soil quality. When done effectively, home composting can produce compost with a quality which is on par or even better than that of industrial composting. Food waste is categorised as active waste due to its high moisture content and low carbon-to-nitrogen C: N ratio (Ruggero et al., 2019). A low ratio of C generates high N mineralization, which in turn causes urea to produce a foul odour. Excessive moisture content restricts O_2 flow and triggers an anaerobic process that produces odours. Despite encouraging responsibility for the environment, composting is a sustainable waste management method that converts organic waste into soil that provides valuable nutrients and supplement (Nguyen et al., 2014).

Composting on a large or local scale offers two different methods for improving the advantages of composting in many contexts. Large-scale composting plants usually handle a great deal of organic waste from businesses, factories, and urban source (Neugebauer & Sołowiej, 2017). These organisations use the latest technology and equipment to manage large amounts of organic materials effectively and hasten the composting process. On the contrary, local-scale composting occurs closer to home, usually in backyards as well, as community gardens, or small farms. Small-scale composting makes use of simpler instruments and methods such as trash piles or vessels, and it generally manages smaller volumes of organic waste. Both large- and small-scale composting provide benefits for the environment, but there are variations in terms of scale, cost of infrastructure, and resource needs (Lohri et al., 2017). Evaluating each strategy's positive and negative aspects while highlighting how each one's advantages to soil health and sustainable waste management have been highlighted in this comparison.

Small Scale Composting

Small-scale composting has emerged as an economically feasible and environmentally sustainable method of treating organic waste, while also improving soil health and reducing the negative environmental effects. When new and a growing number of individuals look for environmentally friendly methods to handle their garbage An affordable and effective strategy to keep organic waste out of the garbage is to compost on a smaller scale (Lohri et al., 2017). the majority in contrast to large-scale industrial composting facilities, small-scale composting may be applied in a range of settings, including people's homes, schools, community gardens, and urban areas (Ducasse et al., 2022).

Figure 1. Small scale composting

This modular approach reduces emissions and transportation expenses associated with the disposal of trash and empowers communities and people to take responsibility for the negative environmental effects they have (Pandyaswargo & Premakumara, 2014). Also Furthermore, small-scale composting provides an opportunity to convert organic waste into "black gold," an expensive resource that may be utilised to increase and enhance soil fertility, nourish plants, and reduce global warming through carbon storage. (Kumar et al., 2009).

Large Scale Composting

An overtime answer to the increasing issues of managing waste that is organic, damaging soil, and emitting greenhouse gases is large-scale composting (Alves et al., 2024). As humanity's population rises and the city grows more naturally occurring waste, such as food waste, is produced. agricultural food leftovers, garden leftovers and scraps have increased to previously unheard-of proportions. Large-scale composting facilities use natural processes to transform organic waste into nutrient-rich compost, enabling a methodical strategy to manage it (Ferronato et al., 2020).

Figure 2 Large-scale composting

Authorities, businesses, and communities are working to shift toward more Large-scale composting, part of the sustainable waste management methods is seen as an affordable, environmentally friendly option that has the potential to develop a circular economy in which debris is seen as a resource rather than a burden that must be disposed of.(Ferronato et al., 2020).

II. Materials and Methods

Usually, this approach consists of a sequence of actions that include gathering food and vegetable waste from a source, like a hostel, and processing, mixing, drying, and grinding the organic waste materials 20 (Andersen et al., 2011).

1. Collection: To minimise noxious smells and decomposition issues, the first step is to collect the waste and verify the waste doesn't stay there for more than three hours (Baptista et al., 2012).
2. It occurs to safeguard the high standards of the compost, hazardous materials that include plastics and inorganic rubbish are kept out of the organic waste. Effective composting necessitates source-level segregation (Zurbrügg et al., 2005).
3. Preparation and Mixing: Dry leaves are placed in a container with the gathered food scraps and vegetable trash. To guarantee enough oxygen delivery throughout the trash, mixing is done. Over time, the frequency of mixing lowers due to the slower rate of 140 decomposition (Furlong et al., 2018).
4. Drying and Grinding: To reduce the amount of water present, the compost is dried alfresco. water content over a decomposition period of around 120 days. After this point, the compost is prepared for storage and shipment. This method may be used to treat and digest organic waste. with success, resulting in helpful, high-acid compost. (Andersen et al., 2011). The compost cannot be exploited as a fertiliser or soil amendment unless it satisfies particular criteria, therefore assessing the composting operation's efficacy depends on these standards (Xu et al., 2017).

Possible standards for evaluation in the composting process

1. Composting Rate: The composting rate evaluates the efficiency with which the components of organic waste break down into compost. is a quicker method of composting.
2. Content of Moisture: The right levels of moisture is needed for the composting process to occur. One may ensure that the compost pile is not too wet or dry by tracking the moisture content, as this can influence how rapidly it falls (Zurbrügg et al., 2004).
3. Odor Control: Managing odours generated during composting is important for environmental and health reasons. Assessment criteria may include the effectiveness of odour control measures implemented during the composting process.
4. Quality of Compost: This criterion assesses the overall quality of the final compost product, including its nutrient content, maturity, texture, and absence of contaminants. High-quality compost is rich in nutrients and beneficial microorganisms (Lin et al., 2018).

Study Area

The study area of small-scale composting for kitchen waste composting (home composting) study is conducted on the campus of the Institute of Engineering and Technology (IET) College in Lucknow, Uttar Pradesh The latitude and longitude of the area is (N 26° 55' 0.8976", E 80° 56' 30.3216"). The process of composting is also done in the institute and food and vegetable waste is collected from the Arya Bhatt Hostel composition is done roof of the civil engineering department and the analysis of the best compost in agriculture is done in the environment lab.

The study area of large-scale composting study is conducted in the rural area of Udhanpura Auraria, Uttar Pradesh The latitude and longitude of the area are (N 26° 30' 0", E 79° 30' 0") The process of composting is also done in the Large-scale composting is a process used to convert large volumes of organic waste materials into compost, which can be used to improve soil health, structure, and nutrient content. This method is commonly employed by municipalities, large farms, landscaping operations, and institutions that generate significant amounts of organic waste (Kumar et al., 2009).

III. Results and Discussion

pH and moisture content in conventional composting processes, a decline of pH value was generally detected in the initial several days and was considered as the result of acids produced by some mesophilic microbes while the pH decline lasted 4 days in run A (Sadef et al., 2015). However, pH values in the five runs shared a similar changing trend and finally decreased to the steady values of 7–7.3, in the range of satisfactory pH values of 7–8.5 that claimed (Pirsaheb et al., 2013). The moisture content of 15–30% in mature bio-compost is the usual value established in Chinese regulations. However, the moisture content was maintained at about 60% to provide a suitable environment for growing microbes in the present study.

Temperature is deemed to be one of the most important factors affecting microbial growth and the composting progress, and 32 °C was usually considered as the demarcation of the thermophilic phase or mesophilic phase in the composting process, as well as the mesophile and the thermophile. down from 50 °C to 30 °C in the last 30 days, and observed no obvious changes in temperature (Van Fan et al., 1097).

TABLE 1
The Small-Scale Compost's Chemical Compositing

S. No	Tests	Results
1	pH	8.4
2	Electrical Conductivity	2439.0
3	Available nitrogen N (kg/ha)	134 (LOW)
4	Available Phosphorous P (kg/ha)	21 (Medium)
5	Available Potassium K (kg/ha)	113 (Medium)
6	Available Iron Fe (mg/kg)	14.23 (Sufficient)
7	Available Copper Cu(mg/kg)	0.97 (Sufficient)
8	Available Magnesium Mg (mg/kg)	7.01 (Sufficient)
9	Organic Carbon C (%)	4.3 (Sufficient)
10	Available Zinc Zn(mg/kg)	0.54 (Sufficient)

TABLE 2
Evaporation Analysis of Different % of Small-Scale Compost Mixture Kitchen Weste Vegetables and Fruits Peels Sample in Open Atmosphere (Baird et al., 2012).

S. No.	Composition	Day	Water Available (gm)
1	100% Vegetables and Fruits Peels	1	198
2	75% Vegetables and Fruits Peels, 25% Compost	15	304
3	50% Vegetables and Fruits Peels, 50% Compost	60	400
4	Vegetables and Fruits Peels are proper	90	00

TABLE 3
The large -Scale Compost's Chemical Composition

S. No	Tests	Results
1	pH	7.4
2	Electrical Conductivity	2281
3	Available Nitrogen N (kg/ha)	65 (LOW)
4	Available Phosphorous P (kg/ha)	45 (Medium)
5	Available Potassium K (kg/ha)	70 (Medium)
6	Available Iron Fe (mg/kg)	11.78(Sufficient)
7	Available Copper Cu(mg/kg)	0.67 (Sufficient)
8	Available Magnesium Mg (mg/kg)	4.2 (Sufficient)
9	Organic Carbon C (%)	2.8 (Sufficient)
10	Available Zinc Zn(mg/kg)	0.34 (Sufficient)

TABLE 4
Chemical Composition of the Compost

S. No.	Composition	Day	Rate of Evaporation
1	100% Soil	1	51
2	75% Soil, 25% Compost	1	66
3	50% Soil, 50% Compost	1	83
4	25% Soil, 75% Compost	1	73

The usefulness of compost as a soil amendment is heavily dependent on its chemical structure (Ferronato et al., 2020). The results of numerous tests on the fertiliser, including those measuring its pH, organic carbon content, and the availability of essential components like nitrogen-containing compounds, are shown in Table (N), zinc (Zn), iron (Fe), copper (Cu), phosphorus (P), potassium (K), and dolomite (Mg). The acidity or alkalinity of the compost can be assessed by measuring its pH level; a pH of 8.4 signifies somewhat alkaline circumstances. This alkaline pH may have an impact on the soil's microbial activity and nutrient availability, which might leave an impact on the development of plants and nutrient uptake. The 4.3% organic carbon (OC) percentage indicates that the compost contains organic merchandise (Pandyaswargo & Premakumara, 2014) which can improve the cycling of nitrogen, water retention, and soil structure. Yet to prevent deficiencies in nutrients and excessive microbial activity, the OC % needs to be regulated. For plants to develop and grow, nutrients like N, P, and K must be available. According to this investigation, the compost has a medium level of potassium (113 kg/ha), phosphorus (21 kg/ha), and low nitrogen (134 kg/ha) availability (Lohri et al., 2017). These levels show that more nutrient supplementation is required to meet the requirements of crops put in the compost-treated soil. likewise, the compost has enough concentrations of micronutrients including Fe, Cu, Mg, and Zn, which are necessary for a variety of plant metabolic activities. The best possible plant health and productivity can be guaranteed by adequate nutritional availability (Neugebauer & Sołowiej, 2017).

Analysis of different compost mix soil sample numbers dissolving in an open atmosphere results of an evaporation analysis conducted on soil samples along with various compost percentages appears in Table 5.2. 100% soil, 75% soil and 25% compost, 50% soil and 50% compost, and 25% soil and 75% compost are the composition of the samples. The evaporation investigations shed light on the soil compost combines' capacity to retain water. It illustrates how various compositions affect the rate at which water evaporates from the soil surface, which is important information for interpreting irrigation needs and methods to manage water in agricultural operations. These results demonstrate that the amount of water in the soil-compost combinations varies according to composition, with higher compost percentages typically translating to more available water. It also suggests that adding compost to soil can increase its ability to retain water, which could lead to less frequent irrigated or preservation of water reserves.

Comparison of Tests Nos. 1, 2, 3, and 4's Cumulative Water Drain with Comparing soil samples with varying compositions over time in terms of cumulative water drain is shown in Table 5.3. From 100% soil to 25% soil and 75% compost, the samples include different ratios of compost to soil. With the help of this comparison, we can evaluate the long-term effects of the drainage features on the composition of the soil-compost mixture. To manage soggy or overly drained soils, optimise irrigation techniques, and stop nutrient leakage, one must have a thorough understanding of drainage behaviour.

IV. Conclusion

Composting on a small scale and large scale. After 120 days of composting, the final compost in both cases was free of pathogenic organisms and well-matured. The nitrogen levels of both composts were attained within the suggested range.

A few noteworthy beneficial effects of the compost undergoing large scale include better odour control and a few other parameters (humification process, fat reduction, and N content). Not a single other measured statistic showed a discernible improvement. These findings demonstrate that, depending on the kind of waste to be handled and its intended use, large-scale composting is required to aid in the procedure of composting. Anywhere there is a source of nutrients, the microbial population might rapidly multiply and hasten the composting process. More research should be done on the larger scale, such as in-vessel solid-state fermentation or the industrial scale, utilising an entirely novel kind of feedstock. This may give case-by-case explanations on what is needed for microbial calculation also as the C: N ratio shows a negative correlation with cellulase and amylase activity and a positive correlation with pH, this study suggests applying it to follow the process of composting. Knowing the complicated relationship between soil health, nutrient availability, water retention, and plant growth plays an important role in the field of agricultural science.. The characteristics of drainage to explain any prospective ramifications for agricultural practices. A crucial part of sustainable the agricultural sector, compost has the potential to be an effective soil amendment that will increase soil fertility, improve water retention, and encourage the growth of plants. Our research on Compost's chemical makeup has offered significant details on the nutrients it contains and the pH of the soil, two aspects which greatly affect how effective it is as an amendment to the soil. Furthermore, the compost's 4.3% organic carbon concentration in order highlights its potential to add organic matter to the soil, boosting soil structure, water retention, and nutrient cycling. Microbes from the soil utilise organic carbon as a substrate, which promotes their actions and gradually increasing soil fertility. The compost exhibits poor nitrogen (N) availability and medium levels of phosphorous (P) and potassium (K) availability, which are critical nutrients for plant growth considering its high organic matter concentration This illustrates how essential it is to enrich compost with more minerals in order to fulfil the necessities for crops grown in the treated soil. likewise the compost offers substantial levels of micronutrients, such as iron (Fe), zinc (Zn), copper (Cu), and magnesium (Mg), which are required for several plant metabolic processes. Sustaining robust yields, stress tolerance, and excellent plant health are contingent upon sufficient accessibility for micronutrients.

Proceeding on to the evaporation analysis, the study we conducted offers insightful in form out the water soil-compost mixes' capacity to keep moisture. We looked at samples with different compositions, from 100% soil to combinations with up to 75% compost, in order to assess the effects of compost incorporation on soil water retention. The results of our evaporation examination suggest soil-compost mixtures with more compost generally retain water longer than mixes containing less compost. It also indicates that adding compost to soil might improve its capacity to hold water. reducing the rate of irrigation and safeguarding water resources. likewise, a comparison between the overall water drainage over time and various sample variables This illustrates how compost could boost aeration of the soil and mitigate the consequences of waterlogging. This study concludes by outlining the several benefits of compost as a soil conditioner. By enhancing soil fertility, hydrogen availability, water retention, and drainage, compost has a great deal of potential to enhance soil health and promote agriculture in a sustainable manner.

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