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Research Article

Study on the qualitative assessment of in-vessel food waste compost by indexing method

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Abstract
The consumption of different food-based goods produces a considerable amount of waste that needs to be conserved in an eco-friendly manner. A study was carried out on food waste compost made from the in-vessel compost process for use in agriculture and its marketability for its fertility and contamination potential. Food waste samples were collected from the canteen and hostels of GITAM University, Visakhapatnam (Andhra Pradesh), India and were transferred to a 125Kg in-vessel food waste composter (Molten Mind F125) and allowed to digest for 24 hrs followed by curing for seven days. After curing, the samples were characterized for nutrient content for fertility index (FI) and heavy metal contamination for clean index (CI). The compost quality index was derived from FI and CI to assess its suitability for agriculture. The pH of the food waste compost sample was reported as 8.4 and the C/N ratio was 28, which was higher than the standard ratio (15-20). The other physicochemical characteristics were analyzed using the standard methods and the concentration of metals was analyzed using Inductively Coupled Plasma Mass Spectrometry (ICPMS). From the analysis, it was evident that heavy metal concentrations were well within the permissible limits. Further, the compost was characterized to know the fertility index (FI) and contamination index (CI) and its suitability to the soil. FI value was reported as more than 3.1 and CI value more than 4, which indicated that compost was best in quality, having high-value potential and low heavy-metal content, which will be suitable for high-value crops such as organic farming.

Keywords: Fertility index, Food waste, Heavy metals, In-vessel composter, Index method

INTRODUCTION

Composting is the oldest method used to manage organic waste; when it comes to food waste, rice and vegetables are high in carbohydrates, whereas meat and eggs are high in proteins and fats. According to reports, between 2005 and 2025, the yearly volume of urban FW in Asian nations will rise from 278 to 416 million tonnes (Ogwu, 2019). A total of 1.4 billion hectares of arable land (or 28% of the world's agricultural acreage) are lost or wasted each year in food production. In addition to losing food and land resources, it is estimated that food waste adds around 3.3 billion tonnes of CO_2 to the atmosphere every year, which contributes to greenhouse gas (GHG) emissions. This food waste, a part of municipal solid trash, is often burned in an incinerator or dumped in landfills (Ritchie and Roser, 2020; Melikoglu *et al.*, 2013). Even though the condition persists in many nations worldwide, other countries are developing new environmentally friendly techniques for managing FW, including the utilisation of biological processes like composting or anaerobic fermentation. Both strategies are efficient and sustainable alternatives to traditional FW management (Cerda *et al.*, 2018; Waqas *et al.*, 2018). Composting is still not a disposal technique typically applied in rural areas. Automatic/electric composters are used for quick and effective urban composting of food waste in individual homes, restaurants, schools, and other canteens (Kucbel *et al.*, 2019). It is getting increasingly popular to manage trash while creating valuable products (Abdel-Shafy and Mansour, 2018). A more cost-effective and environmentally benign alternative that is gaining attention globally is the production of organic fertilisers from FW (Awasthi *et al.*, 2020; Waqas *et al.*, 2018). In India, food loss costs are estimated to be in the range of 92,000 crores annually. In Indian households, each person wastes 50 kg of food annually (UNEP 2021). As a result, applying compost to the soil provides it with crucial minerals for plant growth, such as nitrogen, carbon, sulphur, and phosphorus (Sayara *et al.*, 2020)

The Green Revolution's technologies, including high-yielding cultivars, chemical fertilisers, and pesticides, and irrigation development, changed India from a net food importer in the 1950s and 1960s to a self-sufficient nation in the 1980s (Eliazer Nelson *et al.*, 2019). However, the procedures employed to boost agricultural yields have resulted in severe surface and groundwater pollution, a rise in pests and illnesses, and a loss of biodiversity (Tudi *et al.*, 2021). Farmers in India confront various issues, such as rising production costs and debt (Reddy *et al.*, 2019). These issues have piqued the interest of farmers, academics, politicians, and other stakeholders in organic agriculture. Organic farming is a type of integrated agricultural system that relies on active agroecosystem management rather than external inputs (Vogt, 2021). Both certified and non-certified food systems are included in organic agriculture. It is found that both economic and non-economic factors, such as improved soil fertility, environmental protection, quality food products, and health (Lotter *et al.*, 2003; Mohammed, 2018), influenced the farmer's decision to adopt new technologies. India is home to 30% of the world's organic producers. Yet, it only accounts for 2.59 percent (1.5 million hectares) of the 57.8 million hectares of total organic agricultural land (Pandey and Sengupta, 2018). However, in India, low yields, a shortage of organic manures, and a lack of technical understanding were the main barriers to organic agricultural adoption (Das *et al.*, 2021). It is necessary to enhance natural starting points such as green excrement, bone feast, food waste compost and so forth to make organic farming sustainable (Elayaraja and Vijai, 2021). In this context, the present study aimed to evaluate in-vessel food waste compost for its suitability and efficient utilization for agriculture uses using the Indexing method.

MATERIALS AND METHODS

In-vessel composting process

Food waste samples were segregated at source during morning breakfast and afternoon lunch hours and stored in a closed container. The food waste is used within six hours of waste generation for vessel composting. Care has been taken not to mix the food waste with water or other materials. 100kgs of segregated food waste collected from Canteen and hostels of GITAM Deemed to be University, Visakhapatnam (Andhra Pradesh) and were transferred to 125Kg In-vessel food waste composter (Molten mind F125) and allowed to digest for 24 hrs followed by curing for 7 days. After curing, the samples were brought to laboratory and characterized for nutrient content and heavy metal contamination.

Characterization of food waste (FW) compost

Matured compost samples were analysed for various physicochemical characteristics following standard operating procedures. pH was analysed using a digital pH meter as per IS:2720 (Part -26), 1987 method. Organic carbon was analysed by using (Walkey and Blacks, 1934) method. Total Available Nitrogen, Available Phosphorus and Exchangeable Potassium were measured as per IS: 10158-1982. For estimation of heavy metals, compost samples are powdered and dried at 60°c till the material was thoroughly dried. A known quantity of dried material was digested with a 5:1 nitric acid and perchloric acid mixture. The digestion was contained until the sample was continuously dissolved and filtered through Whatman no 42 and the dissolved sample was used to measure heavy metals such as zinc, copper cadmium, lead, nickel, and chromium by using ICPMS (Inductively coupled plasma-mass-spectrometry) analyzer. To assess the quality of compost, the index method is chosen to assess the capability of compost for improving soil productivity the index method was calculated based on fertility index (FI) and clean index (CI) using standard values shown Table 1 and Table 2 (Saha *et al.*, 2010; Sharma *et al.*, 2019) and the values are presented in Table 3 and 4. In both cases, weighing factor was taken with respect to FI and CI scores value varied from 1-5 FI was used to determine the soil productivity, while CI was used to determine the phytotoxicity potential of heavy metals. The following formulas are used for the calculation of FI and CI.

$$*FI = \frac{\sum_{n}^{i=1} siwi}{\sum_{n}^{i=1} wi} \quad \text{Eq. 1}$$

$$*CI = \frac{\sum_{n}^{j=1} sjwj}{\sum_{n}^{j=1} wj} \quad \text{Eq. 2}$$

The scoring values are Si and Sj, and the weighing factors are Wi and Wj for the ith and jth values of fertility and heavy metal in the analytical data.

RESULTS AND DISCUSSION

The physico-chemical parameters of the food waste compost's such as pH, conductivity, organic carbon, nitrogen, phosphate, exchangeable potassium, C/N, and heavy metals along with CSE (2019) standard are given in Table 5.

pH

pH is an essential factor in determining the quality of compost. pH tends to increase during the initial degradation process of composting and this condition is favourable for fungi for the decomposition of cellulosic materials. Mature compost generally will have a pH between 6 to 8. In the present study, the mature compost with food reported a pH of 8.1, whereas other studies with vermicompost and municipal solid waste compost reported pH values of less than eight (Soobhany *et al.,* 2017). All windrows compost was reported alkaline pH throughout the composting process 8.3-8.5 (Ameen *et al.,* 2016). The alkaline pH is an essential parameter in evaluating compost maturity and stability. The development of decomposing organisms depends on the environmental factors provided, especially by temperature range (40-70 0C) and the pH between 5.5 and 8.5, respectively. Values outside this range may negatively interfere with the process (Haug, 2018; Xie *et al.*, 2017). In general, the pH tends to increase gradually as the degradation process intensifies, an essential parameter of the chemical properties of the composted material (Neves *et al.*, 2021). However, turning pH into a neutral process during the composting process promotes aerobic bacterial growth and increases compost quality (Valerie *et al.*, 2016). In the present study, a rise in pH value was reported, which indicated the release of ammonia during the decomposition of food waste, specifically proteins, as reported by Chaari *et al.* (2015).

Electrical conductivity

The standard electrical conductivity (EC) value for compost was 4 dS/m (CSE, 2019).EC indicates the presence of mineral salts after decomposition, such as phosphates and ammonium salts. In the present study, higher EC values (6.4 dS/m) were reported indicating the presence of mild salt content and reflecting the degree of salinity expressed by (Castiglione *et al.*, 2021). Higher salt content affects seed germination because the osmotic effect induces poor water intake to plants (Gao *et al.,* 2010; Singh *et al.*, 2015). Overcome this, mixing compost with soil amendment reduces EC value before application to growing crops

Organic carbon

Carbon is a major element required by all organisms and acts as the energy source for composting (Ramnarain *et al.*, 2019). The ideal value for the per-

Table 1. FI (Fertility index) standard values

Fertility parameter %	Score value					Weighing factor
	5	4	3	2	1	
Organic Carbon	>20.0	15.1–20.0	12.1–15	9.1–12	<9.1 5	5
Total Nitrogen	>.25	1.01–1.25	0.81–1.00	0.51–0.80	<0.51	3
C/N	<10.10	10.1–15	15.1–20	20.1–25	>25	3
Available Phosphorus	>0.60	0.41-0.60	0.21-0.40	0.11-0.20	<0.11	3
Available Potassium	>1.00	0.76-1.00	0.51-0.75	0.26-0.50	<0.26	1

Table 2. CI (Clean index) standard values

Heavy metal (ppm)	Score value						Weighing factor
	5	4	3	2	1	0	
Cr	<51	51–100	101–150	151–250	251–350	>350	3
Zn	>151	151–300	301–500	501–700	701–900	>900	1
Cu	>51	51–100	101-200	201–400	401–600	>600	2
Cd	>0.3	0.30–0.60	0.70–1.0	1.10–2.0	2.0–4.0	>4.0	5
Pd	>51	51–100	101–150	151–250	251–400	>400	3
Ni	>21	21–40	41–80	81–120	121–160	>160	1

cent of organic carbon in soil is 0.5 to 3.0. In compost, OC value can range from 12 to 18%. The higher OC in the soil alters pore size distribution, leading to an increased water-holding capacity (Lal *et al.*, 1997; Abdallah *et al.*, 2021). In the present study, food waste compost was reported as 48% of OC, which was very high compared to the standard (Table 5). Higher OC leads to an increase in the C/N ratio and may restrict nitrogen availability to plants (Sudharmaidevi *et al.*, 2017). In such conditions, the application of high OC needs to be amended with soils to bring the C/N ratio applicable to soils.

Nitrogen

It is an essential element for amino acid synthesis, and usually, nitrogen concentration ranges from 0.5 to 2.5% (dry weight basis) in compost (Al-Bataina *et al.*, 2016). In the present study, food waste compost was reported to be 1.6% nitrogen, which determines that the compost is rich in nitrogen availability. The growth of staple crops and vegetables is coupled with nitrogen-rich fertilizers (Chaves *et al.*, 2005). During the decomposition of organic matter, nitrogen transformed into mineralization and immobilization phases. During the mineralization process, nitrogen is in the available form to plants as ammonia. As in the immobilization phase, nitrogen is inaccessible for plants due to a lack of nitrogen species taken up by other microorganisms (Chaves *et al.*, 2007). However, the rate of mineralization depends on process parameters such as temperature, aeration, and moisture (Girkin and Cooper, 2022).

Phosphate

Phosphate is one of the three important nutrients, along with nitrogen and potassium that help plant root growth and improve flowering and seed development. According to Indian Standards, the limit for phosphates in compost is 1.2%, and the present samples reported a low value of 0.20%. Still, it is an organic source of phosphate and completely extractable to crops (Bhushan *et al.*, 2017). Plants absorb phosphates in the form of orthophosphates, but the presence of this ion in the soil is an insoluble form of iron, aluminium, and calcium phosphate (Timofeeva *et al.*, 2022).

Potassium

Potassium is a major activator for important enzymes that help in protein synthesis, nitrogen and carbon metabolism, which in turn improves yield and growth (Oosterhuis et al., 2014; Xuet al., 2020). It is an essential macronutrient for crops responsible for the overall growth of plants (Bhushan et al., 2017). In the present study, the percent of potassium is reported as 0.386, lower than the standard value of 1.2%. It is reported

Table 3. A fertility index score (Fi) of food waste compost

Parameter	FW Compost (si)	Weighing factor (wi)	FW Fertility (siwi)
OC	5	5	25
Nitrogen	5	3	15
C/N	1	3	3
ITP	2	3	6
TK	2	1	2
		Σwi = 15	Σsiwi = 51

*Fi = $\frac{\sum_{n}^{i=1} siwi}{\sum_{n}^{i=1} wi}$ Food waste compost Fi = 3.4

Table 4. Clean index score of food waste compost

Heavy metals	FW Compost (sj)	Weighing factor (wj)	FW Fertility (sj×wj)
Cr	5	3	15
Zn	5	1	5
Cu	5	2	10
Cd	5	5	25
Pd	5	3	15
Ni	5	1	5
		Σwj =15	**Σsjwj= 75**

*CI = $\frac{\sum_{n}^{j=1} sjwj}{\sum_{n}^{j=1} wj}$; Clean index score for food waste compost = 5

Table 5. Comparison of food waste compost with standard values

Parameters	Standard range (CSE 2019)	In vessel (Present study)
Nutrients		
pH	7.5	8.13
EC (ms/cm	4	6.4
C/N Ratio	20	28
OC (%)	12	48
Nitrogen %	1.2	1.6
Phosphorus %	1.2	0.201
Potassium %	1.2	0.386
Heavy metals (ppm)		
Cr	50	15.7
Ni	50	5.7
Cu	300	10.5
Zn	1000	77
Cd	5	0.02
Pb	100	3.2

that potassium is highly variable, and the concentration depends on feedstock and composting processes, and it is easily leachable during the composting process (Bhushan et al., 2017).

C/N

C/N ratio is an important parameter in determining the quality of compost (Michel *et al.*, 1996). As per standards, the ideal range is 15-20 (CSE, 2019), and few authors mentioned that C/N range 20-30 as ideal (Vochozka *et al.*, 2017). C/N ratio mainly influences compost maturity, and aeration helps attain the compost's stability (Guo et al., 2012). In the present study, C/N ratio reported is 28, which is higher than the standard value of CSE (2019). When waste material has a high C/N ratio, it slows down the composting process due to the release of high ammonia (Oudart, 2013) and extends the composting maturation time. A high C/N ratio can also affect the nitrogen and carbon losses in compost (Tripetchkul *et al.*, 2012).

Heavy metals

The average concentrations of analyzed heavy metals in food waste compost were recorded as Zn (77 ppm), Cu (10.5 ppm), Cd (0.02 ppm), Pb (3.2 ppm), Ni (5.7 ppm), As (0.387 ppm) and Cr (15.7 ppm) respectively (Table-3) and are within the permissible limits of compost standards (CSE, 2019). Some studies have reported the presence of heavy metals (Cu, Pb and Cr) higher than the permissible limit of FCO Standard in MSW compost (Mandal *et al.,* 2014). Heavy metals like Zn, Cu, and Ni are reported by more than the standard limit in MSW compost and attributed to crop contamination of compost due to their mixed nature (Kurmana and Srinivas, 2021). The presence of heavy metals in compost more than the permissible levels limits the application or use in agriculture. The accumulation of heavy metals in plants also depends on other factors such as soil type, plant species, compost quality, etc. (Zhao *et al.*, 2011).

Index method

The index method helps to assess the quality of compost in terms of FI and CI. To assess the quality of compost fertilizing potential (FI) and heavy metal pollution potential through a clean index (CI) was considered a tool to help the extent of treatment required before its use. As per standard, FI value >3.5 is Excellent; between 3.1-3.5 are Good, and < 3.1 has low fertilizing potential (Saha *et al.*, 2010; Sharma *et al.*, 2019). The present samples showed that FI values were between 3.1 to 3.5 and fall under the category of Good. Similarly, to assess the extent of heavy metal contamination, clean index was calculated (> 4 means meeting compliance and <4 indicates restricted use) and the results showed an index above 4 out of 5 indicates the compost meets the compliance for heavy metals (Saha *et al.*, 2010). A similar study conducted by Mandal *et al.* (2014) with municipal solid waste compost in Delhi found good fertilizing potential but the clean index value varied from 2.33 to 2.87, indicating the restricted use due to the presence of heavy metals. The present work was carried out under controlled conditions using an automated vessel process to prevent cross-contamination and was helpful for agricultural applications to prevent food chain contamination.

Conclusion

The study results indicated that In-vessel waste compost was of good quality with respect to the fertility index and met heavy metal compliance concerning the clean index. But the sample reported high conductivity (6.4 ms/cm) and C/N values (28) indicated a good source of nutrients and need to apply at a low rate. The study suggests amending this material with the soil to make the availability of nutrients more available form.

Conflict of interest

The authors declare that they have no conflict of interest.

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