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Enhancing nitrogen content of compost through addition of oil residues as co-substrates during food waste composting

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ABSTRACT:

The study aimed at co-composting food waste with neem cake (NC), sesame cake (SC), or peanut cake (PC) as co-substrate to achieve an effective composting process and produce a high-nutrient compost. The food waste and sawdust mixed at 1:1 ratio (on dry basis) was mixed with 10% of NC, SC, and PC individually. The mixtures were composted in 20-L in-vessel composters with aeration and monitored through analysis of physicochemical parameters for 42 days. Addition of 10% of organic materials resulted in increases of EC from 1.25 mS/cm to 2.27- 2.40 mS/cm. Total Kjeldahl nitrogen (TKN) content gradually decreased at the beginning of the composting and gradually increased thereafter. The TKN contents were 2.05 ± 0.05 % in FW+NC10, 2.01 ± 0.14% in FW+SC10, 1.89± 0.16% in FW+PC10 and 1.68±0.17 in control treatments. Neem cake showed the maximum seed germination Index (SGI) values followed by sesame cake and peanut cake treatment and the increase in SGI was significant when compared with control. Among the organic amendments, 10% neem cake addition resulted in a higher SGI, relatively more nitrogen content and reduced N loss and thus better than other treatments.

Keywords: Food waste, organic materials, co-composting, NH_3 emissions, neem cake, peanut cake, sesame cake.

1. Introduction

With rapid increase of population and industrialization, vast amounts of food waste are being generated. Food waste is the most abundant organic component of the municipal solid waste (MSW). Around 1.3 billion tons of MSW is generated worldwide each year and is expected to increase over the next two decades (Petrachini et al., 2018). Indian households are estimated to generate around 68.7 million tons of food waste annually at households (UNEP, 2021). Food waste poses many threats to the environment and hygiene due to greenhouse gas emissions, pathogens, and spreading diseases. Current major uses of food waste as a substrate include animal feed, composting, anaerobic digestion, incineration, and other fermentation technologies (Selvam et al., 2021). The use of food waste as animal feed is banned by many countries through disease control organizations. If food waste is not sufficiently heated before being fed to animals, disease transmission may happen (Dame-Korevaar et al., 2021). In some areas, landfilling has been banned because of the lack of landfill sites and the emission of greenhouse gases, which are responsible for global warming (Yeo et al., 2019). Composting, a typical organic waste treatment technology, has become the focus of researchers due to the advantages of low cost, robustness, environmental sustainability, and high recovery efficiency (Selvam et al., 2021). Composting to treat food waste has great potential because it can not only rehabilitate soil contaminated with organic pollutants but also ensure the supply of nutrients. Due to its highly biodegradable nature, food waste is a suitable substrate for composting. In addition, less concentration of heavy metals and pathogens abundance would increase the value of compost products compared with compost products from other substrates (Wong et al., 2016). Furthermore, applying compost products as organic fertilizers can reduce dependence on inorganic fertilizers, improve crop quality and soil quality, control soil pathogens, promote plant growth, and protect groundwater quality. Among the major nutrients, nitrogen (N) plays an essential role in all living cells. Nitrogen-related reactions in a composting process are complex. The principal processes governing the formation of nitrogen species are mineralization, volatilization, nitrification, immobilization, and denitrification (Wong et al., 2017).

Emissions of NH_3, N_2O, CH_4, and VOCs during composting are significant environmental concerns during composting causing odor problems and also reduce the compost quality in terms of N content (Wang et al., 2013). Ammonia is the largest gaseous emission, accounting for nearly 50% of nitrogen loss during food waste composting (Liang et al., 2006; Wong et al., 2017) and is also irritant and toxic. The methods currently used to reduce NH_3 emissions during composting mainly include the addition of different microorganisms and additives (Li et al., 2020; Yang et al., 2013). The control of nitrogen loss during composting can be divided into *in situ* control and ectopic control (Chang et al., 2019; Tong et al., 2019). The ectopic control technology involves collecting the gas by neutralization, adsorption, and leaching after the discharge of nitrogen-containing gas from the composting pile to realize the purpose of nitrogen recovery and reuse. However, these methods do not improve the compost quality. *In situ* control involves adjusting the composition of composting material and optimizing the parameters like pH, C/N ratio, or addition of adsorption materials, microorganisms, and easily degradable carbon materials. These *in situ* methods have the potential to affect the quality of compost and influence N loss (Zhao et al., 2020).

Several studies have demonstrated the use of additives to effectively mitigate NH_3 and N_2O emissions during composting. During food waste composting, addition of sulfur powder reduced 56% of NH_3 and 37% of N_2O (Xiong et al., 2023); 10% vermiculite reduced 26.4% of NH_3 loss (He et al., 2018); 10% of zeolite reduced 18% of NH_3 emissions (Chan et al., 2016);

mature compost and vermicompost reduced 29–69% of NH_3 (Hwang et al., 2020); mature compost reduced 83% of NH_3 emissions; and biochar at 10% reduced 58% of NH_3 loss (Manu et al., 2021).
With other substrates, addition of 10% zeolite reduced 60-75% NH_3, 80-95% of CH_4, 75-97% of N_2O, and 80-90% of GHG and reduced N leaching during manure composting (Wang et al., 2017b; Wang et al., 2018). Addition of 10% medical stone reduced 48.8% of NH_3 loss and 85.3% of N_2O emission during pig manure composting (Wang Q et al., 2016).
Li et al. (2023) reported that the addition of 20% mature compost and rice husk reduced 40.9% of CH_4, 33.6% of NH_3, 16.5% of nitrogen loss and 2.6% of the total GHG emission during chicken manure composting. Chen et al. (2023) demonstrated that adding 5% of biochar reduced 42.7% of NH_3, 48.9% of N_2O and 69.9% of NO emissions during pig manure composting. Additionally, the combination of 12% biochar and 10% zeolite has been found to increase enzyme activity and reduce 58–65% of NH_3 and 70- 95% of N_2O emissions during sewage sludge composting (Awasthi et al., 2016b; Awasthi et al., 2017).

Although many studies have focused on the effects of zeolite, biochar and struvite as additives to reduce GHG and NH_3 emissions during composting, no study has reported the influence of organic materials such as neem cake, peanut cake, and sesame cake during food waste composting.

India is the 4th largest oilseeds producer in the world, producing 36.5 million tons of oilseeds in 2020-21 (DOD, 2023). Extraction of oil from the seeds generates huge quantities of residues, which can be used as co-substrates and recycled through composting. The addition of oil seed cake, the residue after oil extraction, as manure, has been shown to influence the soil reaction, electrical conductivity, nutrient transformation and availability, buffering capacity, etc. The addition of oil cakes serves as a source of both nutrients and organic matter (Tiyagi et al., 2001).

The neem oil cake contains 5.2% of nitrogen (N), 1.2% of phosphorus (P) and 1.4% of potassium (K). Similarly, peanut cake contains 7% of N 1.5% of P and 1.3% of K, while sesame cake contains 5.9% of N, 2% of K and 1.2% of P (Singh and Longkumer, 2018). Therefore, neem cake (NC), peanut cake (PC) and sesame cake (SC) may be used as co-composting substrates to improve food waste composting process and to improve the nutrient content of the composts that needs to be investigated thoroughly.

2. Materials and Methods

2.1 Feedstock materials and composting process

A synthetic food waste (FW) prepared by mixing boiled rice, fried chapati, bread, vegetables, and dhal in the ratio of 13:10:10:10:5 (w/w, wet weight basis) was used in the experiment. The use of synthetic food waste facilitates the comparison of different experiments and eliminates the heterogeneity of real food waste. All the components of the food waste were size reduced to 0.5 cm^3. The sawdust (SW) was procured from a local sawmill, while the neem cake (NC), peanut cake (PC), and sesame cake (SC) were procured from a local fertilizer shop. The food waste and sawdust were mixed at 1:1, on a dry basis, and mixed with organic materials at 10% on a dry basis individually while FW: SW mix was used as a control. Aeration was provided from the bottom of the reactor continuously at 1.5 L/min/kg VS for two weeks and reduced to 0.5 L/min/kg VS thereafter. The initial moisture contents of the composting mixtures were adjusted to~55%. About 12 kg of the composting mixture was prepared for each treatment and composted for 42 days in 20-L homemade bench-scale composting reactors.

The composting mass was mixed thoroughly every three days for the first two weeks and once a week thereafter until 42 days. Compost samples were collected on days 0, 3, 7, 14, 21, 28, 35 and 42 after a thorough mixing for analysis of physicochemical properties. After sampling, the moisture content was adjusted to~55% if necessary.

2.2 Analytical methods

The temperature was monitored and recorded every day by using a digital sensor thermometer inserted into the middle of the reactor. Moisture content was determined gravimetrically and the dried material was used for the analysis of total Kjeldahl nitrogen (TKN) and total organic carbon (TOC). The dry sample was digested and used to analyze the TKN using indophenol blue method (TMECC, 2002). The dry sample was ground to a fine powder and the TOC was determined using modified Walkey-Black method (Nelson and Sommers, 1996). pH and electrical conductivity (EC) were measured in 1:5 w/v, wet basis, water extracts using Eutech PC 700 pH/EC meter. This water extract was also used for the analysis of extractable ammonium (NH_4^+-N) using the indophenol blue method (TMECC, 2002) and seed germination index (SGI) using cress seed (*Lepidium sativum*) following the method of HKORC (2005). Analysis was made using three independent samples and the data were subjected to statistical analysis using SPSS version 11.0 and the multiple range test was performed at $p<0.05$.

3. Results and Discussion

3.1 Temperature Profile

The degradation of organic materials results in the generation of heat in the compost mass. The trend of temperature dynamics in all the treatments is depicted in Fig 1. A good thermophilic phase of at least 1 week is important for the effective removal of pathogenic organisms to produce a hygienic compost product (Wong and Selvam, 2018). Temperatures of all the treatments showed a similar trend with an initial high temperature for two weeks. The temperature of the composting mass in all treatments increased sharply at the beginning of the composting process and reached the temperature of >60°C within three days indicating that the easily available organic matter was rapidly degraded providing sufficient nutrients for microbial growth. Peak temperature was observed on day 3 in all treatments. Thereafter, the temperature slowly decreased and reached the ambient temperature after 4 weeks, indicating that the rapid degradation of organic matter was completed in about 4 weeks. Among the treatments, neem cake showed relatively higher temperatures during the first week of composting. The evolution of temperature indicated that the composting followed a typical composting process with nearly two weeks of the thermophilic period in all the treatments. When compared with the control, the absence of a significant increase in temperature indicates that the food waste and sawdust mix at 1:1 provides an ideal environment and hence the 10% addition of co-substrates could not exert a distinct influence on the degradation pattern. In addition, this may be attributed to the recalcitrant nature of these co-substrates dominated mostly by biopolymers.

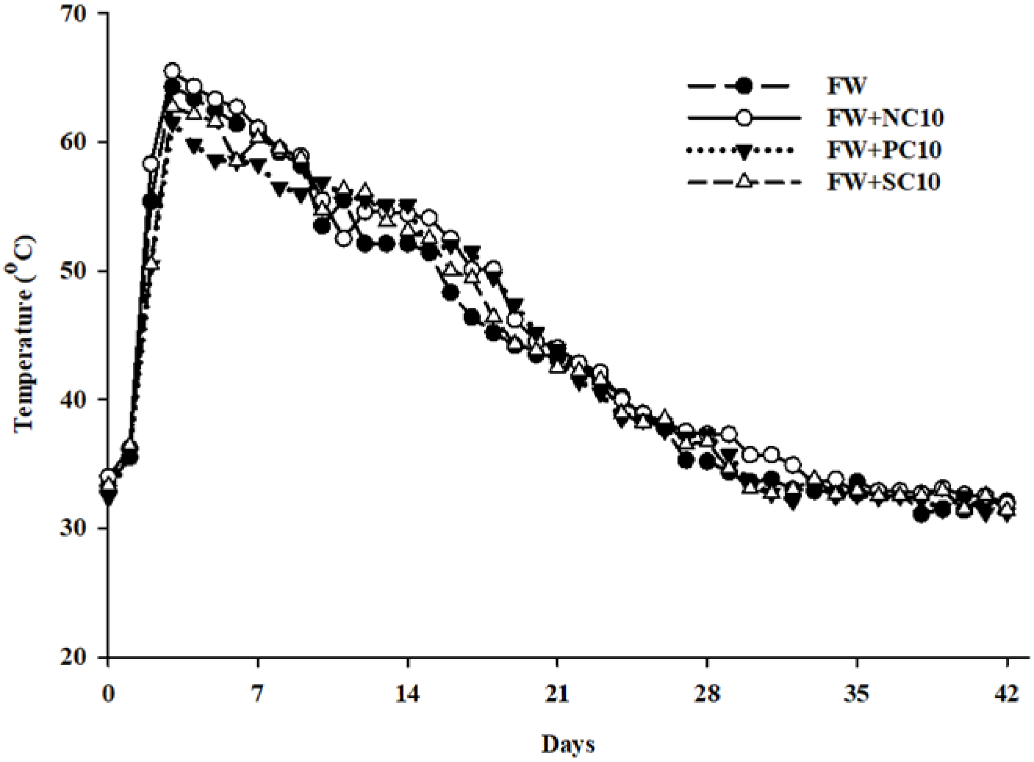

Figure. 1. The changes in temperature during co-composting of food waste (FW) with neem cake (NC), peanut cake (PC) and sesame cake (SC).

3.2 Changes in pH and Electrical conductivity (EC)

Initially, the pH values of the composting mass marginally decreased during the first week of composting (Fig. 2a), which might be due to the generation of organic acids produced by the microbial reactions occurring in the composting mass (Xu et al., 2021). The same pH prevailed for about one week in all the treatments before reaching >6.2 in all the treatments after two weeks. Loss of ammonia during high temperatures reducing the buffering capacity of the system could be another reason for low pH values (Wong et al., 2017). Since the pH was already in the acidic range, a further decline in pH was not observed in this study. It is clear that despite the initial low pH, the sawdust as a bulking agent promoted microbial activities to degrade the organic acids resulting in an increase in pH in the second week. Later on, the pH gradually increased with mineralization of organic nitrogen which eventually released alkalinity probably in the form of NH_4^+-N as reported in a later section. It is also observed that the 10% addition of organic materials amended had slightly higher pH in comparison to the control initially indicating these materials could provide additional alkalinity because of higher N content. The pH values after 42 days of composting for the treatments were 7.23±0.06 in FW, 8.06±0.05 in FW+NC10, 7.51±0.05 in FW+PC10 and 8.09±0.01 in FW+SC10. The addition of organic materials as co-substrate caused relatively higher pH when compared with treatment without additives.

Electrical conductivity (EC) is an indicator of the concentration of soluble salts and is important for determining the potential harm of the compost material to plants. EC values of composting substrates of different treatments are presented in Fig.2b. The generation of low-molecular-weight organic acids and NH_4^+ contribute to an increase in EC during the initial phase of composting (Zhang et al., 2023). Initially, the EC of the composting mass was around 1.5 mS/cm in all the treatments. In all the treatments, the EC increased up to 14 days most likely due to the release of soluble salts and accumulation of cations/anions (ammonium, nitrate, potassium, etc.) and decreased thereafter at varying levels which might be due to the volatilization of ammonia, precipitation of mineral salts and assimilation as reported previously (Waqas et al., 2018). In the control (FW) treatment, the EC increased from 1.35±0.01 mS/cm on day 0 to 2.45±0.01 mS/cm on day 14 and decreased gradually till the end, and reached about 1.25±0.02 after 42 days. Among the co-substrate added treatments, the highest increase in EC was observed in peanut cake (FW+PC10) treatment on day 14 (3.83±0.06 mS/cm), followed by FW+NC10 (3.43±0.06 mS/cm) and FW+SC10 (2.87±0.06 mS/cm). However, after 42 days, the EC values of these treatments were decreased and ranged between 2.27 mS/cm and 2.40 mS/cm. There was no significant difference among treatments ($p \leq 0.05$). The results suggest that the addition of NC, PC and SC will not increase the EC value of compost significantly. Chan et al. (2016) reported that the addition of 5% and 10% zeolite reduced the EC values to 3.23 and 2.82 mS/cm during food waste composting. Compost with high EC concentration may inhibit the germination of seeds. Plants may be harmed when the salinity is higher than 4 mS/cm. Thus, the EC values in all treatments were within the safe limits for compost application.

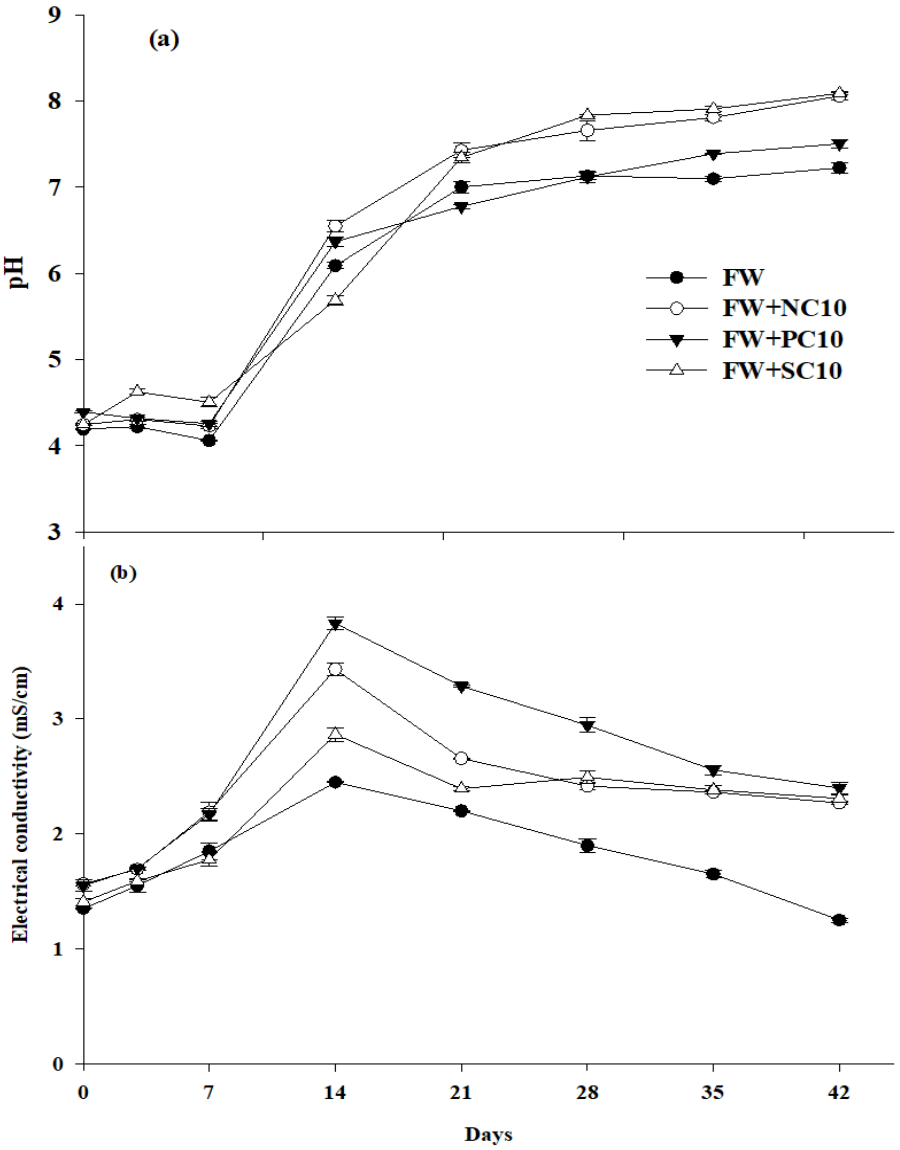

Figure. 2. The changes in pH (a) and electrical conductivity (b) during co-composting of food waste (FW) with neem cake (NC), peanut cake (PC) and sesame cake (SC).

3.3 Changes of Extractable ammonium nitrogen (NH_4^+-N)

Emissions of NH_3 is the biggest reason for the loss of nitrogen during the composting process. It is not only reducing the quality of compost, but also leads to the environmental risk in full scale composting facilities (Wang Q et al., 2016). The pH of the composting influences the volatilization of NH_4^+-N. The mineralization of organic matter releases NH_4^+-N resulting in increasing concentration and is predominant during the active composting period coinciding with the thermophilic period. NH_4^+-N concentrations increased at the beginning of the composting (Fig.3a) and the increase was observed up to day 14.

During the early thermophilic period, the degradation of organic matter results in the release of available nitrogen resulting in increased NH_4^+-N concentrations up to 14 days. Thereafter, the NH_4^+-N concentrations decreased likely due to NH_3 volatilization under high pH and temperature conditions and assimilation by microbes. Control also followed a similar trend although the value is lesser than other treatments. After 4 weeks, the NH_4^+-N concentration ranged between 728.6± 43.2 and 750.2± 64.9 mg/kg in NC, PC and SC amended treatments while in control it was 650.3±85.2 mg/kg. After 42 days of composting, NH_4^+-N content was less than 600 mg/kg in all the treatments meeting the requirements of a matured compost thus, may not exert any negative influence on growth and development. Xiong et al. (2023) reported that the addition of mature with sulfur powder mitigated by up to 56.3% of NH_3 on 15 days of food waste composting. Addition of 10% zeolite increased the adsorption of ammonium ions reducing ammonia loss to 18% resulting in higher total nitrogen content in the final food waste composting (Chan et al., 2016). Hwang et al. (2020) reported that the addition of mature compost and vermicompost reduced 29–69% of NH_3 during food waste composting. Adding 10 % of vermiculite to the food waste also reduced 26.4% of NH_3 loss during food waste composting (He et al., 2018). Addition of co-substrates NC, PC and SC in this study resulted in comparatively higher NH_4^+-N content; however, the contents are less than 700 mg/kg, a limit stipulated by TMECC (2002).

3.4 Changes in Total Kjeldahl Nitrogen

In the early stage of composting, the TKN concentration of all treatments showed a marginal decrease for 1 week probably due to the loss of nitrogen caused by the volatilization of NH_4^+-N and emission of NH_3 during the thermophilic period (Fig 3b). In addition, high temperature and pH may not be suitable for nitrification /denitrification. Thereafter, the TKN content gradually increased which could be attributed to the degradation of nitrogenous compounds and organic matter (Wong et al., 2009). The elevated temperature in all treatments caused nitrogen loss that reduced the TKN contents as observed during the first two weeks of composting. After 42 days, the TKN contents were 2.05 ±0.05 % in FW+NC10, 2.01±0.14 % in FW+SC10, 1.89 ±0.16 % in FW+PC10 and 1.68±0.17 in control treatments. As the composting process progressed, due to the carbon mineralization and the reduction in composting mass, increase in total Kjeldahl nitrogen towards the end of composting was observed as reported in several earlier studies (Wong et al., 2016).

In addition, Wang Q et al. (2016) reported that 10% of medical stone addition was most efficient for nitrogen conservation during food waste composting. He et al. (2018) reported that addition of 10% vermiculite was most efficient for nitrogen conservation during food waste composting. Addition of struvite salts reduced the nitrogen loss up to 23.3- 40.8% during food waste composting (Wang et al., 2013; 2016). Wang et al. (2021) reported that addition of 10% biochar reduced 25.7% of nitrogen loss during grain waste composting.

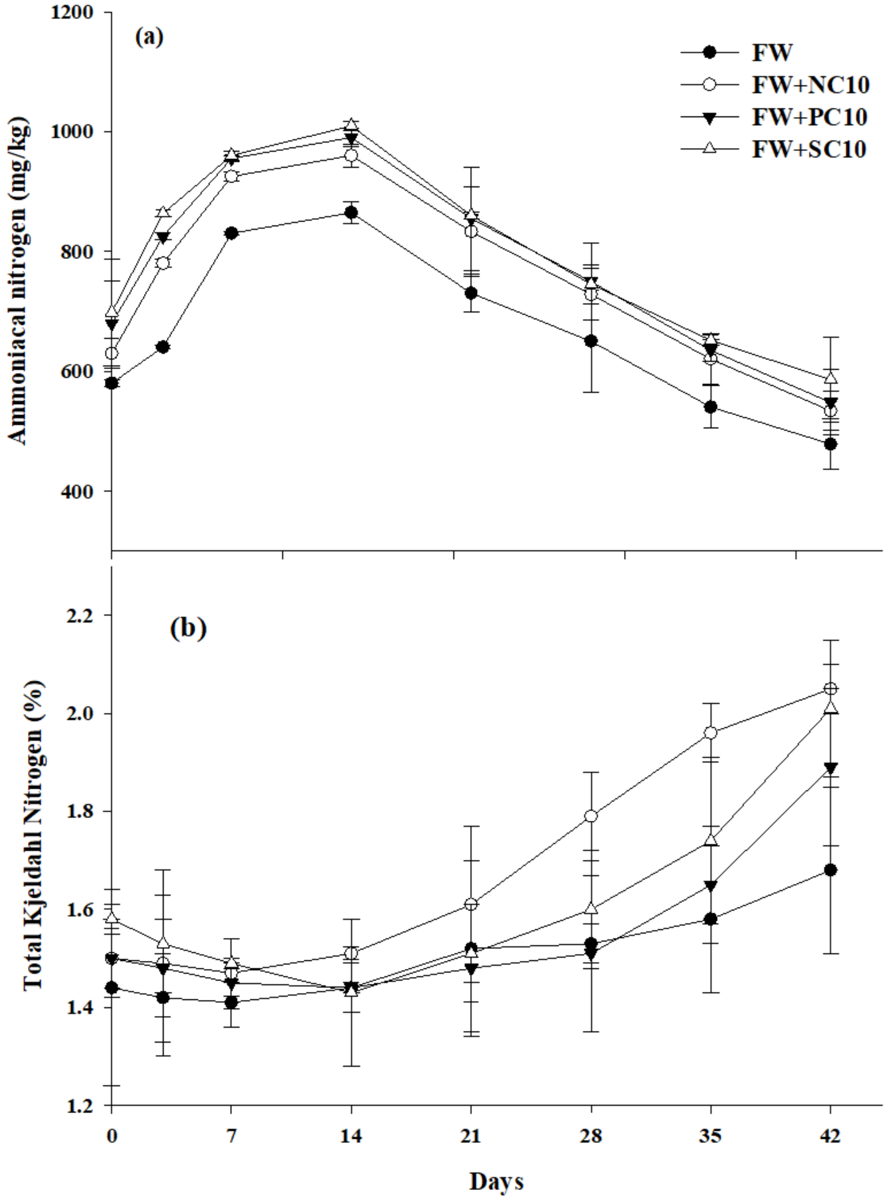

Figure. 3. The changes in extractable ammonium nitrogen (NH_4^+-N) (a) and total Kjeldahl nitrogen (TKN) (b) during co-composting of food waste (FW) with neem cake (NC), peanut cake (PC) and sesame cake (SC).

3.5 Changes in Total Organic Carbon

The total organic carbon (TOC) content during the composting decreases since the microorganism mineralizes the organic carbon as their energy source. About 54% of the weight of organic matter in compost is typically composed of organic carbon. Individual feedstocks' carbon contents may differ from this ratio and the data revealed that the maximum amount of carbon was observed during initial days of composting and the TOC contents gradually decreased thereafter (Fig. 4a). Song et al. (2021) reported that the addition of mature compost reduced 32% of TOC content during food waste digestate composting. During manure composting addition of sawdust resulted in 54.4% of total carbon loss (Sun et al., 2014). The results showed that loss of carbon was 52.44% in control (FW), 43.3% in FW+NC10, 46.7% in FW+PC10, and 48.3% in FW+SC10 after 42 days as calculated from the C contents of the composting mass and the mass of composts available on specific days.

3.6 C/N ratio

Some macronutrients such as carbon and NPK are required for the growth of microorganisms during the composting process and a balance between C and N influences the microbial growth and assimilation which evenly affects the composting process; and the C/N ratio is used for evaluating the compost maturity (Zhou et al., 2018). Thus, carbon content will decrease and nitrogen is normally fluctuating but increases, which lead to decrease in the C/N ratio of the final compost (Ravindran et al., 2022). Similarly, in this study, during the initial stages, all the treatments showed high C/N ratios that eventually decreased towards the end of the composting. After 42 days the C/N ratio of composts were 20.42±3.0 in FW (control), 18.14± 0.7 in FW+NC10, 19.40± 1.8 in FW+PC10 and 18.04 ± 0.9 in FW+SC10 (Fig. 4b). The C/N ratio of struvite treatments was less than 21 during food waste composting as reported by Chan et al. (2016). Similarly, biochar addition reduced the C/N ratio from 22 to 12 at the end of food waste anaerobic digestate composting (Manu et al., 2021). The C/N ratio of final product from all treatments was within the prescribed limit of < 20 as recommended by many standards.

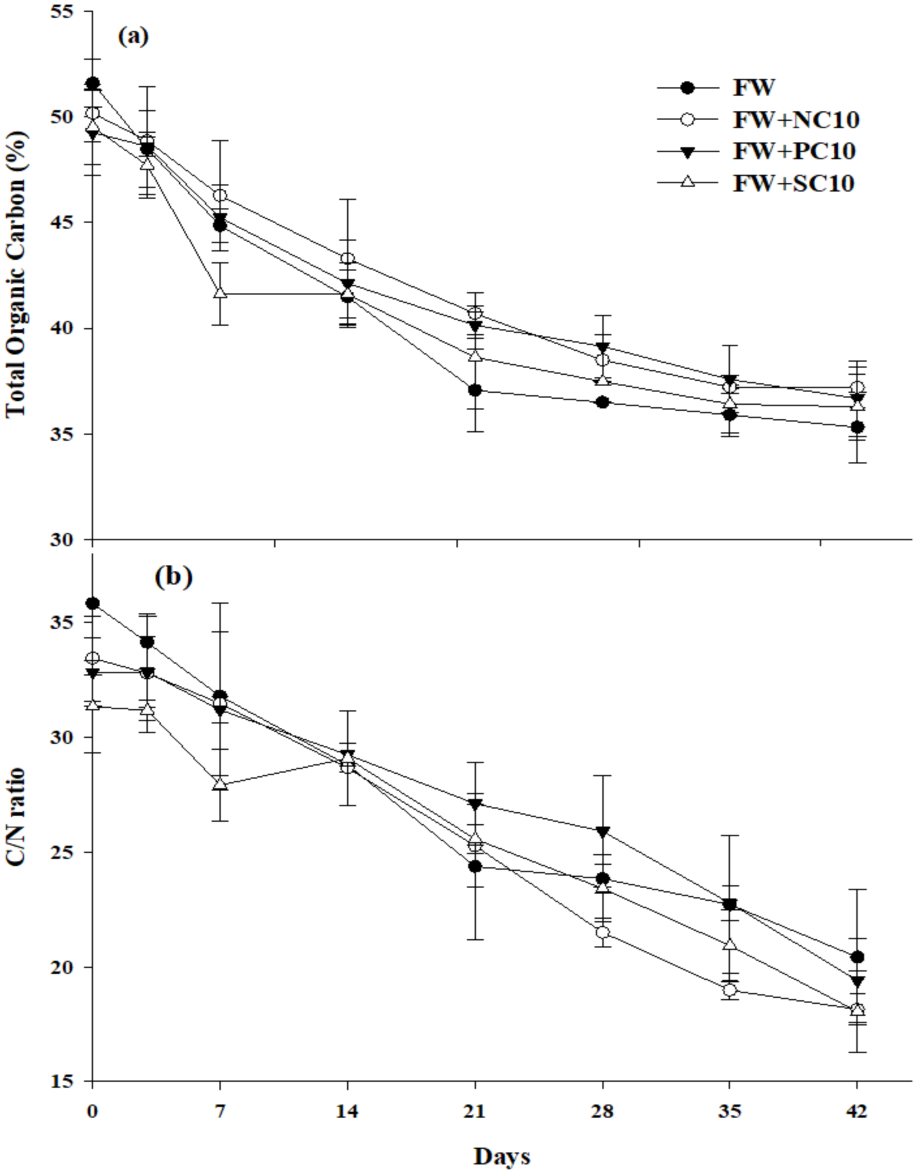

Figure. 4. The changes in total organic carbon (TOC) (a) and C/N ratio (b) during co-composting of food waste (FW) with neem cake (NC), peanut cake (PC) and sesame cake (SC).

3.7 Seed germination index

The seed germination index (GI) is a sensitive and authoritative biological indicator to evaluate compost maturity and phytotoxicity (Zhou et al., 2018). The GI value of >80% is considered an indicator of stable compost (HKORC, 2005) and >90% is indicative of a 'very stable' product (TMECC, 2002).

On day 7, SGI was nearly 10% to 40% due to the phytotoxicity by high NH_4^+-N and probably the generation of low molecular weight organic acids in the composting mass (Fig. 5). The SGI values continuously increased with progression of composting due to the reduction in phytotoxic substances and the formation of humic substances by microbial degradation of the substrates as reported in several earlier studies (Lie et al., 2022). After day 28, NC, and SC treatments showed a GI of >70%. Previously, addition of lime during food waste composting enhanced the GI to >80% after 35-50 days (Wang et al., 2013; Zhou et al., 2018). The addition of 5% and 10% zeolite also showed a high SGI after 8 weeks during food waste composting (Chan et al., 2016). In this study, the highest SGI values were observed in FW+NC10 treatment (121.9% ± 2.8%), followed by FW+SC10 (115.16% ± 5.2%) and FW+PC10 (94.77%±4.0%) treatments and the lowest SGI was observed in FW (81.97 ±15.3). A high SGI could significantly reduce the time needed for compost maturity even though the initial food waste compost feedstock mixture had a relatively lower C/N ratio.

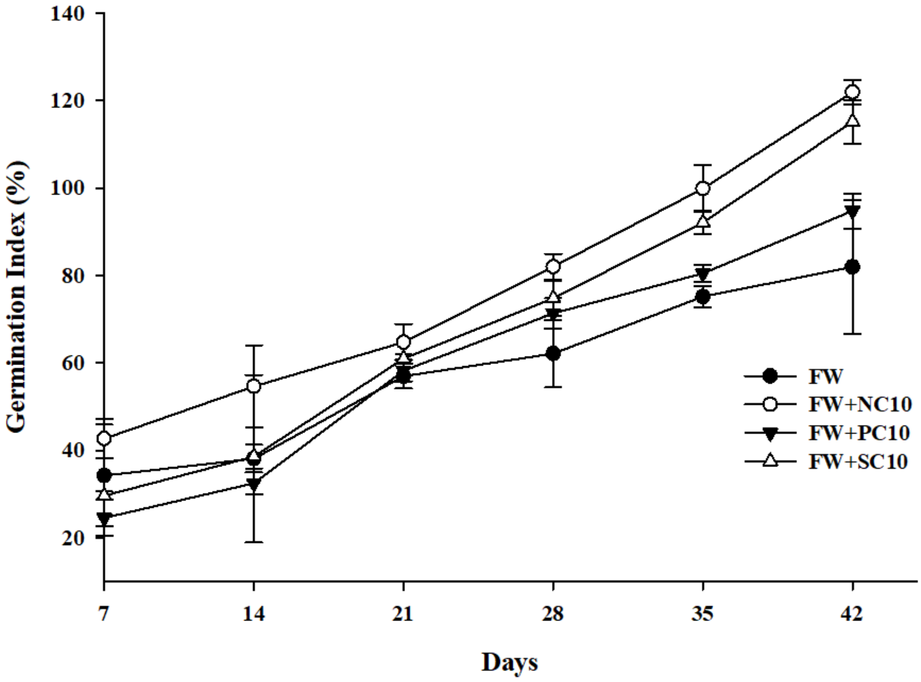

Figure. 5. The changes in seed germination index during co-composting of food waste (FW) with neem cake (NC), peanut cake (PC) and sesame cake (SC).

Table 1. Selected physicochemical properties of initial composting mix

Parameter	FW	FW+ NC10	FW+ PC10	FW+SC10
pH	4.19±0.01*	4.25±0.01	4.39±0.01	4.25±0.01
EC (mS/cm)	1.35±0.01	1.56±0.01	1.55±0.05	1.41±0.03
Moisture content (%)	60.70±1.67	60.13±1.72	61.08±2.32	60.67±1.36

Total organic carbon (%)	51.61±1.13	50.18±1.37	49.27±2.00	49.53±1.79
Total Kjeldahl N (%)	1.44±0.20	1.50±0.08	1.50±0.06	1.58±0.03
C/N ratio	35.84±3.11	33.45±1.86	32.85±1.50	31.35±1.30
NH_4^+-N (mg/kg)	580.50±5	630.0±25	680.30±71	700.70±90

* - Mean ± SD of three replicates. FW- food waste; NC- neem cake; PC- peanut cake; SC - sesame cake.

Table 2. Selected physicochemical properties of compost product after 42 days of composting

Parameter	**FW**	**FW+ NC10**	**FW+PC10**	**FW+SC10**
pH	7.23±0.06*	8.06±0.05	7.51±0.05	8.09±0.01
EC (mS/cm)	1.25±0.02	2.27±0.02	2.40±0.05	2.31±0.03
Moisture content (%)	54.85 ±0.84	55.41 ± 0.23	55.23 ± 0.15	55.35± 4.47
Total organic carbon (%)	34.30±1.67	37.18±0.98	36.66±1.80	36.27±1.56
Total Kjeldahl N (%)	1.68±0.17	2.05±0.05	1.89±0.16	2.01±0.14
C/N ratio	20.42±3.00	18.14±0.70	19.40±1.82	18.04±0.90
NH_4^+-N (mg/kg)	478.60±42.30	534.13±32.50	548.40±54.11	586.40±71.42
SGI (%)	81.97± 15.3	121.90 ±2.83	94.77 ± 4.02	115.16 ± 5.2

* - Mean ± SD of three replicates. FW-food waste; NC- neem cake; PC- peanut cake; SC - sesame cake.

4. Conclusion

Neem cake, peanut cake and sesame cake were used as composting co-substrate with food waste as substrate and the composting process was evaluated. Neem cake addition prolonged the thermophilic period for 2 to 4 days when compared with other co-substrates added treatments. The addition of 10% of organic materials resulted in increase of EC from 1.25 mS/cm to 2.27- 2.40 mS/cm; nevertheless, the values were within the safe limit of 4 mS/cm. TOC contents gradually decreased during the composting process and the loss of C was almost similar in all the treatments. TKN contents gradually decreased at the beginning of the composting possibly due to the loss of N during the active / thermophilic phase. Thereafter the TKN contents gradually increased and higher TKN contents were observed in NC, PC and SC amended treatments. Addition of neem cake, peanut cake and sesame cake treatment achieved the lower nitrogen loss compared with control. Neem cake showed the highest SGI value followed by sesame cake and peanut cake treatment. The overall result revealed that the addition of neem cake, peanut cake, and sesame cake resulted in compost with higher N contents when compared with control. Considering the TKN contents and SGI among co-substrates, neem cake amended treatment produced a stable and high N compost product.

Acknowledgements

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5. References

1. Awasthi, M.K., Wang, Q., Ren, X., Zhao, J., Huang, H., Awasthi, S.K., Lahori, A.H., Li, R., Zhou, L., Zhang, Z., 2016. Role of biochar amendment in mitigation of nitrogen loss

and greenhouse gas emission during sewage sludge composting. Bioresource Technology, 219, 270–280.

2. Awasthi, M.K., Wang, M., Chen, H., Wang, Q., Zhao, J., Ren, X., Li, D. Sheng, Awasthi, S. K., Shen, F., Li, R., Zhang, Z., 2017. Heterogeneity of biochar amendment to improve the carbon and nitrogen sequestration through reduce the greenhouse gases emissions during sewage sludge composting. Bioresource Technology, 224, 428–438.
3. Awasthi, M.K., Duan, Y., Awasthi, S.K., Liu, T. and Zhang, Z., 2020. Influence of bamboo biochar on mitigating greenhouse gas emissions and nitrogen loss during poultry manure composting. Bioresource Technology, 303, 122952.
4. Chan, M.T., Selvam, A., Wong, J.W.C., 2016. Reducing nitrogen loss and salinity during struvite food waste composting by zeolite amendment. Bioresource Technology, 200, 838–844.
5. Chang, R., Li, Y., Chen, Q., Guo, Q. and Jia, J., 2019. Comparing the effects of three in situ methods on nitrogen loss control, temperature dynamics and maturity during composting of agricultural wastes with a stage of temperatures over 70°C. Journal of Environmental Management, 230, 119-127.
6. Chen, P., Cheng, W. and Li, S., 2023. Optimization strategies for mitigating nitrogen loss in the aerobic composting of pig manure and microbial changes revealed by metagenomic analysis. Process Safety and Environmental Protection, 169, 270-284.
7. Dame-Korevaar, A., Boumans, I.J., Antonis, A.F., van Klink, E. and de Olde, E.M., 2021. Microbial health hazards of recycling food waste as animal feed. Future Foods, 4, 100062.
8. DOD, 2023. The Directorate of Oilseeds Development (DOD), Hyderabad. https://oilseeds.dac.gov.in/doddocuments/APYTotalOilseeds.pdf. Last accessed on 13 Feb 2024.
9. He, Z., Lin, H., Hao, J., Kong, X., Tian, K., Bei, Z. and Tian, X., 2018. Impact of vermiculite on ammonia emissions and organic matter decomposition of food waste during composting. Bioresource Technology, 263, 548-554.
10. HKORC. 2005. Compost and Soil Conditioner Quality Standards. Hong Kong Organic Resource Centre. http://www.hkorc-cert.org/download/COMPOST-SD-080124-AEng.pdf (accessed on 6th June 2013).
11. Huang, X., He, Y., Zhang, Y., Lu, X. and Xie, L., 2022. Independent and combined effects of biochar and microbial agents on physicochemical parameters and microbial community succession during food waste composting. Bioresource Technology, 366, 128023.
12. Hwang, H.Y., Kim, S.H., Shim, J. and Park, S.J., 2020. Composting process and gas emissions during food waste composting under the effect of different additives. Sustainability, 12, 7811.
13. Li D, Manu MK, Varjani S, Wong JWC. 2022. Mitigation of NH_3 and N_2O emissions during food waste digestate composting at C/N ratio 15 using zeolite amendment. Bioresource Technology, 359, 127465.
14. Li, H., Zhang, T., Tsang, D.C.W., Li, G., 2020. Effects of external additives: Biochar, bentonite, phosphate, on co-composting for swine manure and corn straw. Chemosphere, 248, 125927.
15. Li, M., Li, S., Meng, Q., Chen, S., Wang, J., Guo, X., Ding, F. and Shi, L., 2023. Feedstock optimization with rice husk chicken manure and mature compost during chicken manure composting: Quality and gaseous emissions. Bioresource Technology, 129694.

16. Liang, Y., Leonard, J.J., Feddes, J.J. and McGill, W.B., 2006. Influence of carbon and buffer amendment on ammonia volatilization in composting. Bioresource Technology, 97, 748-761.
17. Mardini, B., Shibusawa, S., Kojima, Y. and Hosaka, S., 2016. Effect of natural zeolite (clinoptilolite) on ammonia emissions of leftover food-rice hulls composting at the initial stage of the thermophilic process. Journal of Agricultural Meteorology, 72, 12-19.
18. Manu, M.K., Wang, C., Li, D., Varjani, S., Xu, Y., Ladumor, N., Lui, M., Zhou, J. and Wong, JWC, 2021. Biodegradation kinetics of ammonium enriched food waste digestate compost with biochar amendment. Bioresource Technology, 341, 125871.
19. Oshins, C., Michel, F., Louis, P., Richard, T.L. and Rynk, R., 2022. The composting process. In: The Composting Handbook: a how-to and why manual for farm, municipal, institutional and commercial composters (51-101). Academic Press, 2022. Elsevier. https://doi.org/10.1016/B978-0-323-85602-7.00008-X
20. Nelson, D.W., Sommers, L.E. 1996. Total carbon, organic carbon, and organic matter. In: 'Methods of Soil Analysis, Part 3: Chemical Methods, Eds. Sparks D.L. et al. Soil Science Society of America, Inc., American Society of Agronomy Inc., USA, pp. 961–1010.
21. Ravindran, B., Awasthi, M.K., Karmegam, N., Chang, S.W., Chaudhary, D.K., Selvam, A., Nguyen, D.D., Milon, A.R. and Munuswamy-Ramanujam, G., 2022. Co-composting of food waste and swine manure augmenting biochar and salts: Nutrient dynamics, gaseous emissions and microbial activity. Bioresource Technology, 344, 126300.
22. Selvam, A., Ilamathi, K.P., Udayakumar, M., Murugesan, K., Rajesh Banu, J., Khanna, Y. and Wong, J.W.C., 2021. Food Waste Properties. In J.W.C. Wong, G. Kaur, M. Taherzadeh, A. Pandey, and K. Lasaridi (Eds.), Current Developments in Biotechnology and Bioengineering: Sustainable Food Waste Management. Resource Recovery and Treatment (1st ed., pp. 11-41). Elsevier. https://doi.org/10.1016/B978-0-12-819148-4.00002-6
23. Singh, R.K. and Longkumer, T.E., 2018. Compost: the black cold. KrishiVigyan Kendra–Phek, ICAR–NRC on Mithun, Porba, Phek, Nagaland, 112.
24. Song, B., Manu, M.K., Li, D., Wang, C., Varjani, S., Ladumor, N., Michael, L., Xu, Y. and Wong, J.W.C., 2021. Food waste digestate composting: Feedstock optimization with sawdust and mature compost. Bioresource Technology, 341, 125759.
25. Sun, X.P., Lu, P., Jiang, T., Schuchardt, F. and Li, G.X., 2014. Influence of bulking agents on CH_4, N_2O, and NH_3 emissions during rapid composting of pig manure from the Chinese Ganqinfen system. Journal of Zhejiang University Science B, 15, 353-364.
26. Temel, F. A., 2023. Evaluation of the influence of rice husk amendment on compost quality in the composting of sewage sludge. Bioresource Technology, 373, 128748.
27. Tiyagi, S. A., Khan, V., and Alam, M. M., 2001. Role of oil-seed cakes for the management of plant-parasitic nematodes and soil-inhabiting fungi on lentil and mung bean. Archives of Phytopathology and Plant Protection, 33, 453-472.
28. TMECC. 2002. W. Thompson, P. Leege, P. Millner, M.E. Watson (Eds.), Test methods for the examination of composts and composting. The US Composting Council, US Government Printing Office.
29. Tong, B., Wang, X., Wang, S., Ma, L. and Ma, W., 2019. Transformation of nitrogen and carbon during composting of manure litter with different methods. Bioresource Technology, 293, 122046.
30. Villasenor, J., Rodriguez, L., Fernandez, F.J., 2011. Composting domestic sewage sludge with natural zeolites in a rotary drum reactor. Bioresource Technology. 102 (2), 1447–1454.

31. Walkley, A., Black, I. A. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science, 37, 29-38.
32. Wang, Q., Wang, Z., Awasthi, M.K., Jiang, Y., Li, R., Ren, X., Zhao, J., Shen, F., Wang, M. and Zhang, Z., 2016. Evaluation of medical stone amendment for the reduction of nitrogen loss and bioavailability of heavy metals during pig manure composting. Bioresource Technology, 220, 297-304.
33. Wang, X., Selvam, A., and Wong, J. W. 2016. Influence of lime on struvite formation and nitrogen conservation during food waste composting. Bioresource Technology, 217, 227-232.
34. Wang, X., Selvam, A., Chan, M.T., Wong, J.W.C. 2013. Nitrogen conservation and acidity control during food wastes composting through struvite formation. Bioresource Technology, 147, 17-22.
35. Wang, Y., Tang, Y. and Yuan, Z., 2022. Improving food waste composting efficiency with mature compost addition. Bioresource Technology, 349, 126830.
36. Waqas, M., Nizami, A.S., Aburiazaiza, A.S., Barakat, M.A., Rashid, M.I. and Ismail, I.M.I., 2018. Optimizing the process of food waste compost and valorizing its applications: A case study of Saudi Arabia. Journal of Cleaner Production, 176, 426-438.
37. Wong, J. W. C., and Selvam, A., 2006. Speciation of heavy metals during co-composting of sewage sludge with lime. Chemosphere, 63, 980–986
38. Wong, J. W. C., Fung, S. O., and Selvam, A., 2009. Coal fly ash and lime addition enhances the rate and efficiency of decomposition of food waste during composting. Bioresource Technology, 100, 3324-3331.
39. Wong, J. W. C., Selvam, A., and Awasthi, M. K., 2016. Composting for organic waste management. In: Sustainable Solid Waste Management, pp. 233-272. American Society of Civil Engineers (ASCE). https://doi.org/10.1061/9780784414101.ch09.
40. Wong, J.W.C., Wang, X. and Selvam, A., 2017. Improving compost quality by controlling nitrogen loss during composting. In Current Developments in Biotechnology and Bioengineering, pp. 59-82. Elsevier Inc. https://doi.org/10.1016/B978-0-444-63664-5.00004-6.
41. Xiong, S., Liu, Y., Zhang, H., Xu, S., Li, S., Fan, X., Chen, R., Ding, G., Li, J. and Wei, Y., 2023. Effects of chemical additives and mature compost on reducing nitrogen loss during food waste composting. Environmental Science and Pollution Research, 30, 39000-39011.
42. Xu, Z., Qi, C., Zhang, L., Ma, Y., Li, G., Nghiem, L.D., Luo, W., 2021. Regulating bacterial dynamics by lime addition to enhance kitchen waste composting. Bioresource Technology, 341, 125749
43. Xu, Z.Y., Zeng, G.M., Yang, Z.H., Xiao, Y., Cao, M., Sun, H.S., Ji, L.L. and Chen, Y., 2010. Biological treatment of landfill leachate with the integration of partial nitrification, anaerobic ammonium oxidation, and heterotrophic denitrification. Bioresource Technology, 101,79-86.
44. Yang, F., Li, G.X., Yang, Q.Y. and Luo, W.H., 2013. Effect of bulking agents on maturity and gaseous emissions during kitchen waste composting. Chemosphere, 93(7), 1393-1399.
45. Yeo, J., Chopra, S.S., Zhang, L., An, A.K., 2019. Life cycle assessment (LCA) of food waste treatment in Hong Kong: On-site fermentation methodology. Journal of Environmental Management, 240, 343–351
46. Zhang, L., Shi, T., Xu, Z., Bao, Z., Li, J., Li, G. and Yuan, J., 2023. Effect of lime and calcium magnesium phosphate on gaseous emissions, maturity, and bacterial dynamics during food waste composting. Environmental Technology and Innovation, 32, 103306.

47. Zhao, S., Schmidt, S., Qin, W., Li, J., Li, G., and Zhang, W., 2020. Towards the circular nitrogen economy–A global meta-analysis of composting technologies reveals much potential for mitigating nitrogen losses. Science of the Total Environment, 704, 135401.
48. Zhou, Y., Selvam, A., and Wong, J. W., 2018. Chinese medicinal herbal residues as a bulking agent for food waste composting. Bioresource Technology, 249, 182-188.