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Influence of neem cake on composting of food waste

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ABSTRACT

This study aimed to evaluate the effect of neem cake as the additive with food waste (FW) and sawdust on improving the compost quality and composting. The food waste (FW), sawdust (SD) and neem cake (NC) was mixed at 1:1:0.2, w/w, dry basis (FW+SD+NC) while food waste + sawdust mix (FW+SD, 1:1 w/w dry basis) served as control. The mixtures were composted in 20-L bench scale composters for 42 days. The results revealed that addition of neem cake resulted in thermophilic peak temperature of 63ºC while the thermophilic period prevailed for nearly three weeks which were significantly higher than the control. The nitrogen content of the FW+SD+NC treatment (2.20 %) was higher when compared with FW+SD treatment (1.94 %). The physicochemical properties of the FW+SD and FW+SD+NC composts were within the recommended compost standard range. Addition of 20% neem cake proved to be one of the most effective strategies for improving the composting process, enhancing compost quality, and reducing nitrogen loss during food waste composting.

INTRODUCTION

Developing countries generate large amounts of organic solid waste, including food, municipal, and agricultural waste (1). Food waste is the largest organic component of municipal solid waste by weight, accounting for approximately 14–40% in different countries (2). In some regions, food waste constitutes about 56% of total municipal solid waste (3). These organic wastes have a complex composition. They are rich in organic matter and essential plant nutrients (N, P, K), but also contain pathogenic microorganisms, toxic pollutants, and heavy metals that pose risks to environmental and human health (4). Various methods are used to treat organic solid waste, including anaerobic digestion (5), incineration (6), composting (7), landfilling (8), and pyrolysis (9). However, recently landfilling has been banned due to land scarcity and the need to protect groundwater and soil quality (10). This necessitates the application other viable methods to treat food waste.

Composting is one of the most important methods for treating solid wastes and has been widely used for decades due to its effectiveness and simplicity. It helps reduce food waste sent to landfills while enabling the recycling of organic material (11). Compost, rich in organic matter, serves as a natural fertilizer in agriculture. It contains essential nutrients and fiber, positively impacting both soil health and the environment. Stabilized compost products have higher nutrient levels than the original organic feedstocks and do not produce harmful intermediate metabolites that could inhibit plant growth. During composting, microorganisms break down organic matter through various biochemical processes, converting it into stable substances. These processes produce fibrous, carbon-rich humus containing valuable inorganic nutrients such as nitrogen and phosphorus. The final compost product functions as both a fertilizer and a soil conditioner due to its high humus content.

The composting process can cause issues such as nitrogen loss, greenhouse gas emissions, and unpleasant odors. Nitrogen is lost during composting primarily through ammonia (NH_3) volatilization, nitrification, and denitrification. The extent of nitrogen loss depends on feedstock characteristics and various environmental factors, including pH, carbon-to-nitrogen (C/N) ratio, particle size, temperature, and aeration conditions (12). Ammonia emissions are the main cause of both compost quality degradation and odor problems during composting. The total nitrogen loss from bio-waste composting is estimated at 196,000 tonnes per year. However, approximately 62,000 tonnes (about 30%) of this nitrogen can be retained through in situ composting methods, such as adjusting the C/N ratio or adding physical, chemical, or microbial amendments (13).

Food waste composting often results in increased emissions of ammonia, volatile fatty acids, sulfides, and organosulfur compounds, all of which contribute to foul odors (14). Ammonia emissions not only contribute to air pollution but can also irritate the skin and mucous membranes of humans and livestock, posing health risks. Strategies to control nitrogen loss during composting can be divided into in situ and ex situ methods (15-16). Ex situ control involves capturing nitrogen-containing gases emitted from the compost heap through techniques such as neutralization, adsorption, or leaching, allowing nitrogen recovery and reuse. However, this approach does not improve the compost quality. In contrast, in situ control focuses on adjusting the compost material composition or optimizing parameters like pH, C/N ratio, adsorption materials, microbial communities, and chemically degradable carbonaceous substances. Certain additives have proven effective in reducing NH_3 and N_2O emissions during composting.

The effects of specific additives such as biochar, sawdust, zeolites, wood vinegar, apple waste, mature compost, vermiculite, bentonite, magnesium salts, salts phosphorus, and others have been reported in the literature. To reduce NH_3 emissions, it is recommended to add sawdust as an excipient due to its high C/N ratio, high hygroscopicity, and high reactive surface (17). In turn, the filler efficiency can be affected by the substrate-filler mixing ratio (18).

Use of oilseed cake, the by-product remaining after oil extraction, as manure influences several soil characteristics, such as electrical conductivity, buffering capacity, nutrient dynamics, and overall soil behaviour. These cakes serve as a valuable source of both organic matter and essential nutrients. Neem oil cake, for instance, contains about 5.2% nitrogen (N), 1.2% phosphorus (P), and 1.4% potassium (K). Its application helps to improve soil structure and enhances moisture retention. Additionally, when mixed with soil, neem cake can reduce soil alkalinity by producing organic acids (19).

The main objectives of the current study are to investigate the influence of neem cake in reducing nitrogen loss and enhancing the composting process during food waste composting.

2. Materials and methods

2.1. Collection and preparation of substrates

Synthetic food waste was prepared by mixing boiled rice, bread, cabbage, dahl in the ratio of 13:10:10:10:5 (w/w, wet weight basis) was used in the experiment and the size of the raw materials was reduced to 0.5 cm^3. The sawdust was purchased from a local sawmill in Tirunelveli, While the neem cake (NC) was purchased from a local fertilizer shop. The food waste and sawdust were mixed at 1:1 on a dry basis (FW+SD, 1.1, w/w dry basis – control), and to this mix, neem cake was added at 20% (FW+SD+NC, 1:1:0.2, w/w dry basis – neem cake treatment). 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 14 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 two days for the first two weeks and once a week thereafter until 42 days. 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.

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. 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 (20). Moisture content was determined gravimetrically and the dried material was used for the analysis of total organic carbon (TOC) using the modified Walkley-Black method (21) and total Kjeldahl nitrogen (TKN) as per the method of TMECC (2002).

2.3. Statistical analysis

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. Result and Discussion

3.1. Change in Temperature

Temperature plays a vital role in the efficiency and speed of the composting process, as it directly influences microbial activity. As microorganisms break down organic matter (OM), heat is generated, causing the compost temperature to rise. This increase is typically followed by a decline as microbial activity slows down (22). Maintaining the temperature within an optimal range is essential for promoting microbial growth and accelerating the composting process (23). Results indicate that the addition of neem cake at 20% to the composting mix (FW+SD+NC) resulted in significant significant increase of temperature when compared with control (FW+SW). The temperature reached thermophilic range within one day (Figure 1). The highest peak temperature of 63 °C was observed in FW+SD+NC while the peak temperature in FW+SD was 51 °C. Thermophilic temperatures prevailed for three weeks in all treatments. After three weeks, the temperature of both the treatments gradually declined toward the end of the composting process. The addition of neem cake to food waste significantly improved composting temperatures, indicating that neem cake enhances the composting process.

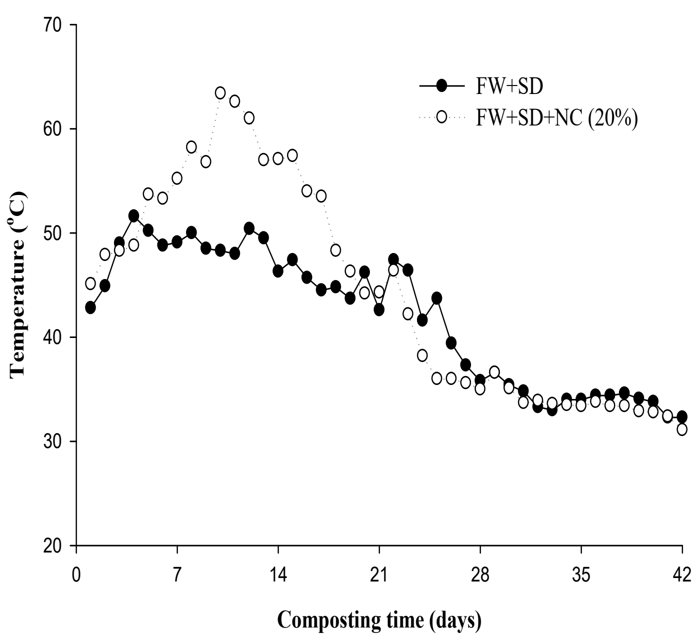

Figure 1.Changes of temperature during the composting of food waste with sawdust (FW+SD) and sawdust + neem cake (FW+SD+NC).

3.2. Change in pH

pH is a crucial factor that affects both microbial activity and the composition of microbial communities. In both the treatments, the pH decreased significantly during the first week and was in the acidic range, 6.2 in FW+SD and 6.5 in FW+SD+NC and the pH (Figure 2a). This initial decrease can be attributed to the accumulation of organic acids such as acetic, lactic, propionic, and butyric acids as well as other carboxylic compounds and volatile fatty acids (VFAs) (24-25). After the first week, the pH of both the treatments rose steadily throughout the composting process. This increase is primarily due to the release of ammonia from protein degradation in the raw materials and the breakdown of organic acids (26). By the end of composting, the pH of both the treatments reached 7.7 and 8.2 in FW+SD and FW+SD+NC, respectively.

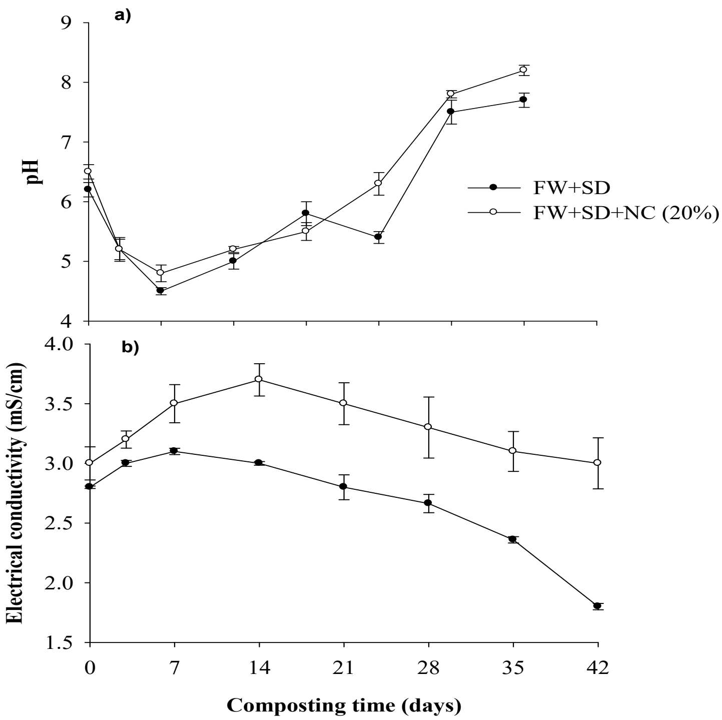

Figure 2 Changes of (a) pH and (b) electrical conductivity during the composting of food waste with sawdust (FW+SD) and sawdust+ neem cake (FW+SD+NC).

3.3. Changes in electrical conductivity (EC)

Electrical conductivity (EC) reflects the concentration of soluble salts in the aqueous extract of compost. Excessively high EC levels can have toxic effects on crops (27-28). In both the treatments, EC values increased significantly during the initial days of composting. This rise may be due to the rapid decomposition and mineralization of organic matter into smaller molecules, leading to an increase in ion concentration. After the first week, a declining trend in EC was observed in both treatments, which can be explained by the volatilization of organic acids and ammonium (NH_4^+), as well as the process of humification (29). By the end of the composting process, the EC values of both the treatments were below 3 mS/cm (1.8 mS/cm and 3.0 mS/cm in FW+SD and FW+SD+NC– treatments, respectively) and are within the recommended range of less than 4 mS/cm.

3.4. Changes in extractable ammonium (NH_4^+-N)

The concentration of extractable ammonium nitrogen (NH_4^+-N) increased during the first week of composting, reaching peak values on day 7 with 5,501 mg/kg in FW+SD treatment, and 5,919 mg/kg in FW+SD+NC. After one week, ammonium levels steadily declined throughout the composting process. The release of NH_4^+-N through ammonification coincided with the active degradation of organic matter during the thermophilic phase (Figure 3a). The final compost ammonium content for the two treatments was 544.49 mg/kg for FW+SD and 534.79 mg/kg for FW+SD+NC (20%). Komilis and Ham (30) reported that approximately 65% of the initial nitrogen in food waste can be lost through volatilization as NH_3. Similarly, Zhou et al. (18) found that high ammonia emissions were closely associated with elevated temperature and pH during food waste composting.

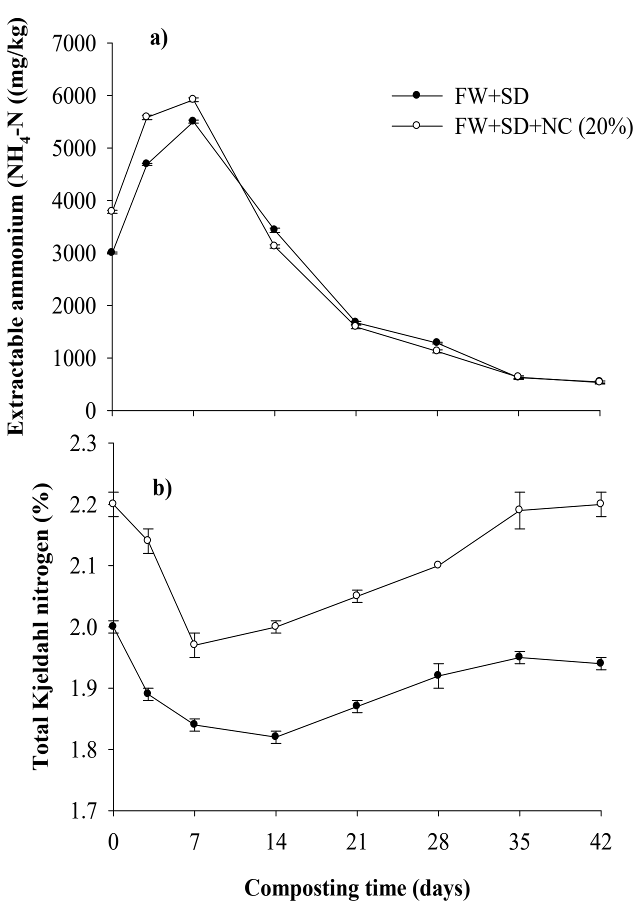

Figure 3. Changes of a) extractable ammonium and b) total Kjeldahl nitrogen during the composting of food waste with sawdust (FW+SD) and sawdust+ neem cake (FW+SD+NC).

3.5. Change in Total Kjeldahl nitrogen

Total Kjeldahl nitrogen (TKN) content of the composting treatments is presented in (Figure 3b). Initially, FW+SD+NC treatment had 2.2% TKN, while the FW+SD treatment had 2.0% TKN. During the first week, TKN content gradually decreased likely due to ammonia volatilization, as well as the relatively high temperature and pH conditions, which are unfavorable for nitrification and denitrification processes (31-32). After the first week, the TKN content in both the treatments gradually increased toward the end of the composting period. By the end, FW+SD+NC showed the highest nitrogen content (2.2%), while FW+SD had the lowest (1.94%). These results indicate that the addition of neem cake improves the nitrogen content of the compost compared to the control. The gradual increase in TKN content over time may be attributed to the degradation of nitrogen-rich organic compounds and a concentration effect resulting from the loss of compost mass (11,33).

3.6. Changes in total organic carbon

Initially, the total organic carbon (TOC) content was 50% for the FW+SD treatment and 51% in FW+SD+NC treatment (Figure 4a). TOC content gradually decreased from the beginning to the end of the composting process. This decline can be attributed to the microbial mineralization of organic carbon, which serves as an energy source for microorganisms (34). Additionally, carbon loss in the form of CO_2 during composting may have contributed to this trend (35). By the end of the composting process, the FW+SD treatment had the highest TOC content at 33.06 %, while the FW+SD+NC treatment had the lowest at 32.40 %. A similar trend was observed in previous studies also (36, 3).

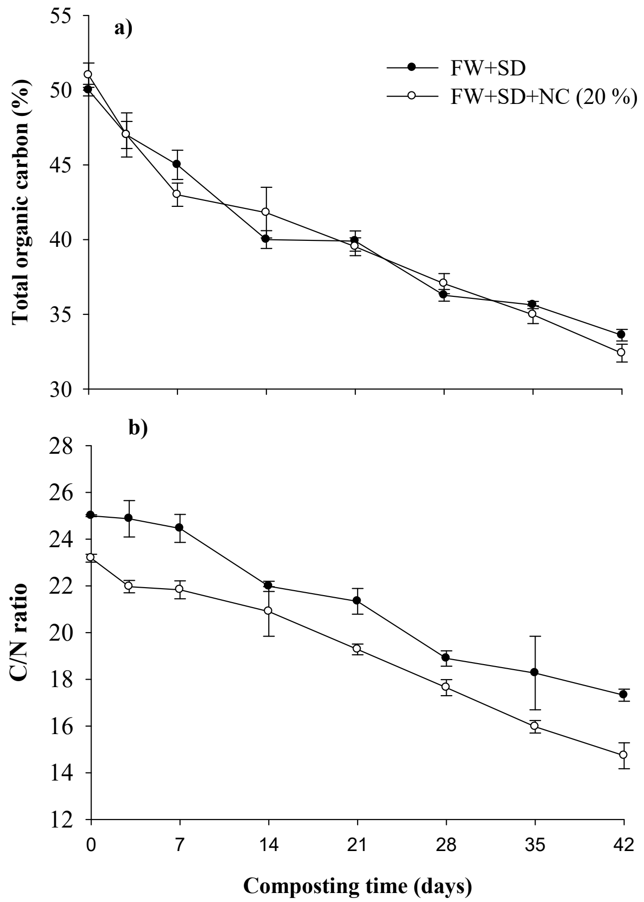

Figure 4. Change of a) total organic carbon and b) C/N ratio and during the composting of food waste with sawdust (FW+SD) and sawdust+ neem cake (FW+SD+NC).

3.7. Change in C/N ratio

The carbon/nitrogen (C/N) ratio is a key indicator of compost maturity. When the carbon content is excessively high, the decomposition rate slows down (37). At the start of composting, the initial C/N ratio was 24.8 in FW+SD and 21.96 in FW+SD+NC. Throughout the composting process, the C/N ratio of all treatments gradually decreased, primarily due to nitrogen loss as ammonia and carbon loss as CO_2 (Figure 4b). At the end of composting, the C/N ratio was highest in the FW+SD treatment (17.31) and lowest in the FW+SD+NC treatment (14.72). Karak et al., (38) also noted that the carbon content of raw materials declines due to CO_2 emissions, while total nitrogen content increases, resulting in a reduced C/N ratio. A mature compost typically has a C/N ratio of less than 20 as reported in several studies (39).

Table 1. Selected physicochemical properties of substrates and bulking agent

Parameters	Substrate	Bulking agents	
	Food waste	Sawdust	Neem cake
pH	4.48 ± 0.02	6.04 ± 0.07	5.01 ± 0.04
Electrical conductivity (mS/cm)	2.21 ± 0.05	1.68 ±0.08	5.16 ± 0.10
Moisture (%)	73.3 ±1.86	10 ±1.99	12.5 ± 0.98
Total organic carbon (%)	49.4 ± 0.78	54.4 ± 0.45	46.93 ± 0.81
Total Kjeldahl nitrogen (%)	2.19± 2.00	0.48 ± 0.11	2.5 ± 0.30
C/N ratio	19.36 ± 0.4	77.89 ± 0.14	16.60 ± 0.2

Table 2. Selected physicochemical properties of composts after 42 day of composting

Parameters	Treatments	
	FW+SD	FW+SD+NC
pH	7.70 ± 0.12	8.20 ± 0.08
Electrical conductivity (mS/cm)	1.8 ± 0.03	3.0 ± 0.21
Extractable ammonium (mg/kg)	544.5 ± 19.0	534.8 ± 30.0
Total organic carbon (%)	33.06 ± 0.39	32.4 ± 0.59

Total Kjeldahl nitrogen (%)	1.94 ± 0.14	2.20 ± 0.72
C:N ratio	17.31 ± 1.14	14.72 ± 0.56

CONCLUSION

This study investigated two composting treatments: Food Waste + Sawdust (FW+SD) 20% neem cake added to the food waste sawdust mix (FW+SD+NC) to revela the impact of neem cake addition on food waste composting. Addition of neem cake was found to improve the composting process and quality. While both treatments performed well, the neem cake treatment improved the nitrogen content in the composting mass and accelerated the composting process**.**The thermophilic phase prevailed for three weeks when neem cake was used as an additive. The physicochemical properties of the FW+SD and FW+SD+NC composts were within the recommended compost standard range. Overall, adding 20% neem cake proved to be one of the most effective strategies for improving the composting process, enhancing compost quality, and reducing nitrogen loss during food waste composting.

AUTHORS' CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work. All the authors are eligible to be an author as per the International Committee of Medical Journal Editors (ICMJE) requirements/guidelines

CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

ETHICAL APPROVALS

This overview does not involve experiments on animals or human subjects.

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