JEE Journal of Ecological Engineering

Journal of Ecological Engineering, 2025, 26(8), 120–131
https://doi.org/10.12911/22998993/203810
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Received: 2025.03.28
Accepted: 2025.05.26
Published: 2025.06.10

Optimized date palm waste composting: Accelerating maturity via C:N ratio and moisture adjustments using a rotary drum system

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ABSTRACT

Date palm waste (DPW) compost poses several challenges attributed to its lignocellulosic composition, which restricts biodegradability. This study used DPW, chicken litter (CkL), and water to achieve 60% moisture and 30 C:N ratio, following a compost recipe calculator. Using a rotary drum bioreactor over 20 days, the thermophilic phase lasted 12 days, achieving a biodegradation rate of 0.51. During this process, bulk density (BD), electrical conductivity (EC), and pH increased with 0.21 g/l, 1.84 dS/m, and 0.86, respectively. In contrast, free airspace (FAS) and moisture content (MC) decreased by 16.18% and 34.74%, respectively. Most nutrient content increased due to the mass loss. Ultimately, the C:N ratio dropped from 32.58 to 21.82, indicating maturity; however, the germination index was 57.56 ± 9.43%, suggesting immaturity and moderate phytotoxicity. Although adjustments to the C:N ratio promoted early maturation, further modifications or time are required for complete maturation of the compost within the 20-day timeframe.

Keywords: date palm waste composting, initial C:N ratio, rotary drum bioreactor, lignocellulosic waste.

INTRODUCTION

Date palm waste is one of the highest-carbon agricultural wastes. However, it has a relatively low nitrogen ratio compared to other waste types; leading to extended decomposition periods in natural environments (Habchi et al., 2022). Incineration, for example, whether regulated or unregulated, is a conventional technique regarded as a cost-effective strategy for these wastes management. This technique results in numerous environmental impacts, both direct and indirect, including the emission of greenhouse gases (Vico et al., 2018).

Composting is an economical and ecologically advantageous approach for managing organic waste and enhancing its value by yielding a mature, stabilized, sanitized, and deodorized product rich in humic substances, devoid of weeds and pathogens, easily stored, and marketable as an organic fertilizer or amendment (Abid et al., 2020; Varma and Kalamdhad, 2014; Vico et al., 2018). It is defined as the biological decay of the organic substance, which entails the decomposition and resynthesis, resulting in a stabilized end product that is free of pathogens and holds humic characteristics (Varma and Kalamdhad, 2014). However, the lignocellulosic composition of certain agricultural waste, including date palm waste, renders it very resistant to decomposition due to its chemical and structural characteristics (Jain et al., 2018b), leading to extended composting periods of 90 to 270 days to produce stable and mature compost using conventional methods (Bernal et al., 2009; Jain et al., 2018a). On the other hand, enclosed composting technologies, such as rotary drum bioreactors, have demonstrated efficacy in farm-scale composting or small projects, promoting the production of matured and stabilized compost within 20 days (Alkoaik et al., 2019; Bernal et al., 2009; Jain et al., 2018a; Varma and Kalamdhad, 2014). While research utilizing this system for date palm waste composting is scarce or nonexistent, a study examining the composting efficiency of date palm waste combined with poultry manure in a rotary drum bioreactor found that a 20-day period is insufficient for the production of fully mature compost (Ouali and Hiouani, 2024).

Moreover, critical factors such as the C:N ratio, oxygen levels, and moisture content of the initial mixture significantly influence composting rate and the quality of the final product (Calisti et al., 2020). Typically, the moisture content should be around 60% to promote microbial metabolism, nutrient dissolution and transport, and migration without anaerobic conditions (Alkoaik, 2019; Kim et al., 2015; Li et al., 2021). On the other hand, a C:N ratio of 25:1 to 30:1 can enhance the breakdown of the mixture and boost product maturation (Calisti et al., 2020). Additionally, it is advisable to implement mechanical frequency turning every 24 hours to enhance oxygen flow and mixing (Kalamdhad and Kazmi, 2009a; Chowdhury et al., 2013).

This study's main objective was to assess the possibility of composting date palm waste over a 20-day period by adjusting the moisture content and C:N ratio to 60% and 30, respectively. This was accomplished by concentrating on the assessment of thermal properties, physico-chemical parameters, and end product quality over a 20-day period.

MATERIALS AND METHODS

Feedstock materials

This study utilizes date palm waste (DPW) as the principal carbon source. DPM was collected from the region of Biskra in Algeria during the pruning season and, then, crushed at a local composting facility to a size of 3–10 cm. Besides, Chicken litter (CkL) was employed as a nitrogen source. We collected it from a farm in the region of Bou Saada, where the experiment took place. The collected feedstocks' characteristics are reported in Table 1.

Experimental setup

Compost dynamics were investigated using three identical rotating drum bioreactors, each with a capacity of 628 L capacity (Ouali and Hiouani, 2024). The bioreactor is made up of a 0.8 m diameter by 1.25 m long drum of 3 mm thick, with a galvanized metal that is fixed on four rubber rollers and turned by hand. Longitudinal angles (40 mm) are welded within the drum to guarantee enough mixing and aeration, and two holes are drilled on top to drain extra water. After 4 daily rotations, both half-side doors are opened to maintain aerobic conditions.

Compost recipe preparation

The mixture is formulated based on the compost recipe calculator outcomes (Ouali, 2024) to achieve a moisture content of 60%, a C:N ratio of 30, and a final weight of 130 kg (Figure 1). This weight represents 50% of the total container volume (i.e. the drum) in order to control the

Table 1. Initial feedstock characteristics and compost recipe

	DPW	CkL	Water
Physico-chemical characteristics			
pH	5.53 ± 0.08	7.06 ± 0.07	-
EC (dS/m)	7.64 ± 0.02	5.42 ± 0.01	-
TOC (%)	50.29 ± 1.6	32.75 ± 3.2	0.00033 ± 0.05
TKN (%)	0.87± 0.2	2.01± 0.2	0.0056 ± 0.03
MC (%)	1.16± 0.7	5.75± 1.4	100
C/N ratio			0.06
Compost recipe			
Weights (kg)	28.02	25.81	76.17
Total weight (kg)			130
DPW: Date palm waste; CkL: Chicken litter; EC: Electrical conductivity; TOC: Total organic carbon; TKN: Total Kjeldahl nitrogen; MC: Moisture content.			

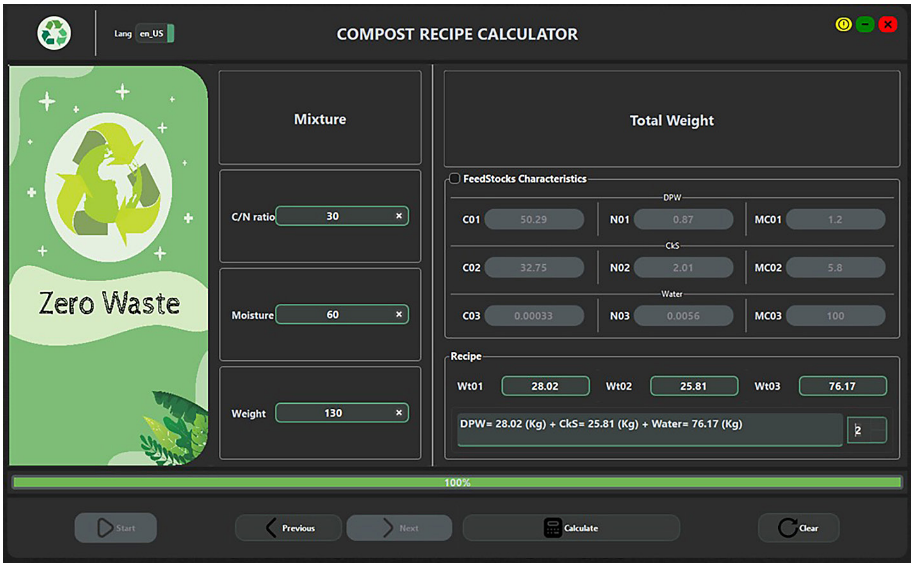

Figure 1. Compost recipe calculator outcomes (Ouali, 2024)

temperature (Muktadirul Bari Chowdhury et al., 2013); considering the ambient temperature as 39 °C. The compost recipe is shown in Table 1.

Sampling and parameter analysis

Every two days (days 0–20) after rotation, 500 g triplicate samples were collected from the middle and ends of each composter and merged to create one composite sample per reactor. Samples were split into two equal parts; one was stored at 4 °C for biological analysis, and the other was over-dried at 105 °C for 24 hours. Then, they were mechanically crushed and sieved using a 0.2 mm sieve to produce a uniform powder for chemical analysis.

In order to identify composting phases over 20 days, a DHT22 and DS18B20 sensor measured the composter's ambient, middle, and end temperatures every 6 hours (Ouali and Hiouani, 2024).

The moisture content (MC) of a fresh sample was determined by over-drying it at 105 °C for 24 hours and then estimated using Equation 1 (Jain et al., 2020).

$$MC\ (\%) = \frac{Wf - Ws}{Wf} \times 100 \tag{1}$$

A 1:10 extract (compost: water) was utilized to assess the pH and electrical conductivity values after 2 h agitating (Jain et al., 2018a; Singh and Kalamdhad, 2019).

At 550 °C for two hours, the LOI (Loss on Ignition) method was employed to measure the organic substance (OS) and total organic carbon (TOC), which were then calculated using Equations 2, and 3 respectively (Rynk et al., 2022). The calculation of organic substance biodegradability was performed using the initial and final organic substance contents, as outlined in the Equation 4 (Nayak & Kalamdhad, 2015).

$$OS(\%) = 100 - \frac{Wi - Wf}{Wi} \tag{2}$$

$$TOC\ (\%) = \frac{OS}{1.8} \tag{3}$$

$$k = \frac{(OSi\ - OSf) \times 100}{OSf \times (100\ - OSi)} \tag{4}$$

The Kjeldahl method was used to estimate total nitrogen (ISO 5663, 1984). First, a 0.2 g sample was digested with concentrated 20 mL sulfuric acid (H_2SO_4) and a 1g catalyst mixture (20% $CuSO_4$ + 80% K_2SO_4) at 400 °C until a colorless solution forms. After cooling and dilution to 100 mL, a 25 mL aliquot is distilled with 6N sodium hydroxide (NaOH) and 2% boric acid (H_3BO_3). The nitrogen content (TKN) is then measured by titrating with 0.1 N sulfuric acid (H_2SO_4) using Tashiro's indicator, and calculated using Equation 5.

$$TKN(\%) = \frac{(Vs - Vb) \times Vt \times 0.1 \times 1.4}{Va \times\ P} \tag{5}$$

To determine the nutrient content, X-ray fluorescence analysis was performed (McWhirt et al., 2012). The sample underwent ignition at 950 °C for 1 hour, homogenized with dilithium tetraborate in a 3:7 mass ratio, and fused into glass disk using an electric fusion apparatus for X-ray fluorescence analysis in the cement mode (ISO 29581-2, 2010). Concentrations as oxide percentages on an as-received basis (XO) are adjusted for loss on ignition (LOI) utilising Equation 6.

$$XO(\%) = XO\ ignited \times \frac{100 - LOI}{100} \quad (6)$$

The germination index (GI) was evaluated following the steps outlined by Ouali and Hiouani, (2024), wherein a 1:10 extract of compost and deionised water was prepared, agitated for 40 minutes at room temperature, and centrifuged at 6000 rpm for 15 minutes. Following this, a 9 mm petri dish containing filter paper was filled with 10 ml of the extract and 10 radish seeds. Distilled water was used as a control. The GI was calculated by measuring the germination rate (RSG) and the relative radicle length (RRG), over 48 hours of incubation at 25 °C in obscurity, according to Equations 7–9.

$$RSG = \frac{NSs}{NSc} \quad (7)$$

where: *NSs* – number of germinated seeds (sample), *NSc* – number of germinated seeds (control)

$$RRG = \frac{LSs}{LSc} \quad (8)$$

where: *LSs* – total radicle lenght of germinated seeds (sample), *LSc* – total radicle lenght of germinated seeds (control)

$$GI\ (\%) = RSG \times RRG \times 100 \quad (9)$$

The wet bulk density (BD) and the free air space (FAS) were both measured on-site as described by Rynk et al., (2022). A 1-liter metal container was used to assess wet bulk density by sequentially filling it to one-third, two-thirds, and full capacity while tapping to reduce pores. The bulk density was calculated using Equation 10; For the FAS, water was then added to the container until the surface was fully submerged, facilitating the dissipation of air bubbles before the application of Equation 11.

$$BD = \frac{Mw}{V} \quad (10)$$

$$FAS\ (\%) = \frac{W_f - W_i}{V} \quad (11)$$

where: *Mw* is the mass of the compost sample (g), and *V* is the container's volume (mL). W_f is the weight of the container after adding water (g), and W_i is the weight before adding water (g).

RESULT AND DISCUSSION

Temperature

The variation in temperature serves as a key sign of compost maturation, being the initial indicator of microbial activity during the composting process (Habchi et al., 2022). It affects reactions rate and contributes to eliminating the pathogenic microbes and plant seeds during composting and, hence, maintaining the process's sanitary efficacy (Jain et al., 2019). This study monitored the temperature profile of a rotary drum composting system consisting of date palm waste and Chicken litter over a 20-day period (Figure 2). The temperature profile shows the progress of the composting process, which can be divided into two distinct stages: the bio-oxidation (from day 0 to day 16) and the maturation (from day 17 to day 20).

The process initiates with a brief mesophilic phase of a few hours, during which the loaded mixture's microorganisms intensively utilize readily biodegradable compounds that are abundant, generating heat in the process (Li et al., 2021). This results in a rapid temperature rise, advancing towards the thermophilic range of (46.28–64.9 °C) within hours. The thermophilic phase recorded a peak value of 64.95 ± 1.4 °C by day 3 and lasted for 12 days, achieving the optimal temperature range required for pathogen elimination and the decomposition of more resistant organic compounds, including lignin and cellulose, resulting in a secure and stable end product (Jain et al., 2018a; Vico et al., 2018). In rotary drum composting, the optimum temperature range during the thermophilic phase should be 45 °C to 65 °C for a minimum duration of three days (Jain et al., 2020; Varma and Kalamdhad, 2014, 2015). Nevertheless, in comparison to other rotary drum composting systems that utilize various lignocellulosic wastes, such as H.verticillata (Kalamdhad and Kazmi, 2008), aquatic waste *E. crassipes* (Jain et al., 2018b), and date palm waste (Ouali and Hiouani, 2024), the maximum thermophilic duration for these is typically 9 days; thus, a thermophilic period of 12 days is considered relatively long.

This long duration is caused by different chemical and physical variables: (1) the bioavailability of the feedstocks, where the lignocellulosic properties of DPW and the substantial carbon content of the CkL influenced the rate of microbial activity (Jain et al., 2018a; Jain and Kalamdhad, 2019;

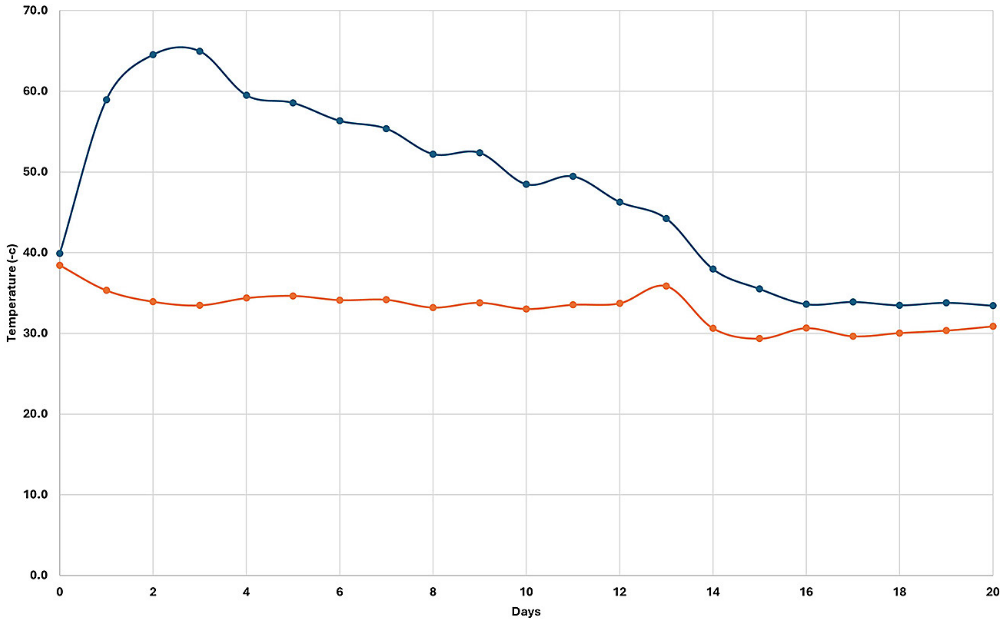

Figure 2. Temperature variation during the composting process

Kalamdhad and Kazmi, 2009b; Rich et al., 2018; Singh and Kalamdhad, 2013; Varma et al., 2017); (2) the environmental conditions (Epstein, 2011; Habchi et al., 2022; Kalamdhad et al., 2009), notably the high ambient temperature, which may have impeded heat dispersion (33.9 °C); (3) the significant insulation capacity of date palm due to its low thermal conductivity (0.496–0.083 W/mK)(EL-Mously et al., 2023), and (4) the aeration rate and turning frequency (Ghanney et al., 2021; Rich et al., 2018). As the readily biodegradable organic substance is depleted and only the molecules that resist degradation remain, the cooling phases (Mesophilic Phase II) occur (day 13 to 16), leading to a decrease in the activity of thermophilic microorganisms (Habchi et al., 2022; Jain et al., 2018a). This means the launch of the maturation stage by day 17. This phase is characterized by the formation of humus as a result of the polymerization of organic compounds, which combine to create a more stable compound (Habchi et al., 2022).

Moisture content (MC)

Moisture content plays a vital role throughout the entire composting process, influencing its various factors (Richard et al., 2002). In addition to dissolving and providing soluble nutrients for microbial metabolism, it promotes chemical and biological interactions as well as microbial mobility (Li et al., 2021; Li et al., 2022). Thus, the absence of sufficient moisture inhibits all significant processes (Oshins et al., 2022). As a result, maintaining an appropriate moisture content throughout the composting process is essential (Jain et al., 2018a; Kalamdhad and Kazmi, 2009a). According to Kim et al., (2015), The recommended MC ranges from 40% to 60%. In this regard, the higher moisture can create anaerobic conditions by saturating pore spaces with water, while moisture below 40% can hinder the microbial activity and potentially cease the process. Moreover, alongside with the C:N ratio and oxygen availability, the initial MC is a crucial factor in determining the success of composting and the quality of the final product (Calisti et al., 2020), with most research recommending it around 60% (Alkoaik, 2019). Using the weight loss calculation, the initial moisture content seems to be around 58.1 ± 0.6 %, which is approximately equal to the targeted amount of 60%. Generally, the variations in moisture content correspond to temperature, aeration, and microbial activity (Antil et al., 2014; Shen et al., 2015). On the one hand, the microbial activity can enhance moisture content through the release of metabolic water as the organic substance decomposes. On the other hand, the increased aeration and high temperatures generated by the microbial activity might improve evaporation rates, possibly resulting in significant water loss (Shen et al., 2015). In fact, the high temperature and airflow developed during composting evaporate substantially more water, leading to the dehydration of the compost (Richard et al., 2002). This loss in moisture content serves as an indicator of the decomposition rate, as the temperature produced during decomposition conducts vaporization (Kalamdhad et al., 2009). Consequently, due to the high ambient and generated temperature, the moisture content rapidly decreased, reaching a value of 33.52 ± 2.15% by the 12th day of the process (Figure 3). As the process progressed, the moisture steadily decreased, eventually ending at a value of 23.36 ± 0.7 %. It is important to note that a leak occurred during the initial days of the operation, which may have further contributed to the reduction of moisture during the process.

Bulk density (BD) and free air space (FAS)

Both bulk density (BD) and free air space (FAS) are critical in the composting process, as they directly or indirectly impact essential variables, such as the mechanical properties (strength, porosity, and compressibility) and the amount and flow of air within the decomposition matrix, which subsequently influences the microbial kinetics, organic substance oxidation, and the transport of heat and mass (Jain et al., 2018a, 2019; Jain and Kalamdhad, 2019). The initial wet BD values were 0.26 ± 0.8 g/l, with a corresponding initial FAS of 74.51 ± 4.1% (Figure 4), which fell within the acceptable range (> 30%) (Jain et al., 2019). Following a 20-day composting period, the wet BD demonstrated a consistent upward trend, with initial values shifting to 0.47 ± 0.7 g/l. Conversely, due to an inverse correlation between FAS and BD (Jain et al., 2019; Jain and Kalamdhad, 2019), FAS decreased to 58.33 ± 1.3%. The fluctuations in bulk density (BD) and free air space (FAS) during the composting process result from the breakdown of organic matter (Zhang and Sun, 2014), which reduces particle size and increases micropores (Azim et al., 2018; Jain et al., 2019). This results in a decrease in compost volume from 50% to 35% (personal observation).

pH and electrical conductivity (EC)

The pH is an essential factor that affects the majority of enzyme-catalyzed metabolic processes, which in turn influence the nutrient bioavailability and the mineral solubility for microorganisms (Habchi et al., 2022). The ideal range for bacterial and fungal growth is 6.0–7.5 and 5.5–8.0, respectively (Varma et al., 2017). Generally, a neutral pH is considered optimal for the composting process (Jain et al., 2019). During the initial mesophilic phase, the pH rapidly increased from 6.32 ± 0.07 to a 6.76 ± 0.07 by day 8 due to the adequate aeration through regular turning (Singh and Kalamdhad, 2013), which allowed complete oxidation and CO_2 removal from the compost regularly, preventing the anaerobic conditions and the formation of acidic compounds (Oshins et al., 2022). Additionally, the high

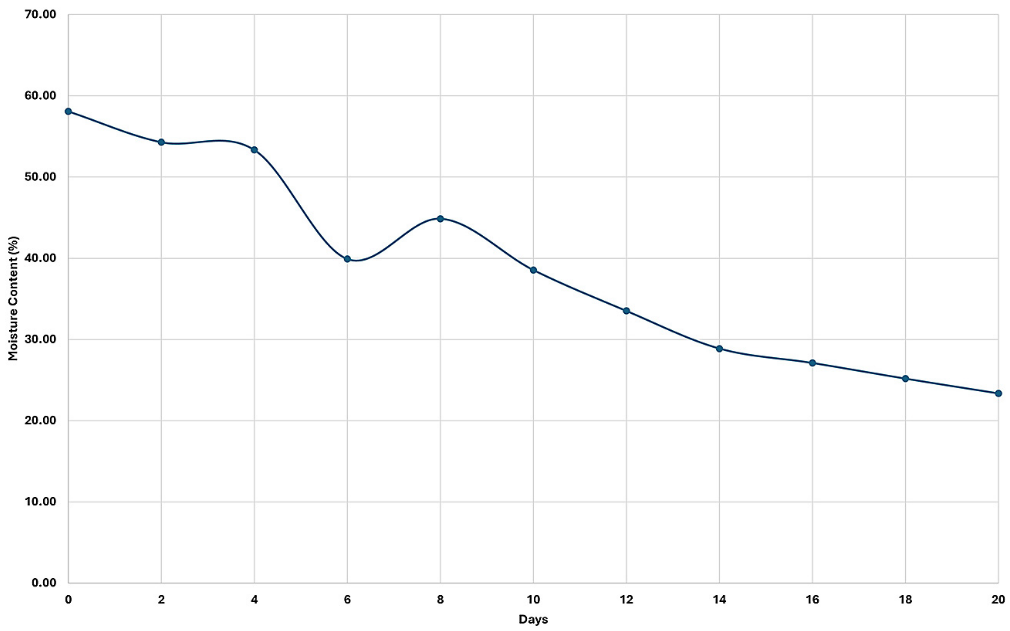

Figure 3. Moisture Content variation during the composting process

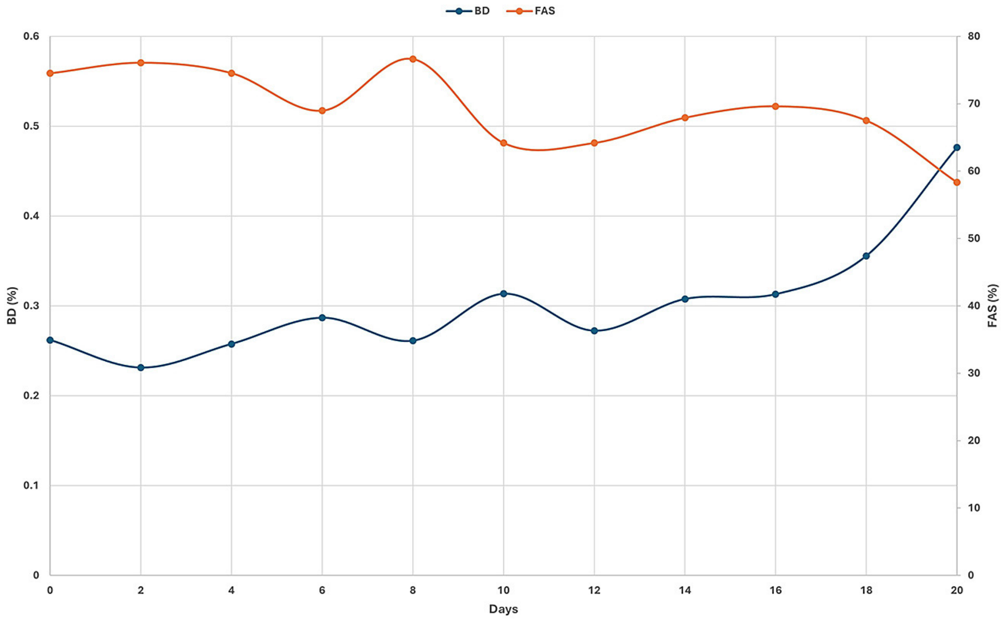

Figure 4. The variation in wet Bulk density (BD) and Free air space (FAS) during the composting process

fungal activity at acidic conditions (acidophilic) contributed to the bio-oxidation of any existing organic acids (Muktadirul Bari Chowdhury et al., 2013; Varma et al., 2017). Subsequently, the pH continues to increase as a result of the high temperature, which stimulates the ammonification of the nitrogenous organic substance and produces ammoniacal nitrogen that interacts with hydrogen ions (H+) (Oshins et al., 2022; Rich et al., 2018); ultimately reaching a maximum value of 7.68 ± 0.02. A later decrease in pH level occurred and ended in a final value of 7.18 ± 0.02. This decline was attributed to the volatilization of ammoniacal nitrogen at high pH levels (above 7.5) and the release of H+ ions owing to the microbial nitrification process carried out by nitrifying bacteria (Kalamdhad and Kazmi, 2009b). The final product has a suitable pH that falls within the acceptable range of 6.0–8.5 for agricultural compost application (Vico et al., 2018).

The electrical conductivity (EC) evaluates the concentration of dissolved salts in compost, which indicates its salinity and suitability for plant growth (Antil et al., 2014). Figure 5 shows a changing pattern in EC similar to pH. The EC increased significantly from an initial value of 5.80 ± 0.01 dS/m to attain a peak value of 7.78 ± 0.06 dS/m on the 14th day. This increase can be attributed to the release of mineral salts and the ammonium ions through the intensive bio decomposition of the organic substance (Kalamdhad and Kazmi, 2009b; Singh and Kalamdhad, 2013). Thereafter, it continually declined due to the volatilization of ammonia and the release of ammonium ions in ammonia form, accompanied by the reduction of other basic groups and the precipitation of mineral salts (Habchi et al., 2022; Kalamdhad and Kazmi, 2009b), eventually reaching 7.64 ± 0.02 dS/m by the end of the composting process. The maximum permissible limit of EC for soil application is 4 dS/m (Jain et al., 2019; Muktadirul Bari Chowdhury et al., 2013). However, the study shows that the EC exceeds this permissible level since the beginning of the process, primarily due to the feedstocks utilized (Table 1). Numerous date palm composting systems utilizing palm leaves with sewage or agri-food waste (Vico et al., 2018) and poultry manure (Ouali and Hiouani, 2024) show a similarly substantial EC, which may limit its agricultural use. Nonetheless, certain studies consider compost with an EC surpassing 4 dS/m suitable for agricultural soil (Kauser et al., 2020); however, it is recommended to lower the EC by either blending high-EC compost with components of lower EC (Rynk et al., 2022) or soaking the feedstocks in water prior to initiating the composting process (Abid et al., 2020).

Organic substance decomposition and C/N ratio

Composting fundamentally consists of the microbial decomposition of the organic substance into various outcomes, including CO_2, biomass, heat energy, and a humus-like substance

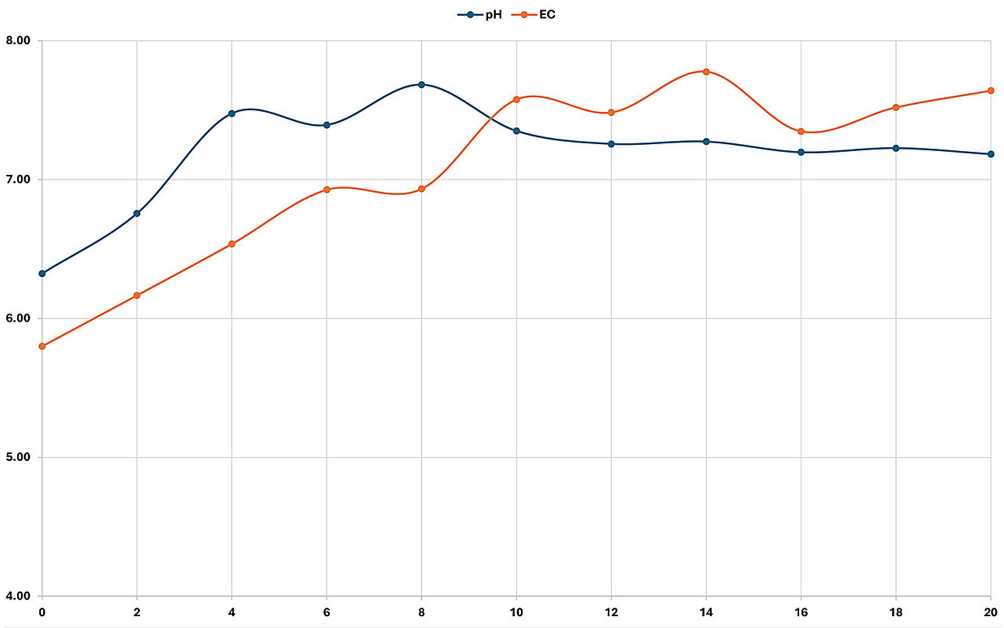

Figure 5. the pH and Electrical Conductivity (EC) variation during the composting process

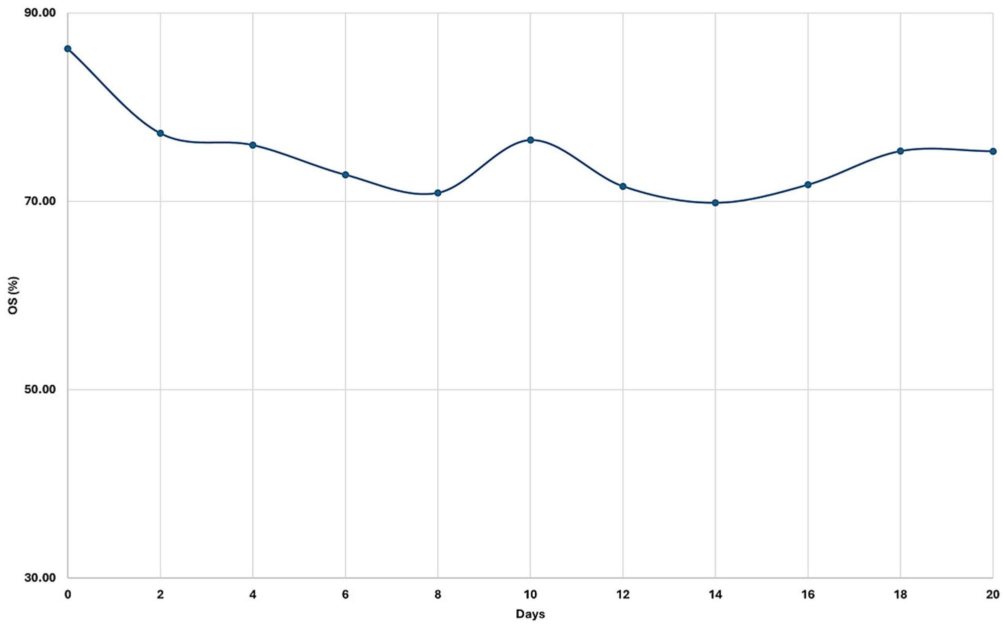

Figure 6. Organic substance evolution (%) during the composting process

(Singh and Kalamdhad, 2019; Xie et al., 2023), transforming unstable organic materials into more stable forms (humus) while modifying the quality and moisture content of the substances involved (Xie et al., 2023). Soon after the initiation of the process, a significant decrease in the organic substance occurred throughout the composting process (Figure 6), dropping from an initial value of 86.22 ± 0.6 to 75.32 ± 1.31% by the end of the process, resulting in a biodegradability of 0.51. The majority of this loss occurred during the initial phases (11.88%), where the OS decreases from the initial value to 75.97± 2.34%, mainly owing to the prioritization and intensive mineralization of readily biodegradable compounds as energy sources (Muktadirul Bari Chowdhury et al., 2013). Once the easily biodegradable compounds are exhausted, the decomposers become less active and shift to microorganism populations that possess a higher capacity for metabolizing recalcitrant components such as cellulose, hemicelluloses, and lignin (Bernal et al., 2009; Oshins et al., 2022) at a slow rate of 0.86% (Table 2). The significant

Table 2. Organic substance (OS) loss, biodegradability, TOC, TKN and C:N ratio at days 0, 4 and 20

Parameters	Units	Days		
		0	4	20
OS Loss	(%)	-	11.88	0.86
Biodegradability	-	-	-	0.51
TOC	(%)	46.79 ± 0.6	42.21 ± 2.34	41.84 ± 0.6
TKN	(%)	1.47 ± 0.03	1.53 ± 0.02	1.92 ± 0.02
C:N ratio	-	32.58	27.66	21.82

OS: Organic substance; TOC: Total organic carbon; TKN: Total Kjeldahl nitrogen.

biodegradation (K = 0.51) observed in this study is mainly attributed to the adjusted C:N ratio. Nayak and Kalamdhad (2015) found that a ratio of 30 achieved the highest biodegradation, followed by 25, while Ouali and Hiouani (2024) study showed a lower rate of 0.46 at a C:N ratio of 46.3. Additionally, the decomposition rate of composted materials is influenced by their nature, particularly the lignocellulosic and fibre content, as well as the particle size; furthermore, microbial activity and the thermophilic phase duration involving thermophilic fungi, along with the overall composting system and its management practices (Abid et al., 2020; Bernal et al., 2009; Muktadirul Bari Chowdhury et al., 2013; Varma et al., 2017).

Carbon acts as the fundamental base for almost all organic compounds, whereas Nitrogen plays a vital role in protein synthesis and cell growth. Life forms generally show a weight ratio of 10 to 15 carbon units for every nitrogen unit. However, they require approximately 25 times more carbon than nitrogen for consumption, due to carbon loss during respiration (Oshins et al., 2022). This is referred to as the C:N ratio, and can be used to measure the decomposition rate and the quality of compost (F. Alkoaik et al., 2019). Low C:N ratios result in an excess of N per decomposable C, which causes the excess in the organic N to be lost by ammonia volatilization or leaching from the compost mass. In contrast, high C:N ratios extend the composting process since there is an excess of biodegradable substrate for the microbes to consume (Chowdhury et al., 2013). Therefore, the initial C:N ratio should be between 20 to 30. The mixture's carbon and nitrogen contents at different phases of the composting process (Days 0, 4, and 20) are shown in Table 2. On day 0, the initial mixture had a C:N ratio of 32.58, which was nearly aligned with the targeted ratio of 30. The C:N ratio steadily dropped as the process progressed, reaching 27.66 on day four and 21.82 on day twenty. The main reason contributing to this reduction was an increased nitrogen

Table 3. Nutrient contents on days 0, 4 and 20, and Germination Index on day 20

Days	Compacts	0	4	20
Nutrient content	SiO_2	20.78	11.99	13.32
	Al_2O_3	4.28	2.65	2.96
	Fe_2O_3	1.63	0.96	1.11
	CaO	4.96	2.84	3.25
	MgO	1.6	0.91	1.56
	K_2O	2.05	1.3	1.58
	Na_2O	0.39	0.26	0.13
	P_2O_5	1.17	0.69	0.89
	TiO_2	0.19	0.11	0.13
	Cr_2O_3	0.012	0.009	0.008
	Mn_2O_3	0.044	0.027	0.031
	ZnO	0.006	0.004	0.004
	SrO	0.027	0.015	0.019
GI				57.56 ± 9.43%

concentration resulting from the nitrification process (Q. Wang et al., 2016), and a decrease in carbon as CO_2 (Kauser et al., 2020) (Table 2). A mature compost should have a C:N ratio of 20 or less in order to improve soil structure and prevent nitrogen loss (Kalamdhad and Kazmi 2009a). Furthermore, before taking maturity and stability into account, a compost must have a C:N ratio of less than, or equal to 25 in order to be acceptable (CCQC, 2001). As a consequence, the final product in this study may be regarded as an initially mature product (< 25), which is substantially lower than the findings of Ouali and Hiouani, (2024), where the C:N ratio reached a final ratio of 32.73 within the 20-day period.

Final product

The analysis of the nutritional properties and the germination index has been conducted and presented in Table 3. The contents of all nutrients show a significant decrease in the initial phase (Days 0 and 4), mostly due to the microbial consumption of the mineralized nutrients (Kalamdhad and Kazmi, 2009a) and/or the occurrence of MC leakage. Following day 4, the concentrations of most nutrients increase, with the exception of certain elements (Na_2O, Cr_2O_3, ZnO), due to the mass loss associated with the mineralization of the organic components, CO_2 release, and water evaporation (Kalamdhad and Kazmi, 2009b; Kauser et al., 2020). The concentration of macronutrients in compost is generally lower than that in the synthetic fertilizers. Therefore, it is frequently applied at higher rates (Varma and Kalamdhad, 2015).

The germination index (GI) serves as an essential metric for evaluating the phytotoxicity and maturity of compost (Huang et al., 2016; Wang et al., 2021). For the compost to be fully mature, the GI must exceed 80%. However, Vico et al., (2018) asserts that a GI of 60 is sufficient for maturity. Thus, the final product of this study can be regarded as immature (GI = 57.56 ± 9.43%), mainly due to the DPW high EC of 7.64 ± 0.02 dS/m (Table 1). Nevertheless, the GI in this study exceeded that observed by Ouali and Hiouani, (2024) (GI = 54.3 ± 7.5%).

With the exception of high EC, the majority of variables fell within, or near, the acceptable range for agricultural application, including the germination index, which approached 60%.

CONCLUSIONS

Adjusting the initial C:N ratio to 30 and the moisture content to 60% significantly improved the efficiency of the date palm waste rotary drum composting process. This adjustment enabled the maintenance of optimal conditions for 12 days and encouraged the activity of thermophilic fungi, which enhanced the bio-decomposition process. However, despite these improvements, the elevated EC negatively impacted the germination index of the end-product, suggesting that it was not fully mature after a period of 20 days. This point to a need for either extended maturation time or blending with stable materials of lower EC prior to soil application.

To achieve a fully mature product within the 20-day time frame, several adjustments could be made. These may include reducing particle size while maintaining porosity, ensuring uniform moisture throughout the process, and limiting moisture and temperature loss by utilizing alternative aeration techniques instead of keeping doors open during processing. Additionally, pre-soaking date palm waste in water could help reduce electrical conductivity, and/or a nitrogen source material with lower electrical conductivity could be used.

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