ORIGINAL RESEARCH ARTICLE

The Dynamics of greenhouse gas emission during food waste composting

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Abstract

Composting is an environmentally friendly method of managing organic waste, but it has a substantial downside in the form of greenhouse gases (GHGs) emissions such as: carbon monoxide (CO), nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2). Organic waste makes up a total of 67% of total waste released daily in Kenya, while cow dung is a readily available resource. The aim of this study was to assess the dynamics of the emissions of GHGs specifically CH_4 and CO_2 from organic waste in an in-vessel aerated composting system. The feedstock was a mixture of cow dung and food waste materials and was composted for a total of sixty days. Five treatments: T0 = 100% cow dung (CD), T1 = 75% CD + 25% food waste (FW), T2 = 50% CD + 50% FW, T3 = 25% CD + 75% FW and T4 = 100% FW + 0% CD were set up in a complete randomized design (CRD) layout. GHGs emissions were collected using a plastic gas pack from each treatment weekly from the 2nd week to the 8th week of the composting process and measured using gas chromatography methods. The GHGs emission gradually reduced as composting progressed. The average carbon dioxide equivalent (CO_2e) for the entire period from treatments T0, T1 and T2 were 1.282, 4.322 and 2.596 kgCO_2e/ton respectively; these were higher compared to, T3: 0.380 and T4: 0.534 kgCO_2e/ton. ANOVA analysis indicated that there were significant differences in GHGs emission between treatments, $p<0.05$. Tukey's HSD affirmed that treatments T0, T1 and T2 were significantly different from each other and from treatments T3 and T4. Treatments T3 and T4 were not significantly different from each other. The C:N ratio at end of the decomposition process ranged between 26:9 and 22:9, which is higher compared to the recommended 15:1 for agricultural production. Treatment T3 emitted the least GHGs to the environment, thus, a combination ratio of 25% CD + 75% FW is recommended which is within EPA recommended range of 0.1 to 0.5 kgCO_2e/ton of composted wet waste.

Keywords: Composting, GHG, Cow Dung, Food Waste

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1.0 Introduction

Rapid growth in the global population leads to increased consumption and generation of waste that ends up in dumpsites and landfills, which are the most common ways to dispose of waste throughout the world (Hasan *et al.*, 2021). According to the Ministry of Environment and Forestry (2021), Kenya generates 22,000 tonnes of waste daily, 67% being organic waste whose makeup is majorly household waste of which, only 10% is recycled. Municipal solid waste's life-cycle activities and manure slurries are a large source of greenhouse gas emissions (GHGs) such as carbon monoxide (CO), nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2) (Owen *et al.*, 2015; Vergara *et al.*, 2019). Approximately 5% of greenhouse gas (GHG) emissions worldwide are attributed to landfills, which contributes to anthropogenic climate change. The main source of greenhouse gas emissions, contributing 1% to 2% of total emissions, is landfill-produced CH_4 (Bogner *et al.*, 2011). The conversion of organic wastes into organic amendments by composting is an appropriate food waste valuation approach (Hodge *et al.*, 2016). The use of compost on farms can enhance soil organic carbon (SOC) stores, balance out the need for artificial fertilizers, and improve soil structure. Although there is ambiguity about the emissions from the composting process, diverting organic waste to composting may reduce greenhouse gas emissions (Bremaghani, 2024). Waste management and soil nutrient recycling are achieved by composting, which is the aerobic breakdown of organic materials mediated by microorganisms (Vergara *et al.*, 2019).

A major concern with food waste (FW) composting has to do with ammonia (NH_4) and greenhouse gases (GHGs), such nitrous oxide (N_2O) and methane (CH_4), which can contribute to stratospheric ozone depletion and global warming (Bogner *et al.*, 2008). The global warming potential (GWP) of N_2O and CH_4 is 265 and 28, respectively, times that of CO_2, (Intergovernmental Panel on Climate Change (IPCC), 2014)

To make well-informed waste management decisions, it is crucial to determine the environmental costs and advantages associated with treatment procedures that may be applied to handle food waste. The goal of this study was to assess the dynamics of GHGs emission from cow dung and food waste management strategies in an in vessel aerated composting system.

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2.0 Materials and methods

The study was conducted in a greenhouse farm at the Laboratory of Land and Water Use Engineering in the department of Agricultural Engineering, Tokyo University of Agriculture, Setagaya Campus. FW was bought from a local store in Kyodo station, Setagaya ward, Tokyo City, Japan. The FW was dis-aggregated into fibre or protein rich. Cabbage, broccoli, spinach, aubergine were classified as fibre rich food waste while peas, broad beans, chicken egg shells, dried fish were categorized as protein rich food waste. The FW were crushed into small pieces using a blender. Crushing food waste increases the surface for microorganisms to decompose food waste. Cow dung was sourced from Isonuma Milk Farm ranch located in Kobiki-machi, Hachioji, on the west side of Tokyo. The protein and fibre rich FW were mixed in a ratio of 1:1. The mixture was then combined with cow dung in varying percentages to yield treatments that comprised of: T0 = 100% cow dung (CD) + 0%, T1 = 75% CD + 25% food waste (FW), T2 = 50% CD + 50% FW, T3 = 25% CD + 75% FW and T4 = 100% FW + 0% CD. The pots in all treatments were labelled and placed in random spots set up in a complete randomized design (CRD) layout as shown in figure 1. The bulk density of samples measured in T0- T4 were 1.395, 1.358, 1.322, 1.305 and 1.305g/cm^3 respectively. Moisture content was measured using a portable Daiki sensor. According to Sullivan et al., (2018), the optimum moisture content for composting ranges from 40-60%, this was maintained by daily of sprinkling water. Temperature was measured daily using a portable Tanita digital thermometer. GHGs emitted were collected using the gas chamber method starting from the second week from the start of the experiment and then weekly from week 3-8. Gas collection entailed covering the composting pot with a perforated plastic lid and then sealing it using Cemedine gap putty plaster hence allowing gas collection via a plastic tube to be collected in a plastic gas pack as shown in figure 2. The compost turning process was conducted once in two days using a hand shovel.

The gas was collected for 24 hours, there after it was transported to the laboratory and stored in a fridge at temperature of 4^{o}C. Before analysis of the GHGs collected, it was ensured that the gases in the pack were well mixed. This was followed by setting the GHGs curve in the Gas Chromatograph machine using a 0.3 ml of standard gas made up of 10.2ppm of CH_4 and 1.03% of CO_2. After machine calibration, the gas collected from each treatment was then injected into the measuring machine one after the other. Machine calibration using standard gas and GHGs measurement lasted about 30 minutes. The concentration (ppm) of CO_2 and CH_4 were obtained using the following formular:

$$Gas\ Concentation\ (ppm) = \frac{Area\ coverage\ of\ gas\ sampled * Standard\ gas\ concetration\ (ppm)}{Area\ coverage\ of standard\ gas}$$

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The CH_4 ppm values were converted into CO_2e in kg/ton, using the following steps:

i) Convert CH_4 ppm to CH_4 concentration in kg/m^3

CH_4 concentration in kg/ton = (CH_4 concentration in kg/m^3) × (mass in g / 1000 g/kg)

ii) Calculate the CO_2e of CH_4:

The global warming potential (GWP) of CH_4 is 28 over a 100-year period, meaning that 1 kg of CH_4 has the same impact on global warming as 28 kg of CO_2 (IPCC, 2014).

CO_2e of CH_4 in kg/ton = CH_4 concentration in kg/ton × GWP of CH_4

Similar procedure to CH_4 ppm conversion was used to convert CO_2 ppm values into CO_2 in kg/ton; however, CO_2 GWP over a 100-year period is 1 (IPCC, 2014).

Nine grams of compost were collected from each treatment i.e. 3g from each replication, in a weekly basis. They were put in a Ziploc bag, transported to the laboratory and stored in a fridge at 4°C. The pH and electrical conductivity (EC) were measured using a LAQUAtwin sensor, whereby, 1g (dry basis) of compost was mixed in 10ml of deionized water i.e. 1:10 v/w. 1ml of the mixture was sampled into the LAQUAtwin sensor. For Total nitrogen (TN), 0.5g (dry wet) of compost was diluted in 200 ml of deionized H_2O. A decomposition liquid was prepared from 4g NaOH and 3g $K_2S_2O_8$ dissolved in 100ml deionized H_2O. 1ml of the compost solution was then decomposed in 10ml NaOH+ $K_2S_2O_8$ solution and 49 ml deionized H_2O. This new mixture was then put in an autoclave for 30 minutes. after autoclaving elapses, the samples were then let to cool to room temperature. A standard NO_3N-1000 solution of; 0 (deionized H_2O) ppm, 0.5ppm, 1ppm, and 2ppm concentration was prepared. Two solutions of HCl were prepared, solution (A): 0.5 ml of HCl was diluted in 250ml deionized H_2O, solution (B) 10ml of HCl was reacted with 160ml of deionized H_2O. 2.5 ml of standard solutions were pipetted into UV cell and mixed with 0.5 ml of solution A, the mixtures were well shaken and one by one beginning with 0 (deionized H_2O) standard solution were put in a spectrophotometer and the standard curve was recorded, that will aid in estimating the concentration of TN in the compost sample. 2.5ml of autoclaved samples were reacted with 0.5 ml of solution B in a UV cell and then measured in the spectrophotometer pre-set at a wavelength of 210, hence yielding TN concentration.

2.1 Data analysis

Single factor ANOVA was performed using MS Excel to analyse whether there was significant variation in moisture content, temperature, pH, EC, CO_2, CH_4, TN and C/N among treatments. In the case where ANOVA analysis was lower than $p< 0.05$, Tukey's HSD was performed using Astata.com, to separate treatments means.

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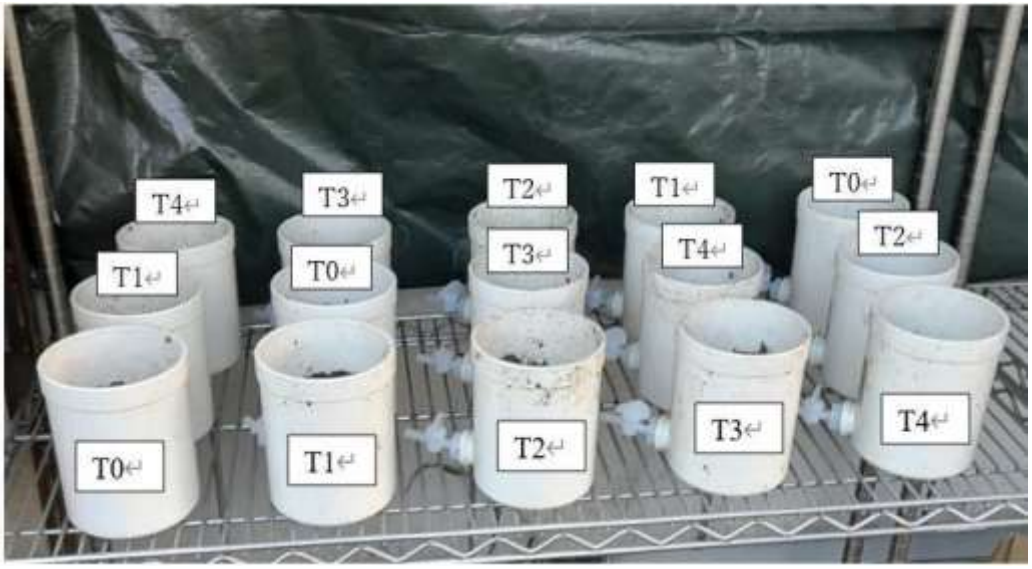

Figure 1: Experimental layout during composting; T0= 100%CD, T1= 75% CD + 25% FW; T2= 50% CD+ 50% FW, T3= 25% CD+ 75% FW and T4=100% FW +0% CD

Figure 2: A sample of how gas was collected from the pots during composting

3.0 Results and discussion

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3.1 Temperature variation

Temperature is a vital element in the composting process. It is a physical biomarker that indicates how intense microbial activity degrades organic materials (Wei et al., 2014; Chen et al., 2018). According to He *et al.*, (2013), complex substrate degradation into simpler components is promoted by temperature. Temperature fluctuation was witnessed over time during the experiment as shown in figure (3).

Thermophilic (40°C - 65°C); Mesophilic (25°C - 40°C) and curing phases (<25°C) were attained from day 1-3, 4-42 and from day 43-60 respectively. High temperatures obtained during the thermophilic phase are responsible for denaturing harmful pathogens in the compost. The temperature recorded from the all treatments were significantly higher than the ambient temperature a part from days 12, 17, 26, 40, 43 and 54.

ANOVA analysis indicated that temperature did not vary significantly between treatments ($p < 0.05$).

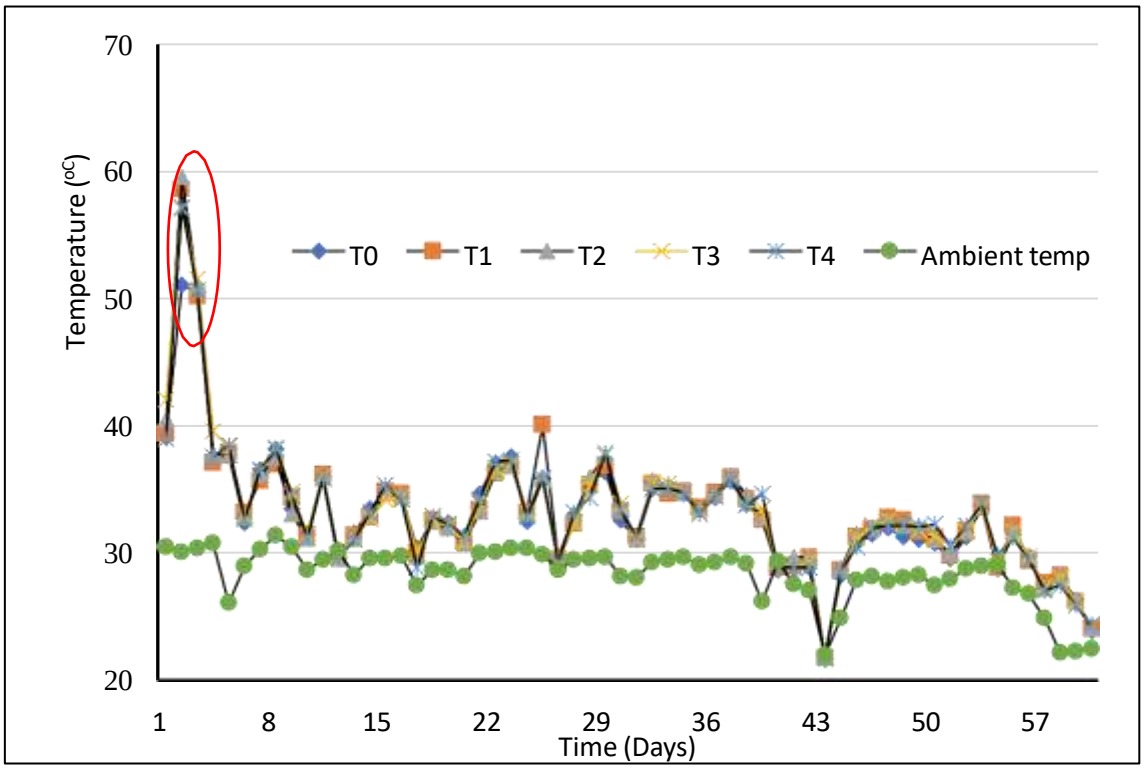

Figure 3: Temperature variation of treatments T0, T1, T2, T3, T4 and ambient temperature during composting. The red oval mark indicates the thermophilic phase.

3.2 Moisture content (%)

Composting rate and final product properties are influenced by moisture content. Composts with high moisture content (over 60%) are typically clumpy and difficult to distribute. Composts with low moisture content (under 40%) are dusty. Higher moisture content leads to less organic

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matter per tonne of compost. Wet weight moisture of about 50% is ideal for O_2 circulation and GHGs emission Sullivan et al., (2018). The average moisture content in all treatments throughout the experiment ranged between 46.69 and 55.66%. Daily sprinkling of water was done to maintain moisture content between (40-60%). At onset of the experiment, the initial moisture content was not significantly different between the treatments according to one way ANOVA (p-value = 0.1578 > 0.05) as shown in table 1. As weeks progressed, moisture differed significantly between weeks as shown in figure 4. A one-way ANOVA p-value 0.0045 was lower than 0.05 from the 2nd to the 8th week, suggesting that the one or more treatments are significantly different. The average highest and lowest moisture content recorded among the treatments across the weeks were T4 55% and T1 46.6025% respectively. Tukey's HSD showed that T4 was significantly different from T1 at 0.01% and from T3 and T0 at 0.05%; however not significantly different from T2 at the end of the experiment as shown in table 2.

Table 1: Initial moisture content (%) pH, EC (mS/cm), C/N ratio and TN (%) of the treatments, at the start of the experiment

Treatments	Moisture %	pH	EC (mS/cm)	C/N	TN %
T0	70±0.816	8.6±0.216^{a}	1.59±0.008^{a}	34.9±0.823	1.43±0.232
T1	68.2±0.163	6.5±0.216	3.16±0.016^{b}	35.1±0.082	1.40±0.136
T2	68±0.816	6.3±0.163	3.85±0.016^{c}	35.1±0.125	1.46±0.112
T3	68±1.633	6.4±0.216	4.49±0.008^{d}	35.6±0.249	1.50±0.118
T4	67.7±0.245	6.2±0.081	4.81±0.008^{e}	35.1±0.163	1.54±0.146

Table 2: Final moisture content (%) pH, EC, C/N ratio and TN (%) of the treatments, as at week 8

Treatments	Moisture %	pH	EC (mS/cm)	C/N	TN %
T0	42.27±1.097^{acd}	6.8±0.082^{a}	2.1±0.082^{a}	24.3±0.374 ^{bac}	1.82±0.065
T1	42.15±1.412^{acd}	8.5±0.082	2.4±0.327^{b}	24.7±0.356 ^{bac}	1.78±0.102
T2	45.53±0.977^{bd}	8.6±0.141	3±0.245^{c}	26.9±0.082^{a}	1.72±0.071
T3	42.46±0.628^{cad}	8.7±0.216	3.5±0.082^{d}	22.9±0.163^{c}	1.95±0.050
T4	49.92±0.188^{d}	8.8±0.082	4.4±0.163^{e}	24.6±0.081^{bac}	1.83±0.075

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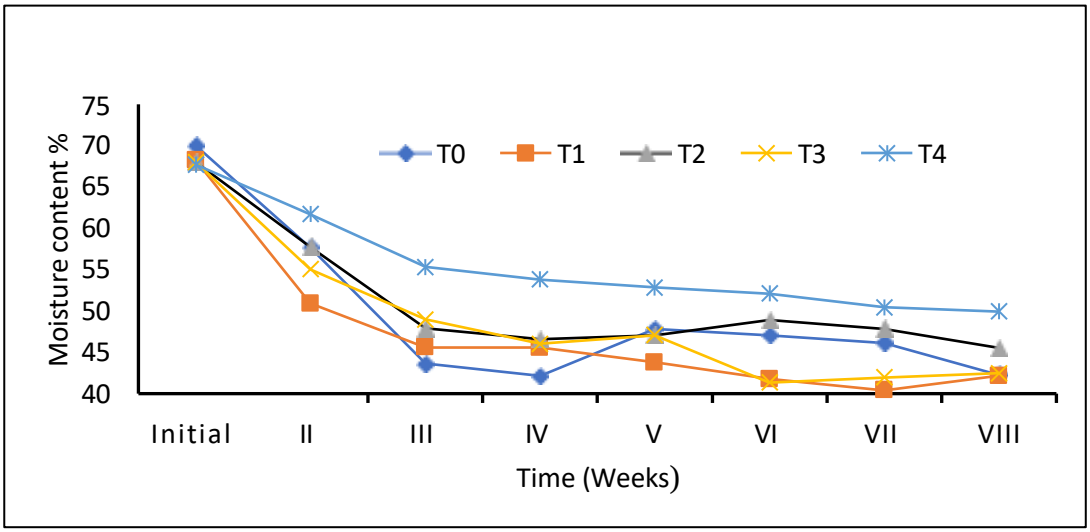

Figure 4: Moisture content (%) of treatments T0, T1, T2, T3 and T4 from the start (initial) to the final period (week 8) of composting experiment.

3.3 pH variation

The pH changes observed during the composting of cow dung and food waste differed due to the varying composition and characteristics of the initial feedstocks (Lopez-Cano *et al.*, 2016). While cow dung typically exhibited a shift from basic to acidic pH, food waste showed an opposite trend, moving from acidic to basic pH during composting as shown in figure 5.

The pH can be a useful predictor of N mineralization rates and denitrification potential. However, N mineralization is particularly sensitive at pH 7 or below. High temperature led to the volatilization of organic acids, thus increasing the pH value (Zhang *et al.*, 2017; Chung *et al.*, 2021). The rise in pH in treatment groups is likely due to ammonia generation during biodegradation (Janczak *et al.*, 2017; He *et al.*, 2013; Wei *et al.*, 2014). The initial and final pH of treatments T1-T4 were (6.5, 6.3, 6.4, 6.2) and (8.5, 8.6, 8.7, 8.8) respectively. While T0 pH decreased from 8.6 to 6.8, is attributed to the ammonia volatilization, and CO_2 emission through microbial action (Chen *etal.*, 2018, Ren *etal.*, 2023). One way ANOVA showed that all treatments were significantly different at $p<0.05$. Tukey's HSD confirmed that treatment T0 was significantly different from T1, T2, T3 and T4 ($p< 0.01$) throughout the experiment as shown in table 1 and 2 except in the 5^{th} and 6^{th} week. During the 5^{th} week, all treatments were not significantly different at $p< 0.05$; however, in the 6^{th} week the T0 was significantly different from T1 and T2 at $p<0.05$ and T3 and T4 at $p<0.01$.

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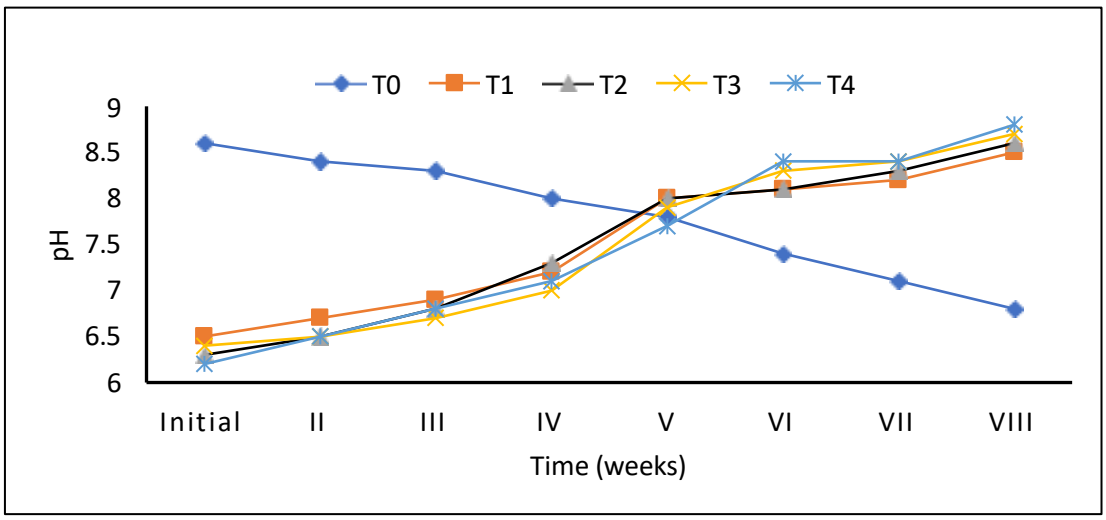

Figure 5: The pH value of treatments T0, T1, T2, T3 and T4 from the start (initial) to the final period (week 8) of composting experiment.

3.4 Electrical conductivity (EC)

EC measures salinity during composting, it indicates the measure of total ion concentration and describes changes in the levels of organic and inorganic ions not limited to: SO_4^{2-} , Na^+, NH_4^+, K^+, Cl^-, and NO_3^- during the composting process (Zhang *et al.,* 2014). It also determines if the compost is suitable for agriculture (Ontario. Ministry of the Environment. Waste Management Policy Branch, 2012; Rynk, 1994). Figure 6 shows the EC fluctuations as recorded throughout the experimental period for each treatment. Initially, water was lost by evaporation due to increased temperatures and the release of mineral salts during OM breakdown, resulting in elevated EC values. Following that, EC values dropped after the 5th week due to mineral salt precipitation and NH_3 volatilization. This phenomenon was also observed by Waqas *et al.*, (2018). The final compost had EC values of 2.1, 2.4, 3, 3.5 and 4.4 mS/cm for T0–T4 respectively. This study's findings are compatible with those of Ravindran *et al.*, (2022) and Jain *et al.* (2018). The EC values for the final composts of treatments (T0-T3) were below the acceptable 4 mS/cm range for agronomic use (Lasaridi *et al.*, 2006). According to one way ANOVA, EC of all treatments at the onset and at the end of the experiment were significantly different at ($p<0.05$) and Tukey's HSD ($p<0.05$). However, there was significant difference between treatments according to Tukey's HSD ($p<0.01$).

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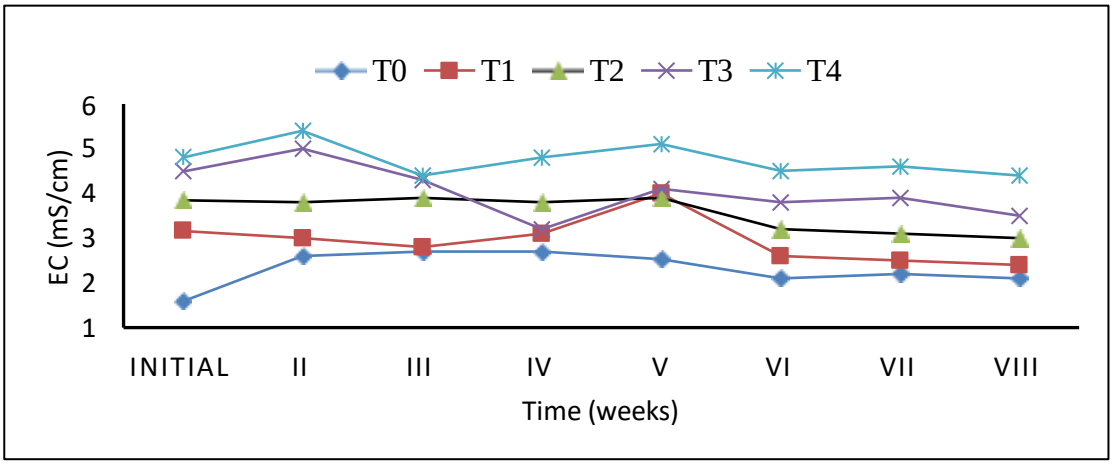

Figure 4.4: The EC (mS/cm) value of treatments T0, T1, T2, T3 and T4 from the start (initial) to the final period (week 8) of composting experiment.

3.5 Total nitrogen

TN trend fluctuated by increasing from the start of the experiment until its completion at the 8th week as illustrated in figure 7. Increase of TN is attributed to C biodegradation in compost piles and mainly unconstrained through CO_2 (Duan et al., 2021). TN values increased to T0=1.82 T1=1.80, T2=1.7291, T3=1.95 and T4=1.83 in the 8th week from T0=1.43, T1=1.40, T2=1.46, T3=1.50 and T4=1.54% at the initial phase of the experiment. Similar TN trends were observed over time in compost experiments by Thambirajah et al., (1995). A one-way ANOVA ($p<0.05$) and post- hoc test with a Tukey's HSD, showed that there was no significant difference in TN means over time. T0, T1, T2, T3, and T4 increase TN from day 1 to day 60 by 11.93, 12.25, 8.38, 14.06 and 8.34% respectively.

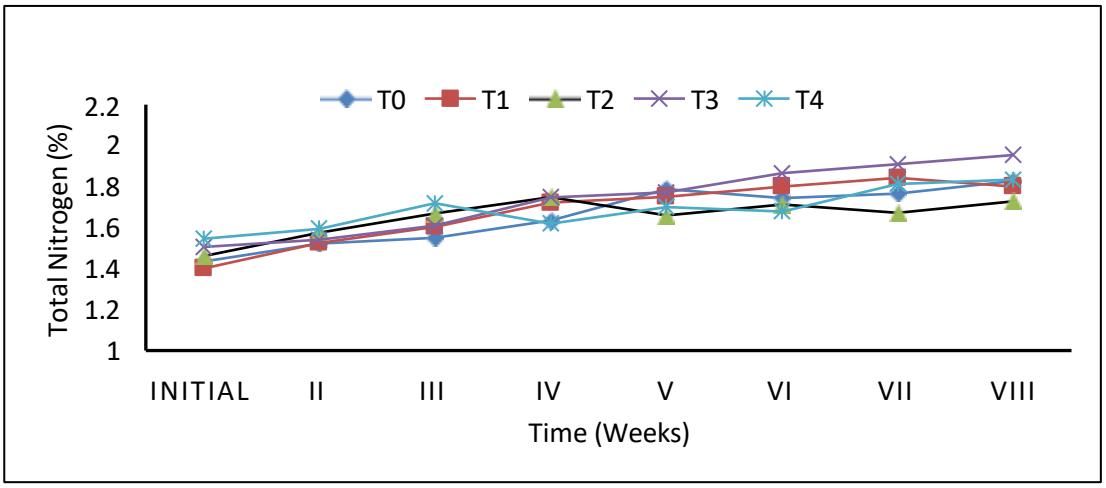

Figure 7: The TN (%) value of treatments T0, T1, T2, T3 and T4 from the start (initial) to the final period (week 8) of composting experiment.

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3.6 C/N Ratio

Composting material's C/N ratio indicates microbial activities of decomposition and progress to maturation, and can also predict CO_2 and N_2O emissions (Huang *et al.*, 2004). The C/N ratio plays a crucial role in composting by influencing temperature, which is crucial for CO_2 and CH_4 emission and pathogen elimination (Macias-Corral *et al.*, 2019). Carbon is absorbed by decomposing organisms for energy, while nitrogen is used for protein synthesis. During the experiment, the C/N ratio decreased, mostly due to reduced carbon concentrations. This reduction indicates a well-functioning compost process (Diaz *et al.*, 2007). The C/N ratio of the starting substrate is the most commonly used metric in composting. Microorganisms may rapidly degrade organic material at a constant C/N ratio of 30:1. When the C/N ratio is too high, the presence of low nitrogen levels slows down the pace of decomposition. When the C/N ratio is too low, there is too much nitrogen, which is likely lost to the environment in the form of ammonia gas, leading to bad odour production. Decomposer organisms must maintain a body C/N ratio of around 8:1. To maintain the health of bacteria organisms, the C/N ratio of applied materials was greater than 8:1 but not so high as to deprive organisms of nitrogen (Lalremruati *et al.*, 2023).

The initial C/N ratio was T0 = 34.9:1, T1 = 35.1:1, T2 = 35.2:1, T3 = 35.6:1 and T4 = 35.1:1.

Although the mean C/N during 60 days of the experiment was reduced (mean values T0: 24.3, T1: 24.7, T2: 26.9, T3: 22.9, and T4: 24.6), none of the compost treatments can be considered matured compost because their C/N ratio exceeds 15:1, making them unsuitable for agricultural use (Chefetz *et al.*, 1996). Other than at the start of the experiment, the C/N ratio varied significantly between treatments according to one way ANOVA ($p < 0.05$) and Tukey's HSD ($p<0.01$). Figure 8 illustrates the trend of C/N during composting.

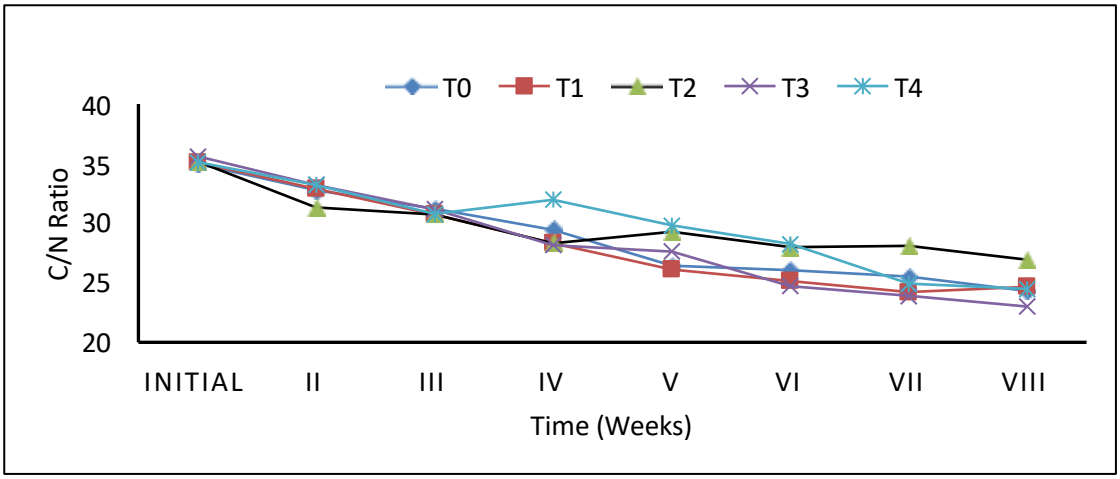

Figure 8: The of C/N value of treatments T0, T1, T2, T3 and T4 from the start (initial) to the final period (week 8) of composting experiment.

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3.7 Methane emission (CO_2e) pattern

Methane fluxes varied with time, with most of the emissions occurring in short spans early in the composting process as shown in figure 4. High CH_4 emission from 2nd - 4th week accounting for 86% of the total emission. High moisture content and decomposition rate of composted material was attributed to this influx of methane (Vergara et al., 2019). T1 had the highest CH_4 emission of 30% while T3 had the lowest emission at 6% of the total emission. The average CH_4 emission from T0 = 1.282±0.005 T1= 4.322±0.005 T2 = 2.596±0.005 T3 = 0.380±0.005 T4 = 0.534±0.005 $kgCO_2e$/ton respectively.

A study done by Ermolaev et al., (2019) found that CO_2e emissions from in-vessel composting of food waste ranged from 0.11 to 0.38 kg CO_2e/ton of wet waste. Similar study by Paredes et al., (2016) observed CO_2e emissions from composting of food waste and cow manure, reporting emissions of 0.2 to 0.4 kg CO_2e per ton of wet waste. According to a 2016 EPA report, well-managed compost facilities have emissions of 0.1 to 0.5 $kgCO_2e$ per ton of wet waste composted (Containers et al., 2016). Treatment T3 = 0.380±0.005 $kgCO_2e$/ton emission was within this range, however; all treatments were below the IPCC (2006) value of 10 kg CO_2e/ton, methane emissions. One way ANOVA $p<0.05$ indicated that there was a significant difference between treatments throughout the experiment as illustrated in table 3.

Table 3: Analysis of CO_2 and CH_4 emission at the 2nd (start of gas collection) and 8th week of composting (the end the experiment period)

	GHGs emission (kg CO_2e/ ton) at week 2		GHGs emission (kg CO_2e/ ton) at week 8	
Treatments	CO_2	CH_4	CO_2	CH_4
T0	75,887.16±642.35^{a}	6.23±0.024^{a}	0	0.017±0.002^{bc}
T1	431,960.7±1459.60^{b}	15.40±0.008^{b}	0	0.026±0.001^{a}
T2	290,218.5±1021.59^{c}	8.96±0.008^{c}	0	0.013±0.001^{c}
T3	53,249.94±612.37^{d}	1.07±0.016^{d}	0	0.0032±0.000001^{d}
T4	63,555.4±415.69^{e}	1.46±0.022^{e}	0	0.011±0.001^{e}

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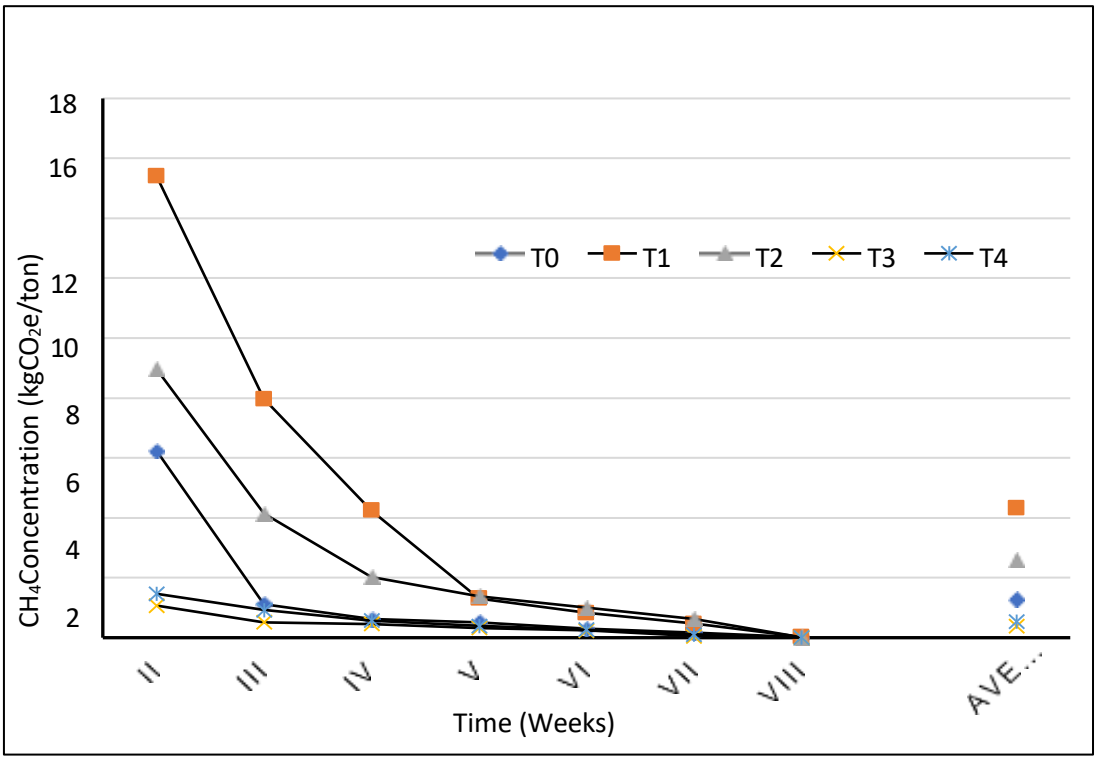

Figure 9: CO_2 equivalent of methane in kgCO_2e/ton emitted from treatments T0, T1, T2, T3 T4 and their averages recorded from the 2nd to the 8th week of composting

3.8 Carbon dioxide (CO_2) emission

High CO_2 emission occurred at the onset of the experiment as seen in figure 5, this trend was also recorded by Chen et al., (2018). There was drastic decrease in CO_2 emissions as the experiment progressed as shown in figure 7. This was possibly due to depletion of organic matter to be digested (Chowdhury et al., 2014). T1 emission was the highest at 43.18% (87,487.04 kg CO_2e/ ton) while T3 had the lowest 6.95% (14,086.78 kg CO_2e/ ton). The biogenic nature of CO_2 emission from composting has been established not to have GWP on the environment (Vergara et al., 2011), thus no matter the quantity produced it is not considered as a threat to altering the climate (Sánchez et al., 2015).

According to one-way ANOVA $p<0.05$, suggested that all treatments are significantly different therefore; Tukey's HSD was performed and it indicated that all treatments are highly significantly different from each other at $p<0.01$. However, T0 was significantly different from T4 at $p<0.05$ and T3 and T4 were not significantly different from each other.

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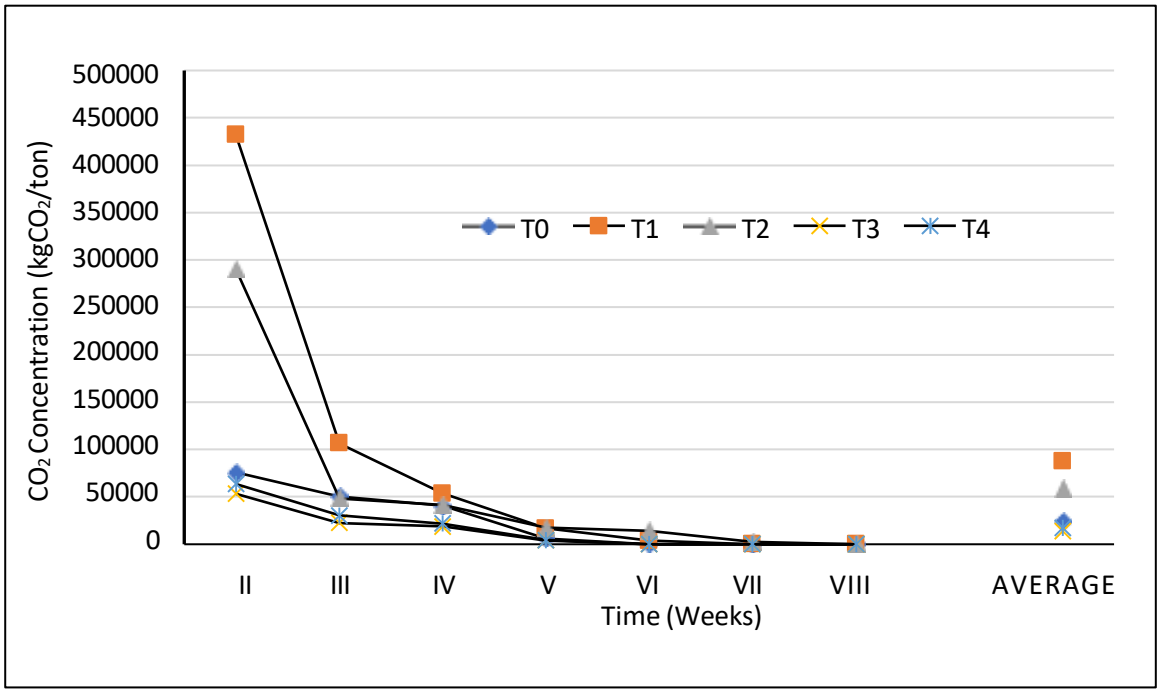

Figure 10: Shows the CO_2 emission in $kgCO_2$/ton of treatments T0, T1, T2, T3, T4 and their averages recorded from the 2nd to the 8th week of composting

4.0 Conclusion

Thermophilic temperature resulted in a significant organic matter digestion and increase in methane fluxes. The average moisture threshold in all treatments was determined to be 50% and CH_4 emissions rose more rapidly when moisture levels were above 56.6%. Composting requires a moisture level between 40% and 60%. Higher levels impede O_2 diffusion, while lower levels prevent microbial action (King 1997). Composting's greenhouse gas emission is influenced by biochemical factors, including the availability of C and N in the feedstock. Carbon concentrations are crucial for understanding emissions patterns. Early in composting, when the feedstock is fresh and the organic C and N are more accessible to microbes, the biggest gas fluxes occurred. Carbon is absorbed by decomposing organisms for energy, while nitrogen is used for protein synthesis. As decomposition progresses, less and less carbon is available, resulting in lower CO_2 emissions. Decomposer organisms must maintain a body C/N ratio of around 8:1. To maintain the health of bacteria organisms, the C/N ratio of applied materials was greater than 8:1 but not so high as to deprive organisms of nitrogen. Treatments 25% CD + 75% FW ratio showed lowest CO_2 and CH_4 emissions and the highest average temperature (50.2°C) during the thermophilic phase compared to other treatments. Additionally, the final compost from the 25% CD + 75% FW ratio treatments has lower C/N of 22.9:1. These findings lead to the conclusion that treatment with 25% CD+ 75% FW ratio were the most suitable mixing ratio for composting although the final C/N is still higher than the recommended 15:1 ratio for agricultural production.

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5.2 General acknowledgement
None

5.3 Declaration of interest
None

5.4 Ethical clearance
Not needed

5.5 Conflict of interest
None

5.6 Data availability statement
The authors confirm that the data contained in this article is from our study and it is accessible upon inquiry with the approval of the authors who possess the data.

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