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Influence of Carbon Source on Composting process

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THIS RESEARCH aims to study the degree and duration of the thermophilic phase by changing the available carbon source to reduce the period of composting within a fully equipped reactor with a controllable stirring and ventilation unit and its impact on the quality of the produced compost. The first stage analysis of raw materials used physically and chemically. Then determined the need for nitrogen supplements and the appropriate particle size of the nutrient.

Initially, the experiment contained six treatments obtained by mixing agricultural plant residues (pepper and broccoli) with cow manure in different mixing ratios: 95:5, 90:10, 85:15, 60:40, 50:50 and 10:90 respectively. Then from the resulting data of the first experiment, the mixing ratios of 50:50 and 60:40 were chosen as the best ratios that showed the highest temperatures, then other parameters were added to them, which are (20 ml used oil and 20% compost as inoculum).

The addition of used oil (50:50) resulted in the record of the highest temperature of 59°C and the thermophilic phase lasted for 5 days. However, with ratios (60:40) recorded 56°C and the thermophilic phase lasted for 4 days and the composting process was completed within 18 days. While when the inoculum was added with (50:50) ratios, the temperature reached 52.7°C and with (60:40) it reached 51°c and the compost was completed ripening after 25 days from the beginning of the experiment.

Keywords: Compost production; used oil; Raw material; C/N ratio.

Introduction

As the world's population rises, industrialization continues and global demand for food increases, due to the fact that urban growth is fuelled by advancements in science, technology, and the economy worldwide, this increases the volume of agricultural waste and solid waste (Bhatia et al., 2020).

Agricultural waste including vegetables, garden waste, greenhouse waste and solid waste generation rates are rising worldwide, with waste generation expected to increase to 3.40 billion tons in 2050, inappropriate disposal of this wastes may cause major environmental problems, and therefore trying to apply reliable technology to deal with these wastes is one of the most important pillars of sustainable development for any country (Samal et al., 2019., Behera and Samal., 2022).

The composting process is technique which deals with agricultural waste and solid waste, especially the organic part of it. Recycling organic waste using aerobic digestion is a strategy of great importance for extracting energy and organic products from underutilized resources (Iqbal et al., 2020).

The biodegradation of organic materials contributes to the reduction of waste volume and the production of an end product extrapolated by nutrients, this process is called compost. This source of energy is used in agricultural activities because of its different positive impacts on the physical and chemical properties of soil and the reduction of the use of inorganic fertilizers, such as increasing the ability to store carbon in the soil, thus reducing global warming and improving porosity and structure of the soil, which increases the ability to retain water (Oviedo-Ocaña et al., 2023; Ampong et al., 2022).

The composting process goes through several main stages, with different communities of microorganisms prevailing during each stage of composting. It goes through four stages: mesothermal, thermophilic, cooling, and finally maturation of the compost; these stages can occur simultaneously rather than sequentially. The duration of each stage depends on the initial frame of the mixture, water content, air circulation, and microbiological composition (Tsivas et al., 2023).

The many factors (humidity, oxygen, temperature, C:N ratio, pH, and biological activity) play an important role in the composting process as key parameters if they are controlled, developed, and applied correctly to obtain a product suitable for agricultural use, as the maturity and quality of the compost is the decisive factor in its marketing (Cerda et al., 2018).

Working with suboptimal C:N ratio increases the composting time (preferred range is 25 to 35 %), affecting the rate of decomposition of organic matter, if there is a lot of carbon-rich substrate for composting, the degradation efficiency will slow

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down while using nitrogen to cause the death of organisms. In contrast, if there is a high nitrogen substrate for starting materials but there is not enough carbon, it will emit excess nitrogen such as NH3 which cannot be used to end the nitrogen cycle. (Neugebauer et al.,2017).

Moisture can significantly affect the spread of gas through substrates during composting. Microbial reactions can be suppressed under low humidity during composting, and dry composting mass is physically stable but biologically unstable (Oshins et al., 2022). If humidity is too high, air may be difficult to enter during the production process (preferred range of 50 to 60%), as water can fill the necessary air spaces that aid aerobic fermentation (Meena et al.,2021).

Particle size is one of the physical factors that can affect composting efficiency. Cutting, chopping or grinding raw materials are useful to enhance the degradation efficiency by increasing the overall surface area to allow for more microbial invasion. In addition, it can make uniform size particles, improve ventilation, retain moisture and increase the value of the finished product (Nemet et al.,2021).

There is a clear temperature shift at different stages of the composting process, so that certain microorganisms dominate each stage (Sardar et al., 2021). Each group of microorganisms at a certain stage of the composting process can highlight different functions under different temperatures. The heat-loving phase is the highest stage of decomposition because complex organic compounds, such as both languages, will degrade with thermal disintegration and actinomycosis (finore et al., 2023). High temperature is important for the destruction of pathogenic organisms such as parasite eggs, bags and flies in the composting process (Wang et al., 2021).

The air supply becomes inadequate, the process becomes slower, and the growth of unsuitable microorganisms may be favored. It was found that the aerobic process of producing compost takes less time than the anaerobic process and that high temperatures lead to a reduction in the time period for producing compost. (Sayara et al., 2020).

So, the main objective of this study is to determine optimal conditions for the composting process by changing the carbon source available to reach the highest temperature and reducing the duration of the composting phases.

Materials and Methods

The experiments were conducted in the Bioenvironmental Engineering laboratory, Agricultural Engineering Department, Faculty of Agriculture, Cairo University, Giza, Egypt. The practical experiments started in July 2023.

In-vessel composting setup

The system as shown in Fig. (1) was used in this experiment, which consists of a frame, three bioreactors, air supply units, and a data acquisition unit.

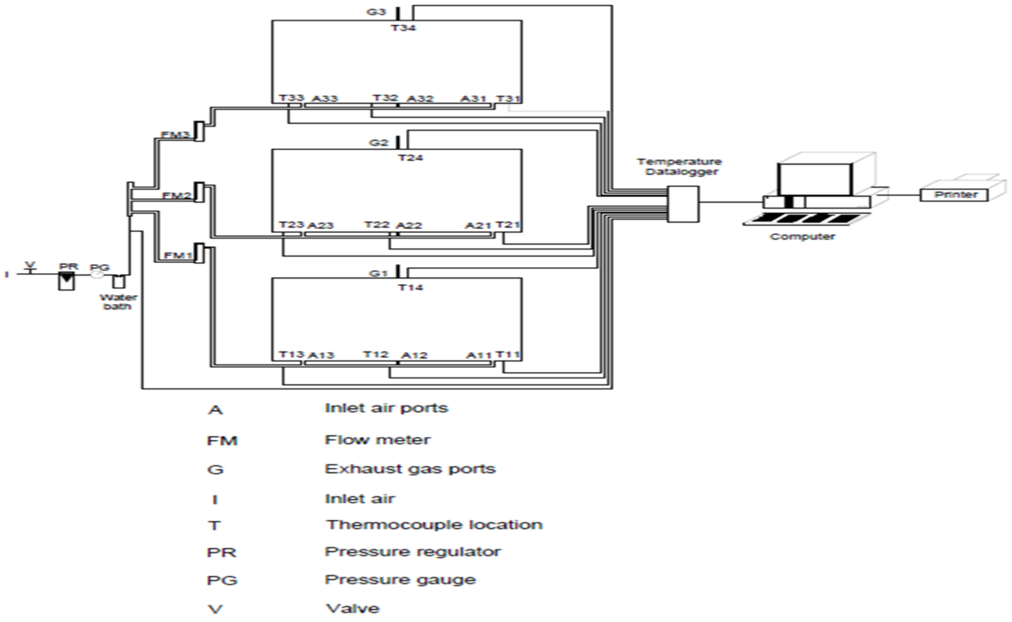


Fig. 1. Experimental system.

Horizontal bioreactor provides space ranging from 3-3.5 kg of compost mixture, plus 25% size as a headspace, each bioreactor was designed with an inner diameter 203 mm, length 520 mm, and thickness 5 mm and then covered with a removable circular glass sheet with inner diameter 203 mm and thickness 6 mm. Inside each bioreactor, a removable stainless steel stirring shaft with a diameter of 10.5 mm was installed, and 5 stainless steel collars with a length of 69 mm and a thickness of 6 mm were installed on the column to perform the stirring process and it was set to rotate at a rate of 5 rpm by DC motor (Dayton- 2H467) (Fig. 2).

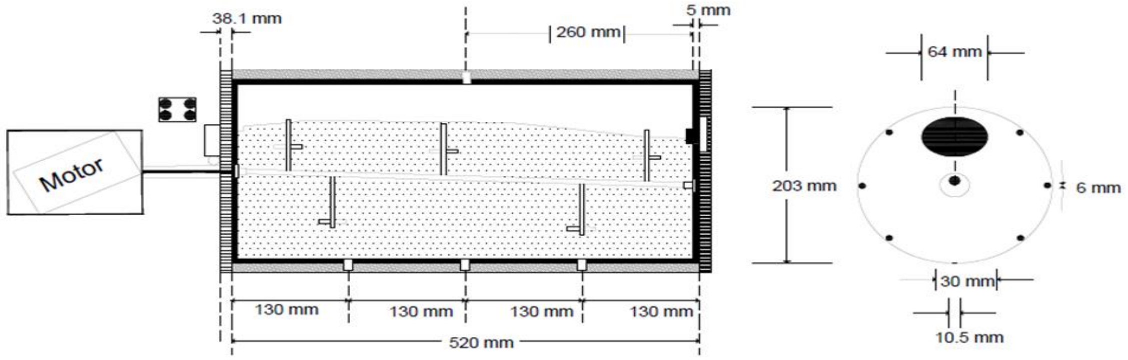
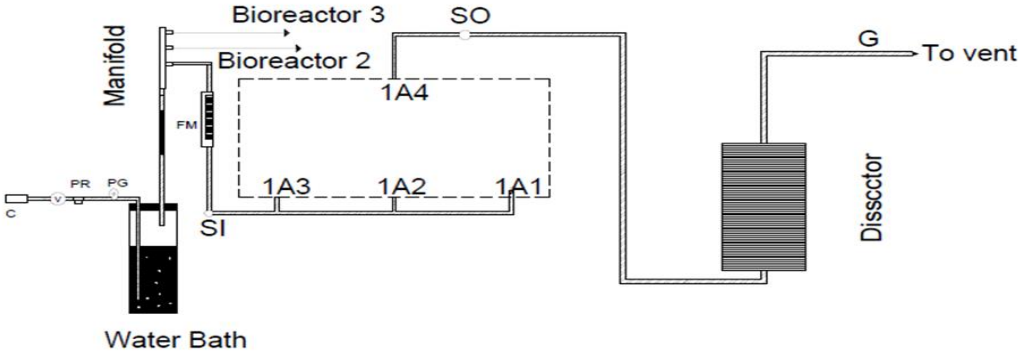


Fig. 2. Bioreactor dimensions.

Air is continuously supplied inside the bioreactor from an air compressor (100 PSI, Mod: LGH-210-H02) passed on a pressure regulator and pressure gauge to maintain a pressure of about 5 Kpa, the air then passes through a water bath (30×13×10 cm) to humidify the air entering the bioreactor, then it goes through a flow meter to control and measure the volume of air entering the bioreactor (Fig.4). The air flow rate is approximately 0.15 m^3/hour (Haug, 2018).

Inside each bioreactor there are 4 thermocouples (MTC/24, Omega, Stamford, CT) for temperature measurements, three of them in the bottom of the bioreactor to measure the temperature of the compost mass, and one was placed in the top near the outlet air hole to measure the temperature of the exhaust gas as shown in Fig. (3).



A	Inlet air
1A 1,2,3	Inlet air ports for the first bioreactor
1A 4	Outlet gas port for the first bioreactor
SI	Inlet air sampling port
SO	Outlet gas sampling port
FM	Flow meter
G	Exhaust gas
V	Valve
PR	Pressure regulator
PG	Pressure gauge
C	Compressor

Fig. 3. The aeration unite used with each bioreactor.

The data acquisition unit consists of temperature data logger and a computer. The thermal scanning card has 24 analog input channels and each channel can be programmed to receive data from the thermocouples.

The software (Omega, Stmford, CT) used was a Microsoft Windows-based preparation and acquisition application program that features a graphical user interface in the form of a spreadsheet through which data is collected and displayed (Fig.4).

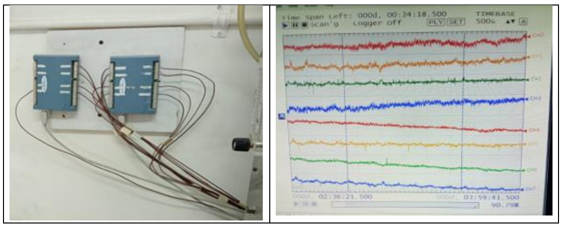


Fig. 4. Data acquisition Logger and software.

Raw materials

The raw materials used in this experiment are pepper and broccoli residues (stem and leaves), which collected from agricultural greenhouses. Cow manure was collected from Agricultural Research and Experiment Station. Cairo University.

Residues were cut using a chopping machine (7.5 hp) to a size of 5-6 mm. This chopping reduces the particle size in order to enhance the microbial decomposition process. As shown in Table (1) some chemical and physical properties of used residues were measured in the Bioenvironmental Engineering laboratory at Agricultural Engineering Department, Egypt, and Complex Research Laboratories, Faculty of Agriculture, Cairo University, Egypt.

To measure the different chemical properties (Ca, K, Na, P, Fe, Mn, Zn), approximately 0.5 g of samples were used for each characteristic, then acid digestion of the sample in the digestion tubes was performed using a hot plate to control the temperature to determine the metal by spectroscopic methods using (Thermos Scientific iCE 3300 Atomic Absorption Spectrometer, German) and using 7 ml of H_2SO_4 and 2 ml of H_2O_2 detectors.

The sample is weighed in the digested tube, then acids are added a drop on the inner wall of the tube, then the solution is gently stirred to ensure that the sample is harmonized with the acids. The tube is placed on the hot plate until the sample becomes a clear solution and left to cool until it reached room temperature, then the solution is transferred to a specific flask and filtered, then the measurement began (Christian and Feldman, 1970; AOAC.1995; Schollenberger.1945).

Volatile solids are the organic matter (largely carbon, oxygen and nitrogen) which are lost at 550°C, leaving only the ash.

About 50 g of representative composite samples were taken on a wet basis for each treatment, dried, and grinded for total nitrogen (TN) and total carbon (TC) analysis (Kalembasa and Jenkinson 1973).

Moisture content was calculated on a wet basis from a 250 g sample dried at 105 ± 5 °C for 24 h until constant weight was obtained. Moisture content (%) was calculated as the mass loss due to water removal (g/g) divided by moisture (Michel et al., 1993).

In distilled water (extract), pH and electrical conductivity (EC) were measured by 1:5 by taking 10 grams of compost and adding it to 50 ml of deionized water and then measured in the extract after filtration using pH and EC electrode (Thomas 1996, Rhoades et al. 1989).

Table 1. Some properties of the different residues.

Parameters	**Pepper**	**Broccoli**	**Manure**
pH	5.84	5.18	7.44
Electrical Conductivity (ds/m)	0.64	0.61	1.15
Moisture content (%)	9.00	10.75	66.70
Volatile solid (%)	85.10	87.20	77.9
Ash (%)	14.90	12.80	22.10
Total Nitrogen (%)	1.82	0.27	2.03
Total Carbon (%)	51.77	47.44	43.64
Ca (%)	0.32	0.56	0.56
K (%)	2.18	4.20	1.80
Na (%)	0.15	0.18	0.28
P (%)	0.22	0.29	2.32
Fe (mg /kg)	24.15	35.84	187.95
Mn (mg /kg)	32.33	33.60	111.95
Zn (mg /kg)	25.47	18.16	212.14

Composting trials and treatments

The first experiment Treatment

Initially, the experiment contained six treatments obtained by mixing vegetables plant residues (pepper and broccoli) with cow manure in different mixing ratios: 95:5, 90:10, 85:15, 50:50, 60:40 and 10:90 respectively, these ratios were selected to see the effect of adding a small, medium and high percentage of manure during composting process.

Broccoli residues were mixed with pepper by 1:1.5 based on dry weight, a quantity of 3.5 kg (weight) of vegetable residue mixture was mixed with different quantities and ratios of cow manure as shown in Table (2).

Table 2. The first experimental treatments.

Treatments	**Mixing ratios (%)**		**Symbol**
	Manure: Agricultural residues	Manure: Broccoli: Pepper	
1	5:95	5:38:57	T_1
2	10:90	10:36:54	T_2
3	15:85	15:34:51	T_3
4	50:50	50:20:30	T_4
5	60:40	60:16:24	T_5
6	90:10	90:4:6	T_6

Measurements methodology

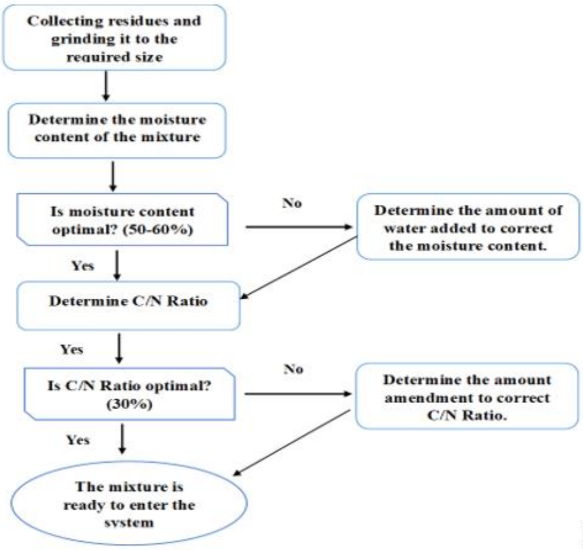


Fig. 5. Compost mixture design diagram.

The previous Fig. (5) shows the design diagram of compost mixture where after grinding residues, the moisture content of each residue was calculated separately after grinding it using Equation (1) and then used to calculate the moisture content of the mixture as a whole using Equation (2) and adjusted to reach 50-60% by adding water to the mixture.

The C:N ratio for each mixture was determined using equation (3) and adjusted to about 30:1 by adding urea (46% nitrogen) as a nitrogen supplement.

$$M = \frac{\text{Wet Weight} - \text{Dry weight}}{\text{Wet Weight}} \times 100 \quad \ldots \quad (1)$$

Where:

M = Moisture content, wet basis (%)

$$M_m = \frac{(Q_1 \times M_1)+(Q_2 \times M_2)+(Q_3 \times M_3)}{Q_1+Q_2+Q_3} \quad \ldots \text{ (2) (Dougherty.1999)}$$

Where:

M_m = Moisture content for mixture (%)
Q_1 = Quantity of material (1)
M_1 = Moisture content of material (1)
Q_2 = Quantity of material (2)
M_2 = Moisture content of material (2)
Q_3 = Quantity of material (3)
M_3 = Moisture content of material (3)

$$\text{C:N ratio} = \frac{Q_1(C_1(100-M_1)+Q_2(C_2(100-M_2)+\cdots}{Q_1(N_1(100-M_1)+Q_2(N_2(100-M_2)+\cdots}$$

… (3) (Dougherty.1999)

Where:

Q_1 = Quantity of material (1)
C_1 = The percentage of carbon in material (1)
M_1 = Moisture content of material (1)
N_1 = The percentage of nitrogen in material (1)
Q_2 = Quantity of material (2)
C_2 = The percentage of carbon in material (2)
M_2 = Moisture content of material (2)
N_2 = The percentage of nitrogen in material (2)

The final mixture used in each experiment was mixed well, then placed in the bioreactor occupying 75% of its total volume, The Stirring unit was then operated at 5 rpm, the system operated at a constant aeration rate of 0.15 m^3/h during all experiments, and temperatures of bioreactors were monitored continuously.

The second experiment treatment

From the resulting data of the first experiment, the mixing ratios of 50:50 and 60:40 were chosen as the best ratios that showed the highest temperatures during the composting process. The second experiment treatments are conducted to study the effect of this treatments on the temperature and time period during the compost production process.

20 ml of used oil was added to each mixture continuously every 24 hours as a bioavailable carbon source, and 20% of municipal was added to each mixture as inoculum, some measurements were made on used oil and inoculum as shown in Table 3.

The parameters of the second experiment are shown in Table (4).

Table 3. Some properties of used oil and inoculum compost.

Parameters	Inoculum compost	Used oil
pH	7.1	5.9
EC (ds/m)	2.9	-
Moisture content (%)	39	-
Volatile solid (%)	86.4	99.92
Ash (%)	13.6	0.08
Total Nitrogen (%)	1.4	0.035
Total Carbon (%)	30	70.76
Ca (%)	1.2	0.006
K (%)	0.8	0.002
Na (%)	0.57	0.03
P (%)	0.26	0.001
Total oil and grease (%)	-	90.56
Carbohydrates (%)	-	7.8

Table 4. The second experimental treatments.

Treatments	Mixing ratios	Symbol
	Manure: Agricultural residues	
Control	50:50	T_{1-1}
	60:40	T_{1-2}
Control + 20 ml of used oil	50:50	T_{2-1}
	60:40	T_{2-2}
Control + 20% of inoculum compost	50:50	T_{3-1}
	60:40	T_{3-2}

Statistical analysis

All data were tested for homogeneity of variance and the experimental results for the maximum temperature obtained and the chemical and physical properties of compost were analyzed using IBM SPSS statistics.25 using univariate analysis of variance and Duncan's tests to examine the significance of the effect of the coefficients at P = 0.05.

Results and Discussion

First experiment

Temperature during the composting process

Temperature is an important and critical criterion for assessing compost maturity and an important indicator that reflects the extent of microbial activity during the production process.

Temperatures continue to rise steadily, moving from the mesophilic range (25-45°C) to the thermophilic range (above 45°C) (Zhang and Sun,2018). Therefore, temperatures were constantly recorded throughout the experiment period and were as follows.

The temperature of the two treatments, T_1 and T_2, reached their maximum temperature of 40.96, 41.6 °C respectively on days 4 and 5 and continued for approximately 4 days. While treatment T_3, the temperature began to rise above 40° C from the third day and reached a maximum temperature of 43.51°C on the sixth day. It continued >40°C for 5 days and began to decrease < 40 from the 9th day of the experiment.

The temperature of treatment T_4 began to rise from the third day and reached the thermophilic stage (>45°C) on the fifth day, where it reached a maximum temperature of 47.7°C. The temperature continued above 45°C for about 4 days and began to gradually decline below 40°c from day 11 of the experiment.

The T_5 treatment reached its maximum temperature of 45.1°C on the 5th day, it dropped below 40°C from day 9 to the end of the experiment. While the highest temperature for treatment T_6 was 29.4°C, with temperatures gradually decreasing in all treatments until the end of the experiment (Fig 6).

Although compost was added to the plant residue mixture to increase the bioavailable carbon content of the mixture, the heat generated by the decomposition of the mixture did not raise the carbon level and temperature to the thermophilic stage for all treatments.

The difference in temperature of the treatments may be because readily degradable organic molecules are being depleted (Wu et al., 2017), as the temperature of any organic material is greatly affected by the carbon source, with small differences between the nitrogen sources over time. T_6 treatment did not reach the thermophilic levels and matured within medium temperatures. This may be due to its high moisture content which agreement with (Dume et al., 2021).

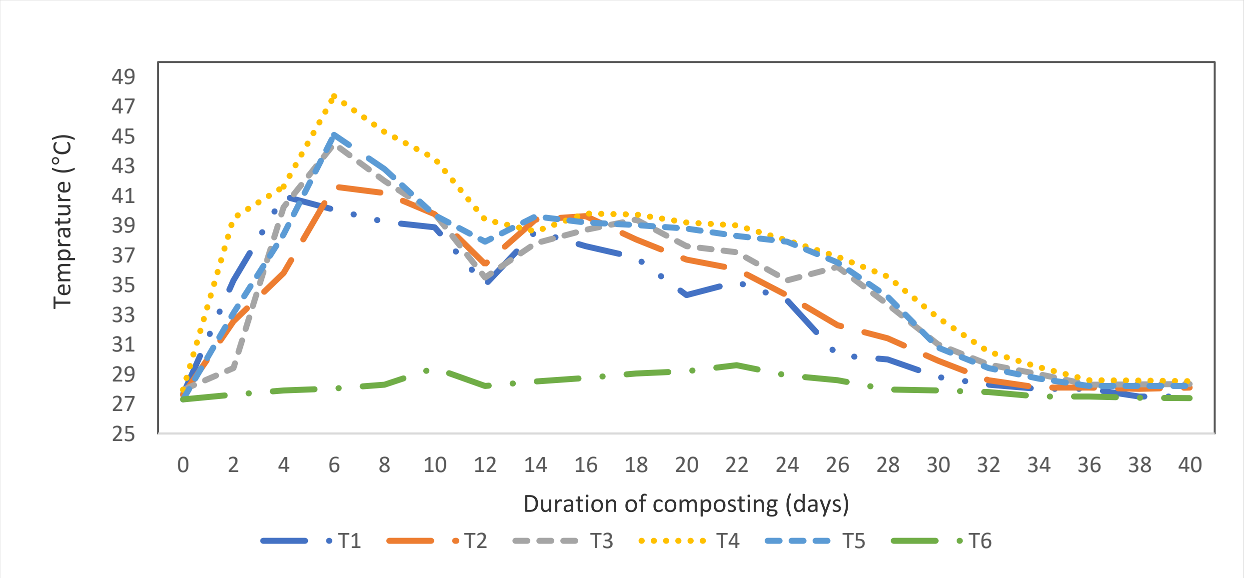


Fig. 6. Temperature monitoring during composting process.

Table 4. The mean value ±standard deviation (p<0.05) between the different treatments for maximum temperature.

Treatment	Mean	Std. deviation	Sig.
T_1	41.0	0.525	b
T_2	41.6	0.361	b
T_3	44.5	0.361	c
T_4	47.7	0.557	e
T_5	45.6	0.458	d
T_6	29.6	0.361	a

Compost pH and electrical conductivity (EC)

The initial pH values of treatments T_1, T_2, T_3, T_4, T_5 and T_6 were 6.05, 6.14, 6.27, 6.9, 7 and 7.45 respectively as shown in Fig. (7a).

The pH range between (7-8) may be suitable for microbial growth and organic matter degradation as in the two treatments T_4, T_5 where rapid degradation of organic matter began from the first week and the pH values decreased as a result and the production of organic and inorganic acids were quickly used and the pH increased.

In the remaining treatments, the pH started to rise from the first week and then after a while it started to decrease until it reached stability due to metabolic activities and microbial respiration.

pH increased to 8.54 in treatment T_6, this value can be explained by ammonia production and organic mining. This is consistent with what was reported by Chung et al. (2021), who suggested that too low or too high a pH is not conducive to effective composting.

As for electrical conductivity (EC) as shown in Fig. (7b), it showed that conductivity values gradually increased. This increase can be considered as a result of the release of mineral ions during the degradation of organic matter and later decreased because during the production process, salt ions and organic acids were converted into humus.

Peng et al. (2023) supported this increase in electrical conductivity until the end of the composting process.

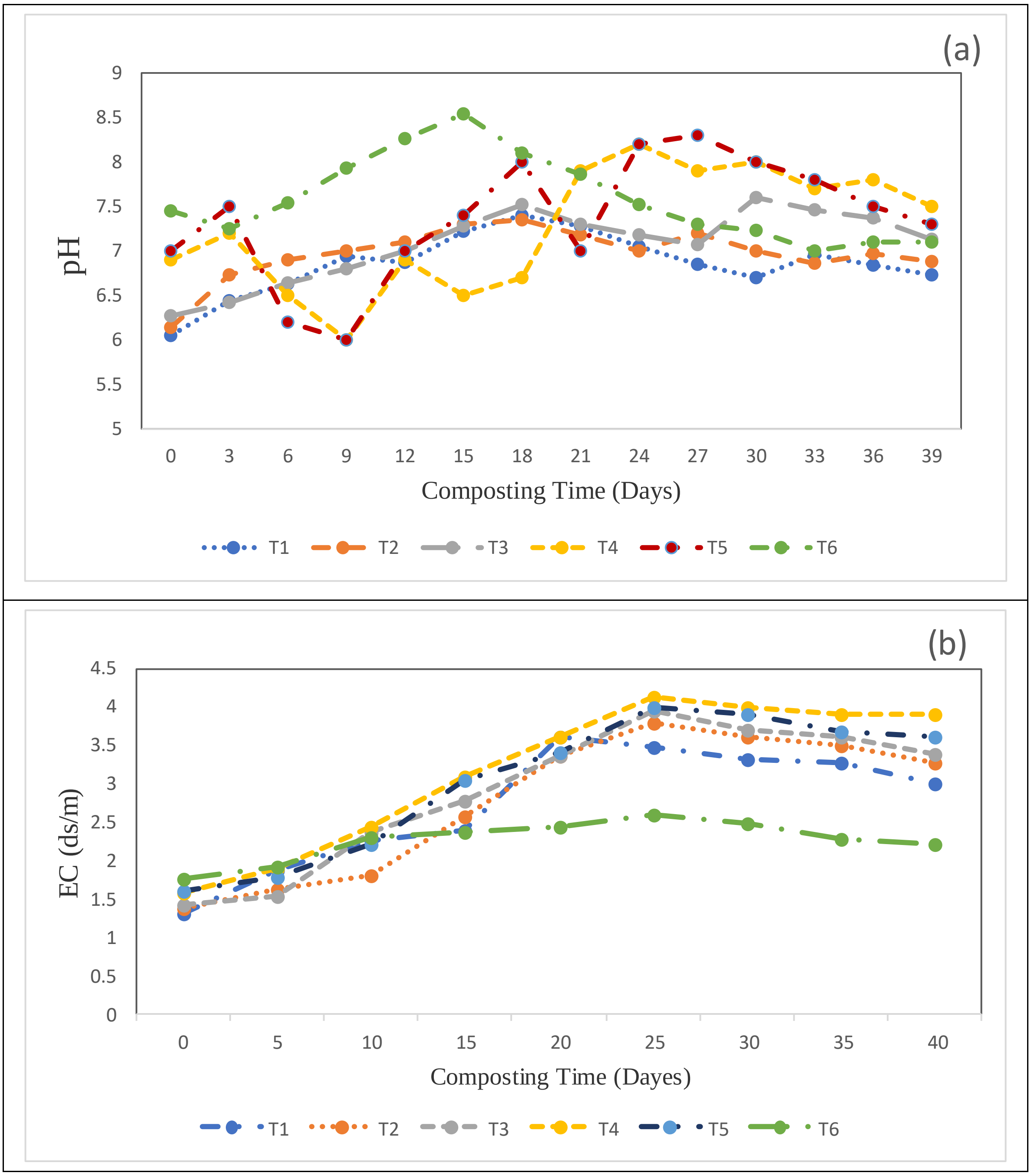


Fig. 7. Temporal changes in the pH (a), electrical conductivity (EC) (b), during composting process.

Second experiment

Temperature

In the second experiment, after adding used oil and inoculum, the temperature reached the maximum in each treatment, with differences between the treatments. The temperature of treatments T_{2-1} and T_{2-2} (adding used oil) reached the thermophilic phase (>50°C) on days 2,3 and continued for 5 days in treatment T_{2-1} (50:50) and reached its highest temperature of 58.74°C on the 7th day of the experiment (Fig.8b).

Treatment T_{2-2} (60:40) recorded the highest temperature of 55.7°C on the 7th day. The thermophilic phase continued for 4 days (Fig.8c), then the temperature began to drop gradually until the end of the experiment. All thermophilic microorganisms were enhanced and became more active, meanwhile all the pathogens could be completely inhibited and the composing process occurred in an ideal way and directed to maturation, this is consistent with previous studies (Koura et al., 2020; Putranto and Chen, 2017).

The compost matured in T_{2-1} and T_{2-2} treatments after 18 days and reached its final form compared to the remaining treatments which took 25 and 40 days, as a result of the adaptation of the microorganisms that are converted into compost faster to the cooking oil used as nutrients compared to other treatments.

Treatments T_{3-1} and T_{3-2} (adding compost as inoculum) reached the thermophilic stage (>50°C) on the 7th day. The temperature continued to be greater than 45°C in treatment T_{3-1} for 5 days, reaching its highest temperature of 52.7°C on the 6^{th} day of the experiment.

The T_{3-2} treatment reached its highest temperature of 50.5°C on the 7th day of the experiment. The temperature began to drop gradually to the end of the experiment, as the compost matured 25 days after the beginning of the study, compared to the control treatment which took 40 days (Fig.8a).

The temperature initially increased due to the rapid degradation of easily biodegradable organic matter, as microorganisms used organic substances to obtain their energy and create the growth of new microbial cells. The continuous addition of used oil led to an increase in the reduction of volatile solids. Microorganisms have preferred the oil added to other sources of carbon in the mixture. The longer the period of higher temperature, the greater the decrease in the total volatile solids.

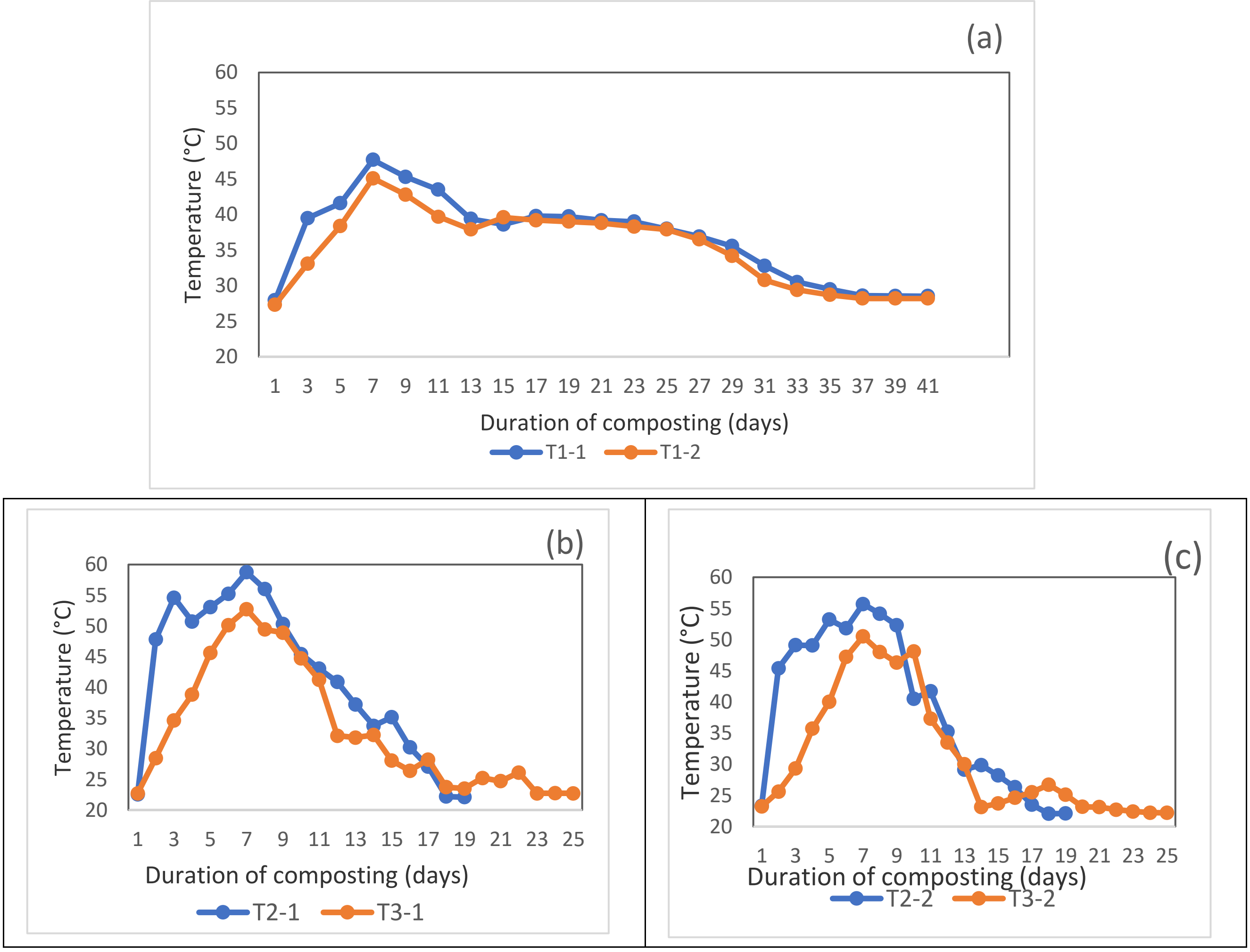


Fig. 8. Temperatures monitoring during composting process (a) control treatment, (b) 50:50 treatment, (c) 60:40 treatment.

According to previous studies (Tuzel et al., 2020), under high temperatures, the degradation of fat, proteins and complex carbohydrates is accelerated, meaning that more carbon will become bioavailable and this explains the higher temperatures as a result of the addition of used oil.

As a result of adding used oil and compost as inoculum led to an increase in temperature over the control treatment by 23.5% and 11.9%, respectively, thereby reducing the maturity period of the compost from 40 days to 18 and 25 days respectively.

Table 5. The mean value ± standard deviation ($p<0.05$) between the different treatments for maximum temperature (Exp.2).

Treatment	Mean	Std. deviation	Sig.
T_{1-1}	47.7	0.656	b
T_{1-2}	45.1	0.173	a
T_{2-1}	58.74	0.175	f
T_{2-2}	55.7	0.361	e
T_{3-1}	52.7	0.458	d
T_{3-2}	50.5	0.436	c

pH

During the initial phase of the composting process there were decrease in pH values due to the degradation of organic matter and the production of organic and inorganic acids due to the activity of microorganisms. This is indicated by the results of changes in pH values in this experiment in Fig (9), which agrees with Koura et al., (2020). The decrease in pH values may also be due to the production of carbon dioxide (CO_2) and increased concentration of organic acids from microbial activity (Varma et al.,2017).

During the successful compost processing and as a result of good ventilation, acids degrade rapidly and are themselves used by the microbial community leading to a rise in pH values.

High pH values can also be explained as a result of mineralization of organic matter and generation of ammonia (NH_3) through microbial activities which agree with Hwang et al. (2020).

During the thermophilic phase and as a result of high temperature the pH remains in the weak alkaline range or acid and the possibility of this occurrence is due to the loss of nitrogen as a result of ammonia (NH_3) emissions and this was confirmed by Raza et al., (2021) and Zhang et al., (2017). But at the end of the compost process, as a result of the microbial nitrification process, the ammonia nitrogen volatilizes and hydrogen is released, so the pH values are slowed down.

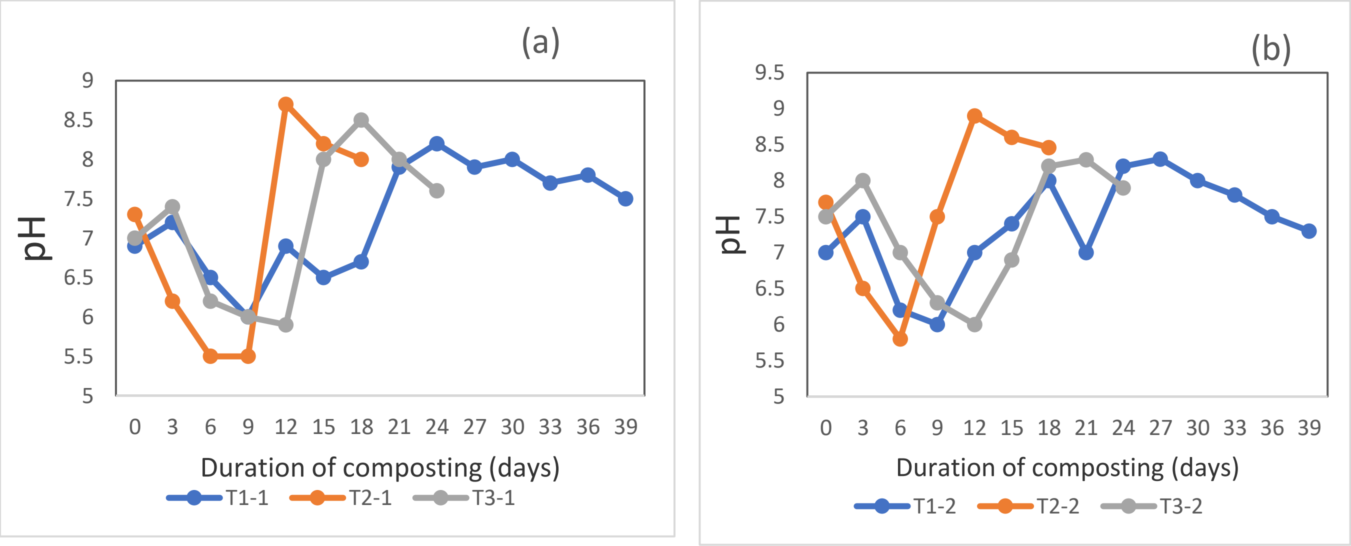


Fig. 9. Effect of carbon source on pH (a) 50:50 treatment, (b) 60:40 treatment.

Table 6. The mean value ± standard deviation ($p<0.05$) between the different treatments for final pH (Exp.2).

Treatment	Mean	Std. deviation	Sig.
T_{1-1}	7.5	0.361	ab
T_{1-2}	7.3	0.469	a
T_{2-1}	8	0.362	bc
T_{2-2}	8.46	0.235	c
T_{3-1}	7.6	0.356	ab
T_{3-2}	7.9	0.223	abc

Electrical conductivity (EC)

Fig (10) shows the changes in electrical conductivity (EC) for all treatments. This data indicates that the EC in the first phase of the composting process increased in all treatments. This can be explained by the fact that during the degradation of organic matter mineral ions such as phosphates, ammonium, potassium and other cations are released. Then values gradually decreased until the end due to ammonia volatilization and mineral salts deposition.

This is agreed with the results studies of Ramnarain et al. (2019) and Varma et al. (2017) that showed that increased electrical conductivity due to the degradation of organic matter and the release of minerals such as P, K, Mg, Ca, which are Interchangeable in available formats on a cations image.

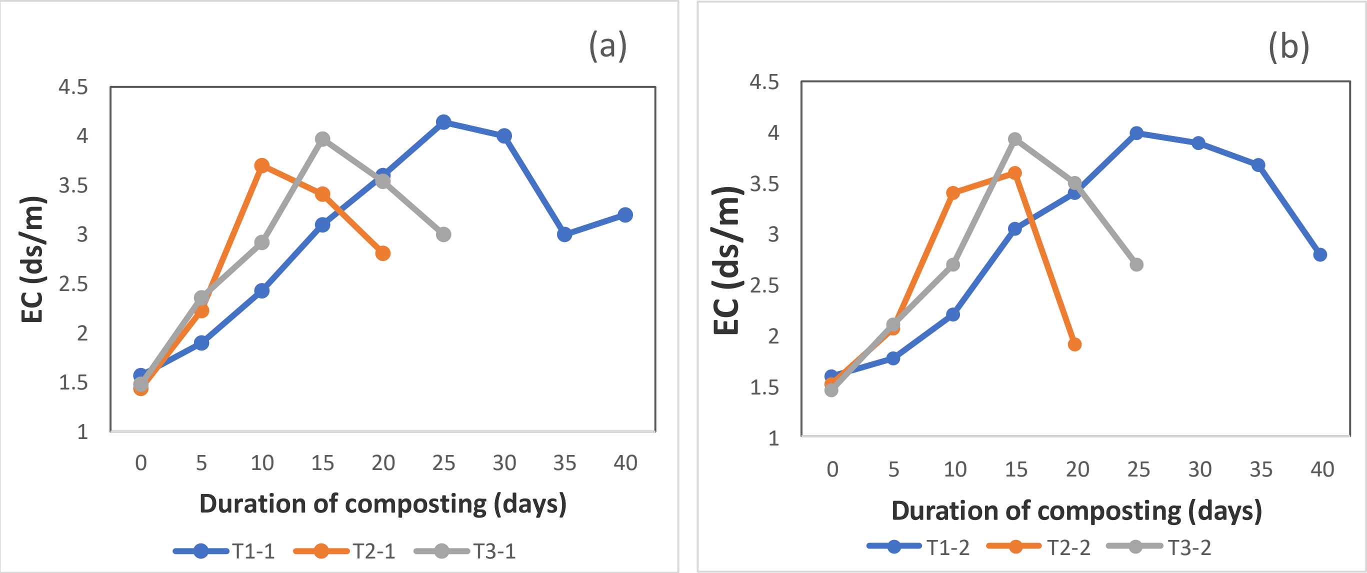


Fig. 10. Effect of carbon source on EC (a) 50:50 treatment, (b) 60:40 treatment.

Table 7. The mean value ± standard deviation ($p<0.05$) between the different treatments for final EC (Exp.2).

Treatment	**Mean**	**Std. deviation**	**Sig.**
T_{1-1}	3.9	0.387	c
T_{1-2}	3.6	0.280	bc
T_{2-1}	3.2	0.269	ab
T_{2-2}	2.8	0.410	a
T_{3-1}	3.5	0.211	bc
T_{3-2}	3.3	0.354	abc

Total Carbon (TC), Total Nitrogen (TN) and the C: N Ratio

The initial C: N ratio is considered a major and important factor to ensure the success of the composting process. The optimal ratio is between 25-35%, so it was calculated before the experiments started and set at 30%.

Their decline from this ratio inhibits microbial activity due to insufficient carbon source available and results in slow and incomplete degradation of raw materials, but when increased, indicates inadequate nitrogen supply, which limits microbial metabolism.

With the passage of time and the progress of the composting process, the C:N ratio decreases due to mineralization of the substrates or an increase in the total nitrogen concentration after the decomposition of carbon and the deterioration of the nutrient material until the end of the composting process as mentioned by Esmaeili et al. (2020).

C:N ratio less than 20 is an indicator of maturity, which may be due to the decomposition of organic matter as organic carbon deteriorates and total nitrogen increases (Kim et al., 2017).

Temperature change, moisture content, pH, C:N ratio, electrical conductivity are the end indicators of the composting process. The final samples were therefore analyzed to indicate the evaluation of the characteristics of the final composting materials for all treatment. The final analysis of the samples indicated that there were significant differences in some characteristics and no moral differences in some characteristics as shown in Table (8).

Table 8. The properties of the final compost materials.

Treatment	Moisture content %	Total carbon % (TC)	Total Nitrogen % (TN)	C:N ratio	Organic matter (%)	P (%)	K (%)	pH	EC (ds/m)
T_{1-1}	43±3 bc	29.6 ±0.229 a	2.22 ±o.225 b	15.4±1.82a	74.91±1.49 d	0.64 ±0.13 b	0.88±0.25 a	7.5 ±0.361 ab	3.9±0.387 c
T_{1-2}	39±1.4 ab	30.1±0.278 a	2.018 ±0.158 b	15±1.28a	77.4±2.61 d	0.234± 0.05 a	0.78± 0.27 a	7.3±0.469 a	3.6±0.280 bc
T_{2-1}	33±2 a	32.89±0.553 c	1.92 ±0.260 a	17.1±1.05 b	63.73±1.53 b	0.31±0.07 a	0.70±0.13 a	8±0.362 bc	3.2±0.269 ab
T_{2-2}	35±0.8 a	30.74±0.33 b	1.74 ±0.252 a	17.7±1.3 b	68.93±1.73 c	0.231±0.04 a	0.74±0.13 a	8.46±0.235 c	2.8±0.410 a
T_{3-1}	40±4 b	31.12±0.242 b	2.1 ±0.3 ab	14.8±1.4a	46.7±2.2 a	0.28±0.08 a	0.86±0.09 a	7.6±0.356 ab	3.5±0.211 bc
T_{3-2}	45±1.3 cd	30.09±0.193 a	2.194 ±0.296 ab	13.7±1.8a	45.2± 0.5 a	0.228±0.06 a	0.83±0.12 a	7.9±0.223 abc	3.3±0.354 abc

Conclusion

The results of this study showed that during composting process the moisture content remained within the optimal range due to the balance between the water resulting from the respiration of microbes and the water lost with the exhaust gas. While increasing the amount of bioavailable carbon by adding used oil enhanced the biodegradation process resulting in a further reduction of the moisture content (33%).

The heat generated by the degradation of organic matter raised the temperature during the three thermal phases. The addition of the inoculum reduced the delay phase and increased the rate of temperature rise, while the addition of used oil accelerated the degradation of fat, proteins and complex carbohydrates, making more carbon biologically available to maintain longer periods of high temperatures, thus reducing the compost maturation period to 19 days.

A higher decrease in total nitrogen was observed in the used oil treatment compared to the other treatments, as it reached 1.74%.

Consent for publication:

All authors declare their consent for publication.

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The author declares no conflict of interest.

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