EVALUATION OF STABILITY PARAMETERS FOR COMPOSTING OF SOLID WASTE PRODUCTION AND CHARACTERIZATION OF COMPOST

Hussein N. Abd [1] Hussein M. Flayeh [2]
Researcher Assist. Prof.
Dept. of Environ. Engine. Coll. of Engine. , University of Baghdad, Baghdad, Iraq,
hussein.juma2011m@coeng.uobaghdad.ed[1]: Hussain-altemmimi@coeng.uobaghdad.edu.iq[2]

ABSTRACT

The compost product enhances soil quality, lowers erosion, and aids in the reduction of plant diseases without having a negative influence on the environment. The possibility for compost recovery from organic waste, fruit waste, agricultural residues, domestic garbage, and animal manure was examined in this study. These wastes are composted in a five-week aerobic -pile composting process. The temperature, pH, moisture, electrical conductivity, carbon to nitrogen ratio (C/N-ratio), nitrification index (NH4-N/NO3-N), and NPK (Nitrogen, phosphorous, and potassium) value of the finished compost were all measured both during and after the composting process. These physio-chemical characteristics and parameters that affected the composting process included temp., pH, moisture, and electrical conductivity.The results revealed long - term negative impacts characteristics for moisture content, electrical conductivity (reached 1.5-2.34 dS/cm), total organic carbon, C/N ratio (reached 17.3-13.5), and increase in nitrogen content per unit material for the more, with composting time the nitrification index NH4+/NO3-ratio decreased by less than 0.5, as with overall increasing PH profiles. pH-value varying from (4–8) during the composting process, and GI values greater than 90 at the conclusion of the composting period. The bio-pile R3 was found to be the most helpful for composting, according to the data. It maintained the highest temperature for the longest period of time (52–60 oC), then gradually dropped to ambient temperature, which is seen as a sign that the composting process had ended and the finished compost was a mature and stable product.

Keywords: solid waste composting, C/N ratio, microorganisms, stable and mature, climate action, responsible consumption and production

تقييم معايير الاستقرار لتحويل النفايات الصلبة إلى سماد إنتاج وتوصيف السماد

حسين نجم عبد [1] حسين مجيد فليح [2]
باحث استاذ مساعد
قسم الهندسة البيئية /كلية الهندسة / جامعة بغداد

المستخلص

يعزز منتج السماد العضوي جودة التربة ويقلل من التعرية ويساعد في الحد من أمراض النبات دون أن يكون له تأثير سلبي على البيئة. تم في هذه الدراسة فحص إمكانية استعادة السماد العضوي من النفايات العضوية، ومخلفات الفاكهة، والمخلفات الزراعية، والقمامة المنزلية، وروث الحيوانات. يتم تحويل هذه النفايات إلى سماد في عملية تسميد هوائية مدتها خمسة أسابيع. قيمة درجة الحرارة، ودرجة الحموضة، والرطوبة، والتوصيل الكهربائي، ونسبة الكربون إلى النيتروجين (نسبة C / N)، ومؤشر النترجة (NH4-N / NO3-N)، وNPK (النيتروجين والفوسفور والبوتاسيوم) تم قياس جميع السماد العضوي أثناء وبعد عملية التسميد. تضمنت الخصائص والمعايير الفيزيائية والكيميائية التي أثرت على عملية التسميد درجة الحرارة، ودرجة الحموضة، والرطوبة، والتوصيل الكهربائي، وكشفت النتائج عن خصائص التأثيرات السلبية طويلة المدى لمحتوى الرطوبة، والتوصيل الكهربائي (وصلت إلى 1.5-2.34 ديسي سيمنز/ سم)، المجموع. الكربون العضوي، نسبة C / N (وصلت إلى 17.3-13.5)، وزيادة محتوى النيتروجين لكل وحدة مادة لأكثر، مع وقت التسميد، انخفض مؤشر النترجة NO3 / + NH4 بنسبة أقل من 0.5 ، كما هو الحال مع زيادة الملامح PH الإجمالية. تتراوح قيمة الرقم الهيدروجيني من (4-8) أثناء عملية التسميد، وقيم GI أكبر من 90 في نهاية فترة التسميد. تم العثور على كومة R3 ليكون الأكثر فائدة في التسميد، وفقًا للبيانات. حافظت على أعلى درجة حرارة لأطول فترة زمنية (52-60 درجة مئوية)، ثم انخفضت تدريجيًا إلى درجة الحرارة المحيطة، وهو ما يُنظر إليه على أنه علامة على انتهاء عملية التسميد وأصبح السماد النهائي منتجًا ناضجًا ومستقرًا.

الكلمات المفتاحية: سماد النفايات الصلبة، نسبة C/N، الكائنات الحية الدقيقة، مستقرة وناضجة، العمل المناخي، الاستهلاك والانتاج المسؤولان.

Received:27 /9/2022, Accepted:28/12/2022

INTRODUCTION

Massive levels of nonhazardous municipal solid waste (MSW) production have increased environmental and public health risks, as well as economic and social issues (1,7). Landfilling is the final disposal method most frequently used. Landfills are solid waste management facilities that pose significant environmental dangers due to gas emissions and the production of leachate, which have the potential to contaminate the air, water, and land (10, 33, 39). One of the most challenging waste streams to dispose of in a landfill is the organic portion of MSW, which accounts for around 40% of the residential waste stream and whose degradation results in landfill leachate and methane emissions (26,30,34,35). Municipal solid waste can easily be transformed to energy sources through composting thanks to the biodegradable portion (27,36). Composting has consequently grown in significance as a treatment method for MSW's biodegradable organic fraction. Any degradable substance can be composted using a biological process that is environmentally benign (6). Degradable organic waste is transformed into a stabilized product that can be used as a source of nutrients and soil conditioner. Microorganisms use the organic solid waste compounds in composting as sources of carbon and nitrogen. Microorganisms change leftover plant organic matter into increasingly complex humic-like substances by combining it with molecules of microbial origin (32). The non-biodegradable solid waste must be removed prior to the composting process using a variety of pretreatment techniques. First, the biodegradable portion is treated. In order to provide the ideal circumstances for composting, the first step in the composting process, known as pre-processing, entails eliminating undesirable material and size reduction, modifying moisture content, adding bulking agents, and mixing organic waste material. In the second stage, known as the high-rate phase, microorganisms break down complex organic matter into simple organic matter and minimize biodegradable volatile substances. This stage is divided into two phases, each of which is distinguished by a distinct group of microorganisms. The temperature rises to 45 °C in the first step when mesophilic microbes utilize carbon sources. The compost's temperature will then rise to 70 °C as a result of the breakdown, at which point thermophilic microorganisms begin to grow. To inactivate pathogens and plant seeds, the thermophilic phase's high temperature is crucial. The temperature falls below 40°C during the third stage, known as the curing phase, as a result of a decline in microbial activity, allowing organic waste to begin stabilizing and maturing. Water, carbon dioxide, and stabilized matter are the byproducts of a composting process (20,44).Prior to the composting process, the classification of municipal solid waste is crucial to balancing the recipe's requirements for moisture content for aeration, pH for a suitable microbial environment, and carbon to nitrogen ratio for healthy microbial development (2). In this study, an aerobic compost system was used to provide soil amendment and reduce the amount of organic waste that was dumped in sanitary landfills. Investigated and evaluated were the primary determinants of the biodegradation of organic solid waste, including the types of composting materials, particle size, temperature, moisture content, electrical conductivity (EC), C/N ratio, germination index, and NPK in aerobic composting.

MATERIALS AND METHODS

Raw waste and bulking agent : The carbon source for each mixture of horse manure (HGM), sheep manure (SHM), and activated sludge (AS), collected in clean plastic bags, was mixed together and chopped into smaller pieces. The agricultural residues included dry and wet leaves and branches of trees, fruit residues, litter (FW), and agricultural residues from agricultural waste. To balance the carbon-to-nitrogen ratio of the composting material, an appropriate amount of mature compost, horse manure (HGM), sheep manure (SHM), and activated sludge (AS) were added to the pile. The raw materials' characteristics are displayed in the table (1).

Table 1. Characterize of raw material (13)

Material	% oisture	% Carbon	% Nitrogen	C/N Ratio
FW	80.0	56.0	1.4	40
AL	38.0	48.6	0.9	54
GFW	53.0	36.0	2.4	15
SHM	69.0	43.2	2.7	16
HGM	72.0	48.0	1.6	30
AS	25	33.6	5.6	6

The mature compost also served as a source of microorganisms to simplify the composting process. The composting process consisted of six experiments lasted about five weeks, with the following raw waste material as shown in table (2). The Cornell Institute for Waste Management's Excel program was used to calculate the actual C:N ratios (13;29). For the initial mixtures, the C: N ratios were R2, R3, and 20/1. The other blends, P1, P2, and P3, have a 30:1 ratio. Each cell had a total weight of 25 kg and 60% moisture content in the mixture

$$G = \frac{M_1Q_1+M_2Q_2+M_3Q_3}{Q_1+Q_2+Q_3} \quad \text{........ (1)}$$

Where Q is mass of material n (wet weight basis), G is moisture goal (%), and Mn is moisture content (%) of material n

$$R = \frac{Q_1(C_1\times(100-M_1))+Q_2(C_2\times(100-M_2))+\cdots}{Q_1(N_1\times(100-M_1))+Q_2(N_2\times(100-M_2))+\cdots} \quad \text{......(2)}$$

Table 2. The composition of the composting mixture

Experiment no.	Mixture	Ratio %	Weight (Kg)
R1	FW:AL:GFW:SHM	36:32:22:10	9:8 :5.5:2.5
R2	FW:AL:GFW:HGM	42:22:28:8	10.5:5.5:7:2
R3	FW:AL:GFW:AS	52:38:5:5	13:9.5:1.25:1.25
P1	FW:AL:GFW:SHM	26:14:52:8	6.5:3.5:13:2
P2	FW:AL:GFW:HGM	28:6:9:57	7:1.5:14.25:2.25
P3	FW:AL:GFW:AS	44:30:12: 14	11:7.5:3.5:3

where R is C/N ratio of compost mixture, Q_n is mass of material n (wet weight basis), Cn is carbon (%) of material n, N_n is nitrogen (%) of material n, and M_n is moisture content (%) of material n. By simplifying and rearranging the above equation, the mass of the third material required would be Eq. (3.3)

$$Q_3 = \frac{RQ_1N_1(100-M_1)+RQ_2N_2(100-M_2)-Q_1(C_1\times(100-M_1))+Q_2(C_2\times(100-M_2))}{C_3(100-M_3)-RN_3(100-M_3)} \quad \text{.....(3)}$$

Q3 is third article

Composter design

Due to its capacity to hold compost in a sturdy structure, effectiveness, and stability, the in pallets approach was chosen for this investigation. A compost pallet of laboratory size was created. The pallets' perforations, which are 55 cm, long, 36 cm wide, and 62 cm high, allow air to enter, oxygen to supply, and discharge the gaseous emissions and heat of decomposition. Moving compost material from bin to bin on a two days basis makes rapid compost, and to provide aeration. The turning method is used to make more suitable for food waste and compost quickly. The pallets was provided by aluminum plates cells surrounded by a copper net (fly deterrent) and at the bottom of each cell there is an aluminum basin (10 cm high) and tilted at an angle of 15 degrees, and at the end of the basin is a hole of diameter (5in) and to collect a leached, if any. Approximately 25 kg of solid waste material was composted in each pallet. The useful volume of the bioreactor is 59044 cm^3, were filled to 75% of their volume details are shown in figure (1), and (2) Experimental work site in Baghdad.

Fig1. Fertilization system

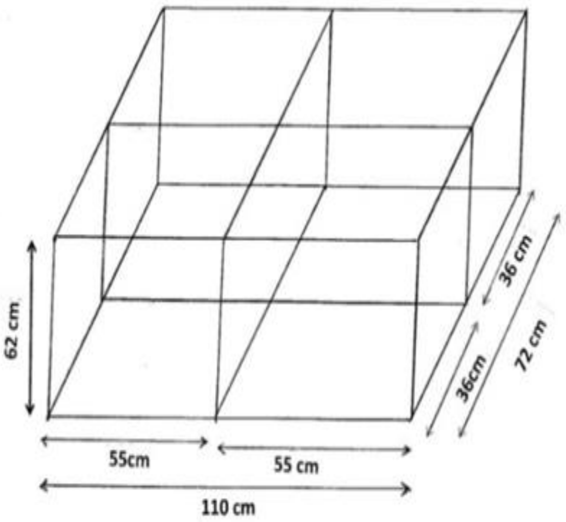

Fig 2. Dimensions and design of the system

Measurement of physicochemical properties of compost: There is a five-week composting process. In order to create a homogenized sample of the composter's pallets, 200 gram samples were taken throughout the composting process from various points, primarily the top, middle, and bottom. After the composting process had been going on for 0 days, 1, 5, 10, 15, 20, 25, 30, and 35 days, triplicate samples were taken and stored at 4°C for biological analysis of the wet samples within 2 days. The sub-samples were promptly air dried, crushed to pass through a 0.2 mm filter, and then stored for additional physicochemical study. Temperature, pH level, moisture content, and electrical conductivity (EC) were continuously monitored during the composting process using the Kjeldahl method (28). To the completion of the composting process, total nitrogen, NH4+-N, NO3-N, and total organic carbon were monitored together with the compost pile's temperature on a regular basis every 5 days (TOC) using the Mohee method (33) . At the conclusion of the composting process, the Nitrogen-Phosphorus-Potassium (NPK) value of the final compost was calculated. A metric of biodegradable organic matter was COD by the dichromate method (47). The analytical procedure for determining the outcome of the physical, chemical, and biological properties of the mixed material is described below.

RESULTS AND DISSCUSCION

Particles size: The particle sizes of materials have a greater impact, so lowering the size of waste materials will increase the surface area and improve microorganism activity and accelerate the composting speed. But on the other hand, too small waste materials also reduce the oxygen content and prevent the flow of air in composting, then lowering micro-organism activity composting speed (29). various sizes of materials, should be decreased by shredding the organic components According to the ideal particle size for composting is between 1 and 2 inches in diameter. As it was adopted in all six composters R1, R2, R3, P1, P2, and P3 respectively.

Carbon to nitrogen ratio(C/N Ratio)

When evaluating the stabilization and decomposition of organic waste during composting, the change in the C/N ratios is frequently used. Living microorganisms that use the carbon in the organic matter as a source of energy and the nitrogen in the mixture to form cell structures decompose the organic material in compost mixtures. The compost mixture may become too heated, killing the microorganisms, or it may enter anaerobic conditions, producing a stench-filled mess, if the N concentration is too high. The compost mixture won't heat up if the N content is too low(17:18). In R1, R2, R3, and P1, P2, P3, the range for C/N ratios at the beginning of the composting process is roughly 30/1 to 20/1 (often recommended). The C/N ratio drops during the course of the five-week composting process, with the final compost's ratios being (15; 17.3; 13.5), and, (18.9,16.6,17.1) as shown in the table (3). Results showed that primary stabilized composts were aged first, and then highly matured compost was produced. When the C/N ratio is 17 or below, compost may be deemed mature (21; 43). All compost mix's carbon content was reduced by turning it into carbon dioxide and water. Due to the transformation of nitrogen into nitrate and then ammonia (NH3), a decrease in nitrogen was anticipated (NO_3). Because only a small amount of organic nitrogen is actually transformed, this trend cannot be seen (38).

Table 3.Carbon %, Nitrogen %, and C/N Ratio in initial and final composting

Material mixtures	Carbon		Nitrogen		C/N	
	initial	final	Initial	Final	initial	final
R1	77.84	52.36	2.59	3.5	30.1	15.0
R2	79.21	60.52	2.6	3.5	30.5	17.3
R3	79.47	53.87	2.65	3.99	30.0	13.5
P1	74.21	61.35	3.7	3.24	20.1	18.9
P2	79.35	69.54	3.96	4.2	20.0	16.6
P3	89.21	80.24	4.45	4.7	20.0	17.1

Temperature

Figure (3) displays the compost mixture's measurement. The temperature rises from the ambient temperature at the start of the composting process to a range of 52–60 °C, reaching a peak value of 60 °C and 58 °C for R3 and P1 on the eighth and ninth days, respectively. R1, R2, P2, and P3 had respective temperatures of 55°C, 55°C, 50°C, and 50°C(46). The temperature then gradually dropped to the surrounding air towards the conclusion of the composting process. The activity of the thermophilic bacteria present in the compost mixture was what caused the abrupt increase in compost temperature during the first few days(47). These bacteria release heat throughout the composting process by breaking down the organic carbon in the compost mix.The temperature drop that occurs 25 to 35 days into the composting process may be caused by mesophilic microbes predominating over thermophilic microbes as they break down the remaining organic matter in the compost mix (11). According to numerous studies, the ideal composting temperature range is between 52 and 60 °C (9; 16; 21) and(5).

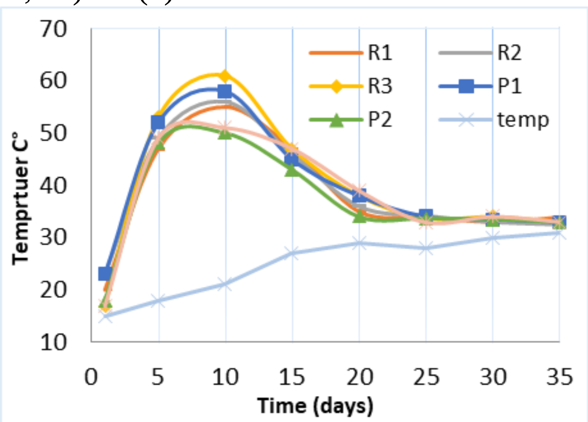

Figure 3. Temperature profile of waste mixture Vs. Time

Moisture content

The initial compost mix was prepared to have relatively high moisture content (60%, 58%, 61%, 60%, 58%, and 56% for R1, R2, R3, P1, P2, and P3, respectively) to maintain the thermophilic phase (43). The changes in moisture content in the compost gradually decreased from this initial compost mix. The compost mixture's temperature will decrease due to the evaporation of moisture from the compost, compost drying, and perhaps heat loss. The decomposition of organic materials in the compost mixture is indicated by the moisture content's decline (40). As shown in Figure(4), the moisture content steadily reduced at the end of the composting process, reaching 53%, 52%, 51%, 53%, 54%, and 56% for R1, R2, R3, P1, P2, and P3, respectively.

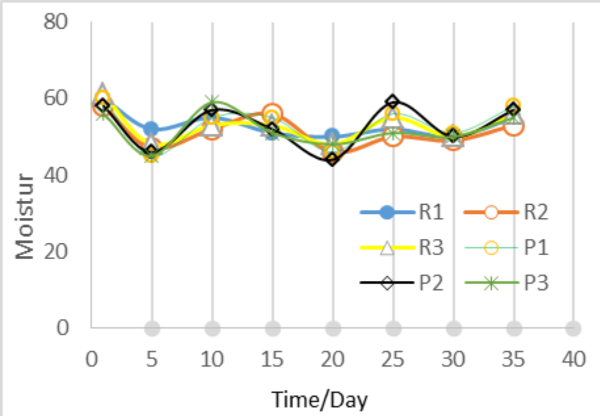

Figure 4.Moisture Profiles of waste Mixture Vs. Time

pH value

The compost mixture's initial average pH values ranged from 5 to 6. These values have no impact on the activity of the overall composting process. Due to anaerobic conditions in the compost mix, which lead to the synthesis of organic acid, pH values gradually decrease during the early stages of composting and reach 4 and 5 on day 4. Following this, the pH levels tend to return to neutral after 12 days due to the aeration caused by stirring the compost mixture, which created aerobic conditions and allowed the microbial activity to convert the acid to carbon dioxide as shown in figure (5). Because of the absorption of protons during the biodegradation of volatile fatty acids, the mineralization of organic nitrogen, and the production of carbon dioxide, the mineralization of amino acids, proteins, and peptides causes rises in volatile ammonia and also leads to an increase of pH-value to alkaline ranges (8; 31). During the chilling phase, the pH level decreases gradually and in mature manure, it achieves a value of 7 to 8 (16). This pH value is within the recommended range and suggests a high-quality fertilizer (6-8.5), which were equal to the findings reported by (4).

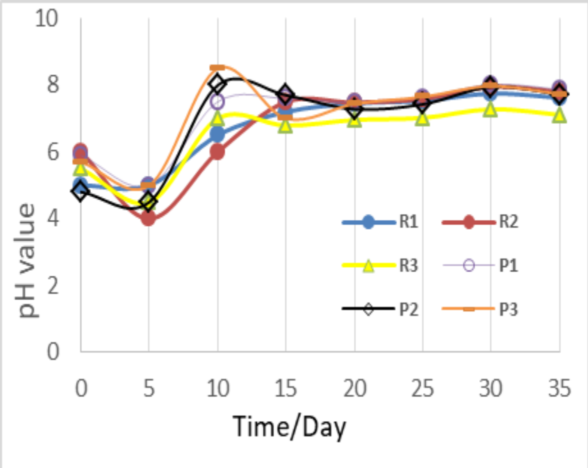

Figure 5. PH Profile of waste mixture Vs. Time

Electrical conductivity (EC)

The level of salinity in the composting mixture is indicated by the electrical conductivity value, which also reflects any potential consequences on plant growth from phytoxicity. According to (28), the significant increase in electrical conductivity value at the beginning of the composting process may be caused by the release of ammonium ions and mineral salts through the decomposition of organic matter. Electrical conductivity as shown in figure (6) was showing peak at the beginning of the composting process, with the highest value recording in mixtures R2 (8.05 dS.m1) (22). A decrease in electrical conductivity at a later stage of the composting process may be caused by the precipitation of mineral salts and the volatilization of ammonia.The decrease in electrical conductivity at ambient temperatures is depicted in Fig. (5). Mineral salt precipitation and ammonia volatilization are two possible causes for the lower EC values in the final stages of composting (37). After composting, the values for cells R1, R2, R3, P1, P2, and P3 stabilized at 2.23, 2.22, 2.35, 2.35, 1.55, and 2.04, which were equal to the findings reported by (3).

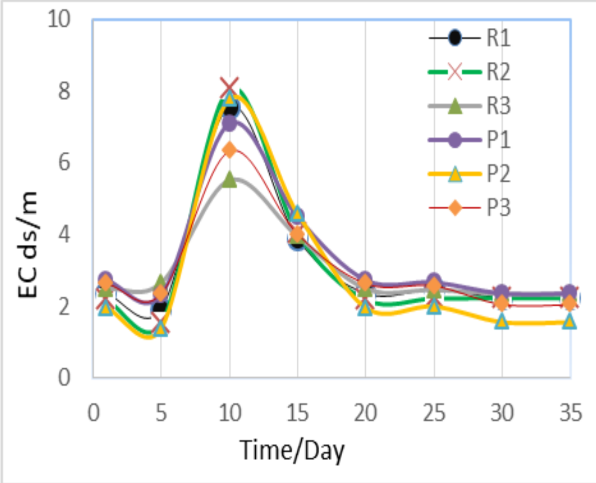

Figure 6. EC Profile of waste mixture Vs. Time

Chemical oxygen demand (COD)

The removal efficiency was 90.4%, 88%, 89.3%, 87.8%, 89.4%, and 89.6% in R1, R2, R3, P1, P2, and P3, respectively, and stabilized over the course of the composting process as shown in Fig. 7. The COD values dramatically decreased from 5410, 4760, 5060, 4350, 4720, and 5630 mg/l initially to 520,570, 540, 530, 500, and 588 mg/l This shows that during the first phase of the composting process, the easily biodegradable organic matter decomposed quickly, and more slowly during the second.Stage 1 (compost age between (0 and 2 weeks) and Stage 2 (compost age between 2 and 5 weeks) of the temporal profile of compost stability were categorized as active degradation and intermediate or stability period, respectively. In terms of the outcome, the drop in COD concentration levels over the course of two weeks is comparable to (17). A comparable result was reached (39).

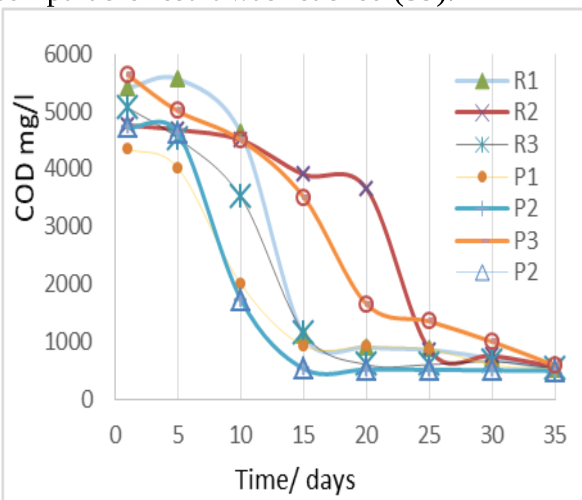

Figure 7. COD concentration vs time Vs. Time

Nitrogen content (NH_4^+, NO_3):

Figures 8 and 9 show the general pattern clearly. In the compost mixtures R1, R2, R3, P1, P2, and P3, extracts of fresh compost revealed high NH4-N concentrations of 1.2, 1.3, 1.08, 1.03, and 1.02 percent and very low NO3-N concentrations of 0.11, 0.24, 0.3, 0.1, 0.15, and 0.21 percent, respectively. As composting progressed, NH4-N levels generally decreased during the initial stages, but NO3-N levels significantly increased in late samples. On the other hand, during the maturity phase, a substantial improvement in NO3-N quantity was seen. Similar results were reported in 2006 by (12). The finding that bacteria necessary for nitrification were severely hindered by temperatures above 40°C (24) may help to explain this outcome.The maximum content of NH4 after 5 days in the thermophilic phase was recorded in compost mix R3. As the composting process progressed, the decrease in NH4 content coincided with an increase in NO_3^-, the nitrification process is usually rapid, and the NH4 generated as a result of ammonia is rapidly nitrated to NO_3^- (42). The final ammonia concentrations after five weeks were 0.15, 0.108, 0.12, 0.19, 0.2, and 0.13 percent

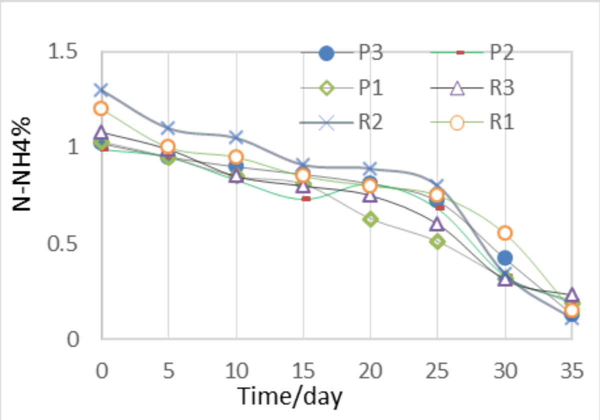

Figure 8. N-NH4 Profile of R1, R2, R3, P1, P2, and P3 Vs. Time

The first three days following fertilization see a significant spike in nitrite NO3 concentration, followed by a steady increase in nitrite levels that roughly stabilizes after 30 days. Nitrogen fixation, which moves in the opposite direction of nitrogen mineralization, always takes place concurrently (14). and the compost mix R1, R2, R3, P1, P2, and P3 had nitrate-nitrogen concentrations of 0.7, 0.83, 0.63, 0.67, and 0.13 after 35 days, respectively. Additionally, the proportion of inorganic forms, also known as the nitrification index (N-NH4+/N-NO3), was utilized to gauge the compost's stability and maturity. Maximum values were achieved during the early part of the composting process, which was proceeded by a substantial reduction during the cooling stage Figure 10. After the process in the acquired compost, the ratio of nitrification index was less than 1, with nitrate increasing and ammonia decreasing as composting progressed (as the ratio of N-NH4/N-NO3 was 0.2, 0.15, 0.14, 0.3, 0.29, and 0.19 for cells R1, R2, and P1, and respectively), the ratio being less than 0.5 very mature, (0.5-3) mature, and more than 3 immature (19). These findings concur with those of (15) about the relationship between ammonia and nitrate when compost is being produced. The same result was also published by (18).

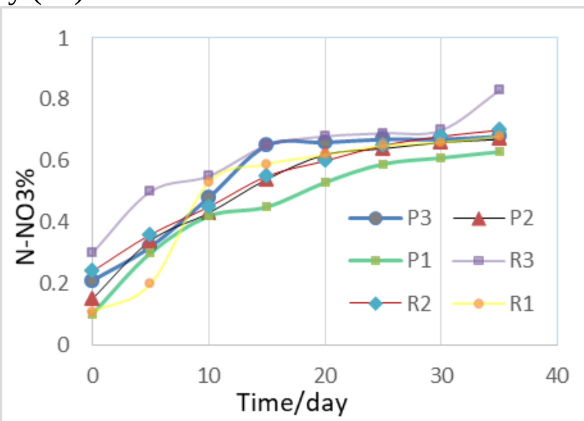

Figure 9. N-NO3 Profile of R1, R2, R3, P1, P2, and P3 Vs. Time

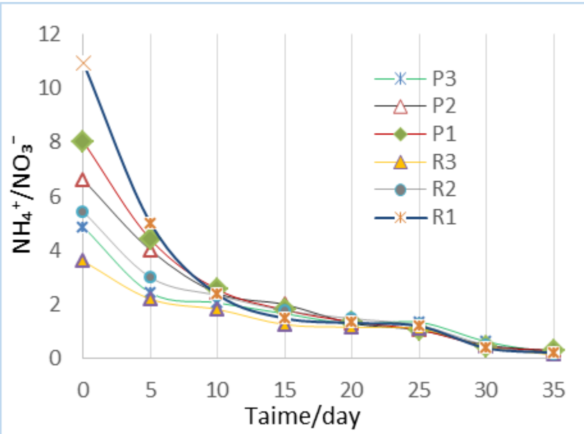

Figure 10. N-NH4/N-NO3 Profile of R1, R2, R3, P1, P2, and P3 Vs. Time

Phosphorous and Potassium content

The beginning and final potassium and phosphorus contents of compost are shown in Table 4. Phosphorous (P), which makes up between 0.1 and 0.4 percent of a plant, is crucial for energy transfer and storage, adventitious roots, earlier maturing, viability, and disease resistance. The consumption of phosphoric materials during cell development may be responsible for the decrease in phosphorus content which were equal to the findings reported by (23). Potassium concentrations in vegetative tissue typically range from 1 to 4% of dry weight basis. Potassium affects protein synthesis, nitrogen uptake, transpiration, and translocation in addition to water and energy balance. Comparing different compost mixes, compost mix R3 had the greatest beginning and final readings of potassium (K) content.Although not consistently, the K values may rise during the composting process. Due to the microbes' need for nutrients at specific times, which caused an increase and drop in potassium, the potassium level fluctuated over the course of the composting process. Additionally, increasing potassium content from increased microbial metabolism on organic materials encouraged a high incidence of conversion (25). It is therefore perfect for plant development. Compost should contain greater than 1% of both phosphorous and potassium (NPK).

Table 4. P and K levels in initial proportions and final composts

Mixtures	P %		K %	
	Initial	Final	Initial	Final
R1	0.82	0.63	1.65	2.88
R2	0.86	0.54	1.55	3.54
R3	1.68	0.98	2.62	3.99
P1	0.96	0.68	1.34	2.58
P2	0.68	0.45	1.1	1.95
P3	1.05	0.85	2.36	3.52

Germination Index (GI)

The maturity of the compost mix and sensitivity to excessive salt or the incidence of phytotoxicity was tested using the Germination Index value. The maturity of the combination is indicated by a number greater than 80%. (41). The differences in the composting mix's GI are shown in Table 5. Results reveal that, with the exception of mix P1, all of the mixtures had GI values above 80% at the conclusion of the composting process, indicating that phytotoxic chemicals had either completely lost their harmful effects or had at least lost their ability to hinder plant growth (45). In general, the breakdown of phytotoxic chemicals by microorganisms during composting is what causes the decrease in phytotoxicity, which were Similar to the findings reported by (1).

Table 5. Germination Index GI

mixture	Mean no of germinating seeds	Growth Index G (%)	Mean root length(c)	Root length Index L (%)	Germination Index GI (%)
R1	45	90	3.3	94.3	84.9
R2	47	94	3	85.7	80.6
R3	49	98	3.4	97.1	95.2
P1	43	86	3.2	91.4	78.6
P2	46	92	3.1	88.6	81.5
P3	47	94	3.2	91.4	85.9
CONTROL	50	--	3.5		

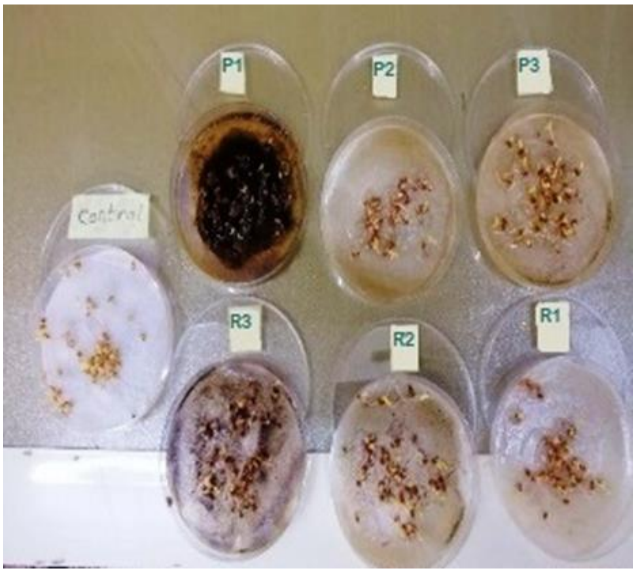

Figure 11. Laboratory images of germination factors

REFINANCES

1. Aseel N. A., F. M. Hassan, and N. H. Hyder. 2024. Evalution of microbial activity in organic solid fraction during composting process to biofertilizer using composting bin methods. Iraqi Journal of Agricultural Sciences, 55(6), 1927-1935. https://doi.org/10.36103/nn61g703

2. Adhikari, B. K., S. Barrington, J.Martinez, and S. King,. 2008. Characterization of food waste and bulking agents for composting. Waste Management, 28(5), 795-804.

3. Ali, H. H. and H M. Flayeh. 2023. Rotary in-vessel bio-converting of agriculture wases into compost. Iraqi Journal of Agricultural

Sciences, 54(5), 1433-1444. https://doi.org/10.36103/ijas.v54i5.1843
4. AL-Saedi, Z. Z., and J. A. K. Ibrahim, 2019. Aerobic municipal solid waste compost quality according to different layers of composting bioreactor. Association of Arab Universities Journal of Engineering Sciences, 26(3), 7-16.
5. Al-zubaidi, A., M., 2013, Solid wastes in-vessel composting for small communities. M.Sc. Thesis. University of Baghdad,21(2)19-22.
6. Al-Khafaji, A. M.H. H., K. D. H. Al-jubouri, F. Y. Baktash, I. J. Abdul Rasool, and Z. J. Al-Mousawi. 2024. Amelioration potato plant performance under drought conditions in Iraq by using titanium dioxide, and biodegrading, biodegradable treatments. Iraqi Journal of Agricultural Sciences, 55(6), 1885-1893. https://doi.org/10.36103/03fway21
7. Asase, M., E. K. Yanful, M. Mensah, , J. Stanford, and S. Amponsah, 2009. Comparison of municipal solid waste management systems in Canada and Ghana: A case study of the cities of London, Ontario, and Kumasi, Ghana. Waste Management, 29(10), 2779-2786.
8. Avnimelech, Y., M. Bruner, I. Ezrony, , R.Sela,, and M. Kochba, 1996. Stability indexes for municipal solid waste compost. Compost Science and Utilization, 4(2), 13-20.
9. Sarika D, J. Singh, R. Prasad, I. Vishan, V. S. Varma, and A. S. Kalamdhad 2014 Study of physico-chemical and biochemical parameters during rotary drum composting of water hyacinth. Int J Recycle Org Waste 3(3):9. https ://doi.org/10.1007/s4009 3-014-0063-1.
10. Bropp, V. R.,A. O.De Silva, C.Spencer, S. J. Brown , S. D. Catingan, , J. E. Smith, and J. W. Roy, 2021. Organic contaminants of emerging concern in leachate of historic municipal landfills. Environmental Pollution, 276, 116474.
11. Chen C, J. Kuo and Y. Chung 2012 Effect of matured compost as an inoculating agent on odour removal and maturation of vegetable and fruit waste compost. Environmental Technology, iFirst, 1–8
12. Chikae, M., R. Ikeda , K. Kerman, Y. Morita , and E. Tamiya, 2006. Estimation of maturity of compost from food wastes and agro-residues by multiple egression analysis. Bioresource Technology, 97(16), 1979-1985.
13. Cornell Waste Management Institute © 1996, Cornell University, Ithaca, NY 14853607-255-1187
14. Doublet, J., C. Francou , M. Poitrenaud, and S. Houot, 2010. Sewage sludge composting: Influence of initial mixtures on organic matter evolution and N availability in the final composts. Waste Management, 30(10), 1922-1930.
15. Eggen, T., and O.Vethe,. 2001. Stability indices for different composts. Compost Science and Utilization, 9(1), 19-26.
16. Beck-Friis, B., S.Smårs, , H. Jönsson, and H.Kirchmann, 2001. Structures and Environment. Journal of Agricultural Engineering Eesearch, 4(78), 423-430.
17. Varma, V. S., and A. S. Kalamdhad, 2013. Composting of municipal solid waste (MSW) mixed with cattle manure. International Journal of Environmental Sciences, 3(6), 2068-2079.
18. Gomez-Brandon M, C.Lazcano, J. Dominguez 2008. The evaluation of stability and maturity during the composting of cattle manure. Chemosphere. 2008;70(3):43644. doi:10.1016 /j.chemosphere. 2007.06.065. [PubMed: 17689588.
19. Gutser, R., T. Ebertseder , A. Weber, M.Schraml and U. Schmidhalter, 2005. Short-term and residual availability of nitrogen after long-term application of organic fertilizers on arable land. Journal of Plant Nutrition and Soil Science, 168(4), 439-446.
20. Haug, R. J. 1993. Edge-state transport and its experimental consequences in high magnetic fields. Semiconductor Science and Technology, 8(2), 131.
21. Huang, G., X. Wang, and L. Han, 2011. Rapid estimation of nutrients in chicken manure during plant-field composting using physicochemical properties. Bioresource Technology, 102(2), 1455-1461.
22. VanderGheynst, J. S., S. Pettygrove, T. M.Dooley, and K. A. Arnold, 2004. Estimating electrical conductivity of compost extracts at different extraction ratios. Compost science and utilization, 12(3), 202-207.
23. Ibrahim, J. A. K., I. S.Salman, , and T.F.Chyad, 2015.Wastewater bio-solids management for fertilizer quality using co-

composting process. journal of engineering, 21(1), 29-44.
24. Iglesias Jiménez E, V.Perez Garcia and Evaluation of city refuse compost maturity: a review. Biol Wastes. 1989.27(2):115–42. doi: 10.1016/0269-7483(89)90039-6.
25. Jamaludin, S. N., A. A Kadir, and N. W. Azhari, 2017. Study on NPK performance in food waste composting by using agricultural fermentation. In MATEC Web of Conferences Vol. 103, p. 05015. EDP Sciences.
26. Jokela, J. P. Y., R. H.Kettunen, K. M. Sormunen and J. A. Rintala, 2002. Biological nitrogen removal from municipal landfill leachate: low-cost nitrification in biofilters and laboratory scale in-situ denitrification. Water Research, 36(16), 4079-4087.
27. Jolanun, B., and S. Towprayoon, 2010. Novel bulking agent from clay residue for food waste composting. Bioresource technology, 101(12), 4484-4490.
28. Kalamdhad, A. S., and A. A. Kazmi, 2008. Mixed organic waste composting using rotary drum composter. International Journal Of Environment And Waste Management, 2(1-2),24-36.
29. Kalamdhad, A.S. 2010. High rate composting of municipal solid waste-an option for decentralized composting, lambert academic publishing GmbH and Co. KG, Saarbrucken.
30. Kayhanian, M., and D.Rich, 1995. Pilot-scale high solids thermophilic anaerobic digestion of municipal solid waste with an emphasis on nutrient requirements. Biomass and Bioenergy , 8(6), 433-444.
31. Liu, D., R.Zhang, , H.Wu, , D.Xu, Z.Tang , G.Yu and Q.Shen, 2011. Changes in biochemical and microbiological parameters during the period of rapid composting of dairy manure with rice chaff. Bioresource Technology, 102(19), 9040-9049.
32. American Public Health Association. 1999. Standard method for the examination of water and wastewater 20th ed. (ed. by LS Clesceri, AE Greenberg, RR Trussell), Washington DC.102) 5220:),pp:2650.
33. Mohee, R., and, A. Mudhoo. 2005. Analysis of the physical properties of an in-vessel composting matrix. Powder Technology, 155(1): 92-99.
34. Mokhtari, M., M.Nikaeen , M. M. Amin, B. Bina, and A. Hasanzadeh, 2011. Evaluation of stability parameters in in-vessel composting of municipal solid waste,22(1),441-448.
35. Mondini, C., F.Fornasier, , and T. Sinicco, 2004. Enzymatic activity as a parameter for the characterization of the composting process. Soil Biology and Biochemistry, 36(10), 1587-1594.
36. Mor, S., K.Ravindra, , A.De Visscher, R. P.Dahiya, and A. Chandra, 2006. Municipal solid waste characterization and its assessment for potential methane generation: a case study. Science of the Total Environment, 371(1-3), 1-10.
37. Noufal, M., B. L. Zhan, and Z.Maalla, 2018. In-vessel composting system for accelerated composting. Nature Environment and Pollution Technology, 17(1), 49-56.
38. Owens, J. M., and D. P. Chynoweth, 1993. Biochemical methane potential of municipal solid waste (MSW) components. Water Science and Technology, 27(2), 1-14.
39. Paxéus, N. 2000. Organic compounds in municipal landfill leachates. Water Science and Technology, 42(7-8); 323-333.
40. Ponsá, S., T.Gea, and A. Sánchez, 2010. Different indices to express biodegradability in organic solid wastes. Journal of Environmental Quality, 39(2), 706-712.
41. Rynk, R., M.Van de Kamp, , G. B. Willson, , M. E.Singley, , Richard, T. L., Kolega, J. J., and W. F. Brinton, 1992. On-Farm Composting Handbook (NRAES 54). Northeast Regional Agricultural Engineering Service (NRAES). 33(1),531-538.
42. Sánchez-Mondero, M.A., A. Roig, C.Paredes, and M.P.Bernal, , 2001, Nitrogen transformation during organic waste composting by the rutgers system and its effects on ph, Ec and maturity of the composting mixtures, Bio Resource. Technol. 78, 301–308.
43. Sullivan D. M., and R. O. Miller, 2001 Compost quality attributes, measurements, and variability. In Stoffella PJ and Kahn BA (Eds.), Compost utilization in horticultural cropping systems (pp 97–120) New York, United States: Lewis Publishers,8(2),251-293.
44. Sun, X. P., P. Lu, T. Jiang, F.Schuchardt, and G. X. Li, 2014. Influence of bulking agents on CH_4, N_2O, and NH_3 emissions

during rapid composting of pig manure from the Chinese Ganqinfen system. Journal of Zhejiang University Science B, 15(4), 353-364.

45. Van der Wurff, A. W., J. G. Fuchs, M. Raviv, and A. Termorshuizen, 2016. Handbook for composting and compost use in organic horticulture. Bio Greenhouse. 20(3),90-99.

46. Wong. J. W. C.; K. F. Mak; N. W. Chan; A. Lam;M. Fang and L. X. Zhou 2001. Co-composting of soybean residues and leaves in Hong Kong, BioSource Technology, 76: 99-106.

47. Yamada, Y., and Y. Kawase, 2006. Aerobic composting of waste activated sludge: Kinetic analysis for microbiological reaction and oxygen consumption. Waste Management, 26(1), 49-61).