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Composting Of Sewage Sludge Based On Different C/N Ratios

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Abstract: Sewage sludge is an unavoidable by-product of wastewater treatment processes; its disposal is generally costly or easy to contaminate the environment. Being rich in micro-and macronutrients, composting of sewage sludge is one of the important disposal alternatives. Nutrients balance plays a vital role in the composting process which is expressed as, carbon to nitrogen (C/N) ratio. Therefore, the aim of this paper is to evaluate the feasibility of C/N ratios (15, 20, 25, and 30) with control on the agitated pile composting of sewage sludge during 30 days. It was observed that C/N 30 produced the best compost, showed highest temperature profile, higher loss in EC value, TOC, CO_2 evolution, OUR, BOD, COD and higher gain in total nitrogen and phosphorus, implying the total amount of biodegradable organic material is stabilized; and a Solvita® maturity index of 8 indicated that the compost was stable and ready for usage as a soil conditioner. On analyzing the results by ANOVA, the physico-chemical, biological and stability parameters varied significantly during the 30 days composting process. Therefore, it can be suggested that the pile composting of sewage sludge at C/N 30 can produce more stable compost after 30 days, while, C/N 15, 20, 25 and control poses least stable.

Keywords: sewage sludge, C/N ratio, cattle manure, pile composting, stability, solvita® maturity index.

INTRODUCTION

Modern wastewater treatment plants use a combination of physical, chemical and biological processes. An unwanted and/or unavoidable by-product of wastewater treatment is sewage sludge; exhibits the challenge to societies for disposing the huge amount of sludge, but at the same time gives us the prospect for beneficial use by recycling of nutrients. Sludge originated from treatment activity must return to soil if a sustainable and ecologically sound management of these materials is desirable[1]. At present the major ways of disposing of sewage sludge are deposition, landfill and incineration, only very few amounts of sludge are used in agriculture purposes. Sewage sludge, which contains higher concentration of nutrients, could be re-used in agriculture as fertilizer and soil conditioner. In addition the use of sludge as a fertilizer would decrease the amounts of chemical fertilizers needed in agriculture and supply micronutrients which are not commonly restored in routine agricultural practice. However, high odor emission, high levels of heavy metals and toxic organic compounds, and the presence of potentially pathogenic microorganisms, demand pretreatment of sewage sludge before application in agriculture[2,3] .

In this regard, composting is a successful strategy for the sustainable recycling of sewage sludge[4,5] . The capacity of reducing the volume and weight is approximately by 50% and resulting in a stable product that can be beneficial in agriculture, made composting a promising alternative[6]. For achieving good quality compost, environmental factors such as temperature, aeration, moisture and nutrients should be appropriately controlled[7] . Initial Carbon-to-nitrogen (C/N) ratio is one of the important aspects of the total nutrient balance affecting compost quality[8-10] . Effect of initial C/N ratio on composting of organic waste shows that 25-30 may be considered as the optimum C/N ratio for pile composting[7,8,10] . Initial waste mixture with lower C/N ratio may consume higher amount of oxygen which extended composting process over a longer period. Furthermore, lower C/N ratio contains quantity of nitrogen in excess to the amount than can be immobilized by the microorganism and thus may experience greater nitrogen losses by ammonia volatilization during composting process[11.]

Higher C/N ratio would show a lower rise in temperature, lower maximum temperature and shorter thermophilic phase and its higher indigenous electrical conductivity would pose a potential inhabitation on plant growth, besides slower rate of organic material decomposition observed[10,12] . Assertions that the only disadvantage for having a low C/N ratio is the loss of nitrogen did not hold well. The degradation of organic materials can be accelerated by increasing the C/N ratio to the optimum value by mixing with easily biodegradable carbonaceous compounds[9] . Therefore, carbon availability plays a major role in the initial C/N ratio. While degrading organic compounds, microbes waste around 60 to 70% of the C as CO_2 and incorporate (immobilize) only 30-40% of the C into their body as cellular components. However, limited investigations have been made on agitated pile composting of sewage sludge in combination with cattle manure and sawdust based on different C/N ratio.

Therefore, present study performed a comparative investigation of the agitated pile composting process of sewage sludge mixed with cattle manure and sawdust in four different proportions based on C/N ratios (15, 20, 25 and 30) with control. The study includes the dynamics of composting in terms of physico-chemical analysis, biological analysis and stability analysis.

MATERIALS AND METHODS

The compost materials: Sewage sludge, cattle manure and sawdust were used for preparation of different waste mixtures. Sewage sludge was collected from the sewage treatment plant of the Indian

Institute of Technology Guwahati campus. The treatment plant consists of aerated lagoon system with two units; one unit is acting in stand-by mode for maintenance purposes. However, this treatment activity is considered to be secondary treatment. Therefore, the sludge procured from the treatment plant is called as secondary sludge. Fresh cattle manure was obtained from nearby Amingaon village. Sawdust was purchased from the nearby rice mill and saw mill, respectively. The compost material was prepared by mixing different proportions (C/N 15, 20, 25 and 30; control) of the collected waste as described in **Table 1**.

Table- 1: Waste composition* and initial characteristics of waste materials

Reactors/Parameters	Waste materials (kg)		
	Sewage sludge	Cattle manure	Sawdust
C/N 15	130	16	4
C/N 20	104	39	7
C/N 25	98	39	13
C/N 30	87	45	18
Control	150	--	--
Moisture content (%)	34.16±2.03	80.77±0.04	10.25±0.26
pH	6.03±0.01	6.61±0.07	6.16±0.01
Electrical conductivity (dS/m)	2.77±0.01	3.28±0.21	0.39±0.01
Ash content (%)	61.54±0.32	29.88±3.85	2.41±0.05
Total organic carbon (TOC) (%)	21.37±0.18	38.96±2.14	54.22±0.03
Total nitrogen (%)	1.91±0.22	1.47±0.20	0.40±0.02
Nitrate Nitrogen (NO_3-N) (%)	0.006±0.004	0.045±0.036	ND*
Ammonical Nitrogen (NH_4-N) (%)	1.47±0.04	0.54±0.02	0.05±0.02
Total phosphorous (%)	4.99±0.29	4.29±0.26	1.69±0.36
Available phosphorus (%)	1.75±0.09	2.76±0.12	0.98±0.16
C/N ratio	11.19±1.21	26.44±2.50	135.88±7.25
Sodium (Na) (g/kg dry matter)	1.03±0.28	0.94±0.12	0.55±0.09
Potassium (K) (g/kg dry matter)	4.83±0.35	6.17±0.19	1.95±0.05
Calcium (Ca) (g/kg dry matter)	2.03±0.34	1.55±0.21	0.80±0.17
Iron (Fe) (g/kg dry matter)	1.18±0.29	6.61±0.32	2.19±0.08
Nickel (Ni) (mg/kg dry matter)	278.0±19.3	231.5±11.4	221.5±23.5
Chromium (Cr) (mg/kg dry matter)	198.5±0.4	89.2±0.2	124.5±0.5
Manganese (Mn) (mg/kg dry matter)	355.3±23.0	496.1±17.5	148.5±19.5
Cadmium (Cd) (mg/kg dry matter)	37.0±2.8	51.5±6.3	58.0±4.3
Copper (Cu) (mg/kg dry matter)	174.5±10.5	45.5±9.0	37.5±6.5
Lead (Pb) (mg/kg dry matter)	130.1±8.0	80.5±5.8	155.0±4.5
Zinc (Zn) (mg/kg dry matter)	967.2±23.3	124.3±11.5	101.9±17.3
Chemical oxygen demand (COD) (mg/L)	692.5±21.8	351.7±5.1	1196.8±10.3
Biochemical oxygen demand (BOD) (mg/L)	278.4±14.6	235.9±11.2	731.4±15.7
CO_2 evolution (mg/g VS/day)	12.1±0.5	17.6±0.5	10.8±0.1
Oxygen uptake rate (OUR) (mg/g VS/day)	17.9±0.2	21.8±1.3	12.5±0.7

***ND- Not detected**

Agitated pile composting: Different waste combinations were formed on agitated pile technique during the autumn season on an open site; which is formed into trapezoidal piles (length 2740 mm, base width 500 mm, top width 75 mm and height 310 mm, having length to base width (L/W) ratio of 5.5. Agitated piles contained approximately 150 kg of different waste combinations and were manually turned on 3, 6, 9, 12, 15, 18, 21, 24, 27 and 30 days. Composting period of total 30 days was decided for agitated pile composting. The samples from the piles were collected after mixing the whole pile thoroughly by hand; when the piles was made (0 day); piles were turned. Triplicates homogenized sample was collected from three different locations within the piles and stored at 4^oC for biological analysis of the wet samples within 2 days. The sub-samples were air dried immediately, ground to pass through 0.2 mm sieve and stored for physico-chemical analysis.

Experimental analysis: Temperature was monitored every 6 h using a digital thermometer throughout the composting period within the agitated pile at three different locations, i.e. at its middle and at its two ends and the mean of the readings was reported. Moisture content (MC) was determined from weight loss of compost sample (105^oC at 24 h). Each sub-samples was analyzed for the following parameters: pH and electrical conductivity (EC) (1:10 w/v waste: water extract with pH and EC meters); volatile solids/organic matter (loss on ignition at 550°C for 2 h), total nitrogen using Kjeldahl method, ammonical nitrogen (NH_4-N) and nitrogen (NO_3-N) using KCl extraction, available and total phosphorus (acid digest) using the stannous chloride method, potassium, sodium and calcium (acid digest) using flame photometry and trace elements (Ni, Cd, Cu, Zn, Mn, Cr and Pb) (acid digest) using atomic absorption spectrometer.

The biodegradable organic matter was measured as biochemical oxygen demand (BOD) by the dilution method[13] and chemical oxygen demand (COD) by the dichromate method[13] . The oxygen uptake rate (OUR) and CO_2 evolution were performed according to the method described by Kalamdhad et al.[14] . The CO_2 and OUR test values were used to determine the Solvita® maturity index on a scale of 1-8, which represents the stability level of the compost samples[15] .

All the results reported are the means of three replicates. Analysis of variance (ANOVA) and Tukey's HSD (Honestly Significant Difference) test were used as a post-hoc analysis to compare the means using Statistica software to determine any significant differences among the parameters analyzed for different sets of experiment.

RESULTS AND DISCUSSION

Physico-chemical analysis

- ***Temperature and moisture content***

The temperature indicates the biological processes taking place during composting process and plays a selective role on evolution and succession of microbiological communities. The variation in mean temperature of composting material with time is illustrated in **Fig. 1.** C/N 30 recorded the highest maximum temperature (54.5°C) on 2nd day among the temperature regimes of all C/N ratios and control, indicating quick establishment of microbial activities. Rapid rise in temperature at the beginning of composting is attributed to higher content of easily biodegradable cattle manure coupled with the presence of sawdust. C/N 15, 20, 25 and control with initial temperatures (27.5, 30.6, 35.1 and 24.3°C, respectively) reached maximum temperatures 45.6, 49.5, 51.8 and 36.4°C respectively, afterwards reduction was observed until the end of the composting process. Control and C/N 15 and 20 showed lower maximum temperatures than others may be due higher proportion of sewage sludge indicates that sewage sludge without appropriate amendments is less favorable for growth and biological activity of microorganisms. After 12th day, when cooling phase started the degradation is mainly carried out by actinomycetes and fungus due to mineralization of complex organic matter, because they degraded at low temperature also. All the composting pile attained ambient temperature at 30 days indicating a good degree of stability.

Moisture loss during the composting process can be viewed as an index of decomposition rate, since the heat generated during decomposition leads to vaporization[19] . Optimum moisture content is required for organisms to survive. Initial moisture content were 70.9, 68.0, 64.9, 62.3 and 66.8% and reduced to 51.0, 49.4, 46.7, 43.3 and 53.6% within 30 day of composting period in C/N 15, 20, 25, 30 and control, respectively (**Table 2**). On analyzing the results by ANOVA, the decrease in moisture content varied significantly between the days ($P < 0.05$). Highest moisture loss occurred in C/N 30 (30.5%) and it correlated with the higher temperature profile of C/N 30. Leachate formation was not observed during the composting period.

- ***pH and EC***

Initially pH was observed to decrease for all the C/N ratios in 3-4 days but later increased to almost neutral after 30 days of composting period. The reduction in pH may be due to CO_2 and organic acids produced during microbial metabolism[16] . As composting proceeds, the organic acids become neutralized and compost material tends toward a neutral pH[17] . Similar observations were found in all C/N ratios; as pH reduced during the initial 6 days after increased gradually up to 7.76, 7.35, 7.38, 7.72 and 7.62 in C/N 15, 20, 25, 30 and control, respectively (**Table 2**). Significant differences in pH were observed between the C/N ratios including control ($P < 0.05$). Aeration tends to decrease CO_2 level in the compost, which in turns will tend to increase pH and also prevents the anaerobic conditions[18] .

The EC value reflected the degree of salinity in the compost, indicating its possible phytotoxic/ phyto-inhibitory effects on the growth of plant if applied to soil[10] . High initial EC values in composting biomass are due to release of ammonium ions. The volatilization of ammonia and the precipitation of mineral salts are the possible reasons for the decreased EC at the later phase of composting[29] . For the improvement of agricultural soils, the acceptable level of EC required in compost[20] should be lower than 4 dS/m. Composts of C/N 25 and 30 approached to the desired EC values after 30 days of composting (**Table 2**). The high final EC values observed in C/N 15, 20 and control may be due to higher concentration of sewage sludge as compared to C/N 25 and 30, which are not suited for better compost and also unsafe for plant use. On analyzing the results by ANOVA, EC varied significantly between the C/N ratios including control ($P < 0.05$).

- ***Ash content and TOC***

The contents of ash increased with composting time with about 17.8, 22.7, 24.8, 27.5 and 15.9 for C/N 15, 20, 25, 30 and control, respectively, owing to the loss of organic matter through microbial degradation (Table 2). The decrease in organic matter synchronized with an increase in the ash mass of the waste mixtures. The loss of organic matter was about 35% in C/N 30, which contained a greater amount of cattle manure in comparison with other C/N ratios and control, which indicated that intensive decomposition was taking place during C/N 30. The change in the total organic carbon (TOC) content during the composting period is detailed in Table 4. The content of organic carbon decreased as the decomposition progressed. Initially, the amounts of total organic carbon were 25.4, 25.8, 27.6, 28.9 and 25.6%, which then reduced to 18.9, 17.1, 18.4, 18.7 and 17.5%, respectively, in C/N 15, 20, 25, 30 and control. More than 33% of the available carbon in C/N 20, 25 and 30 were utilized by micro-organisms as a source of energy in comparison with 25% in C/N 15 and control. Significant variations in ash content and TOC were observed between the C/N ratios including control ($P < 0.05$).

Table- 2: Moisture content, pH, EC and ash content during composting over time

Days	Moisture content (%)					pH				
	C/N 15	*C/N 20*	*C/N 25*	*C/N 30*	*Control*	*C/N 15*	*C/N 20*	*C/N 25*	*C/N 30*	*Control*
0	70.90±0.23a	68.04±0.70b	64.93±0.50c	62.30±0.25d	66.84±0.16e	7.49±0.11a	7.36±0.23a	7.63±0.15a	7.26±0.16a	7.49±0.12a
3	63.10±0.15a	61.80±0.80a	57.70±0.60b	58.00±0.65b	63.30±0.39a	7.34±0.06ab	7.15±0.16ab	7.50±0.23a	7.02±0.24b	7.43±0.09ab
6	60.00±0.09a	59.60±1.10a	56.80±0.80b	56.50±0.44b	62.10±0.11c	7.29±0.23a	7.04±0.29a	7.24±0.14a	6.87±0.14a	7.43±0.31a
9	58.40±0.11ad	60.00±0.90ac	57.40±0.80d	54.90±0.94b	60.50±0.09c	7.14±0.09ab	7.14±0.19ab	7.37±0.16ab	6.98±0.15ab	7.46±0.14a
12	57.20±0.04a	58.97±1.30b	56.00±0.38a	53.30±0.46c	60.70±0.13d	7.04±0.05a	7.29±0.23a	7.20±0.23a	7.07±0.23a	7.39±0.05a
15	56.30±0.07a	57.40±0.70a	54.30±0.65b	52.04±0.04c	58.80±0.04d	7.27±0.04a	7.11±0.26a	7.19±0.22a	7.20±0.09a	7.42±0.17a
18	54.70±0.12ac	56.00±1.10a	53.60±0.63c	50.80±0.11b	58.40±0.03d	7.36±0.13a	7.27±0.16a	7.26±0.14a	7.24±0.21a	7.41±0.11a
21	54.00±0.06a	54.80±0.90a	51.80±0.70b	48.90±0.61c	57.00±0.22d	7.41±0.07a	7.25±0.17a	7.20±0.23a	7.34±0.34a	7.46±0.08a
24	52.50±0.10a	52.50±0.70a	48.90±0.50b	46.00±0.21c	55.00±0.18d	7.58±0.03ac	7.29±0.10bd	7.17±0.12d	7.41±0.12bc	7.52±0.01bc
27	51.70±0.13a	51.00±0.60a	48.60±0.60b	45.80±0.06c	53.90±0.10d	7.64±0.01a	7.31±0.20b	7.37±0.09ab	7.56±0.08ab	7.55±0.05ab
30	51.01±0.01a	49.40±0.60a	46.70±1.29b	43.30±1.50c	53.60±0.07d	7.76±0.09a	7.35±0.13bc	7.38±0.12c	7.72±0.11a	7.62±0.07ac
	EC (dS/m)					Ash content (%)				
0	3.49±0.12a	3.60±0.20ac	2.47±0.04b	3.13±0.02d	3.78±0.02c	54.13±0.03a	53.54±0.10b	50.30±0.20c	47.99±0.06d	57.50±0.23e
3	2.93±0.00a	2.83±0.12a	2.09±0.03b	2.58±0.06a	3.66±0.31c	55.49±0.12a	56.20±0.30b	50.96±0.13c	49.40±0.10d	60.19±0.35e
6	3.16±0.07a	3.23±0.05a	2.13±0.12b	2.90±0.09c	3.68±0.07d	58.63±0.04a	60.30±0.20b	56.60±0.47c	53.70±1.22d	61.70±0.09b
9	3.87±0.02a	4.53±0.11b	2.54±0.10c	3.53±0.01d	4.10±0.09e	59.77±0.15a	64.24±0.08b	57.40±0.03c	55.60±0.52d	62.66±0.13e
12	3.91±0.21ad	4.83±0.12b	3.73±0.05ad	2.63±0.12c	4.24±0.13d	60.90±0.11a	65.82±0.02bc	59.60±0.11a	56.40±1.16d	65.68±0.28b
15	4.13±0.14ae	4.60±0.07b	3.86±0.07c	2.81±0.09d	4.34±0.08e	61.97±0.04a	66.02±0.03b	60.50±0.02ac	58.30±2.09c	64.70±0.19b
18	4.21±0.05ae	4.66±0.06b	3.97±0.11c	2.80±0.02d	4.37±0.05e	63.20±0.14ac	67.33±0.10b	61.98±0.05a	60.60±2.31a	65.69±0.05b
21	4.29±0.08ae	4.60±0.09b	3.69±0.01c	2.69±0.03d	4.44±0.01e	63.89±0.10a	68.10±0.02b	63.96±0.03ac	63.10±2.31a	66.70±0.11b
24	4.20±0.10a	4.47±0.10a	3.54±0.02b	2.56±0.23c	4.32±0.11a	64.50±0.04a	68.80±0.09b	65.70±0.17a	64.60±1.73a	67.82±0.09b
27	4.19±0.04a	4.29±0.08a	3.49±0.08b	2.43±0.18c	4.39±0.08a	65.30±0.04a	69.13±0.01b	66.10±0.01a	65.60±1.62a	68.10±0.12b
30	4.35±0.01ace	4.21±0.04ac	3.43±0.04b	2.31±0.14d	4.46±0.03e	65.82±0.11a	69.28±0.13c	66.90±0.03ab	66.20±1.46a	68.39±0.08b

Mean value followed by different letters in columns is statistically different (ANOVA; Tukey's test, $P < 0.05$)

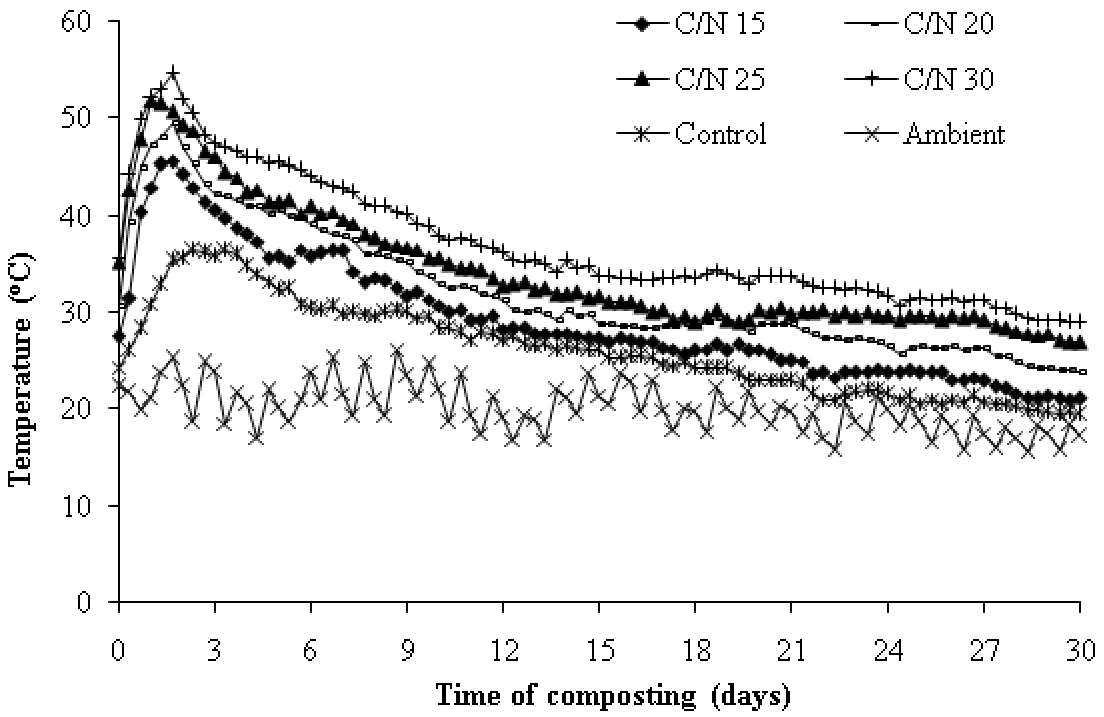

Fig. 1: Temperature variation during C/N 15, 20, 25, 30 and control experiments

- ***Nitrogen dynamics***

Table 3 shows the time course of the total nitrogen consisting of inorganic forms of nitrogen (NH_4-N and NO_3-N). Total nitrogen content in sewage sludge was higher than other composting materials. Hence, initial total nitrogen content of C/N 15 and control containing higher amount of sewage sludge was higher than other C/N ratios. The initial total nitrogen contents in all C/N ratios were in the range of 0.98-1.79%. Higher percentage increase was observed in C/N 30 (57.5) as compared to other C/N ratios and control. Total nitrogen increased within agitated pile composting due to the net loss of dry mass in terms of CO_2 during oxidization of organic matter.

The changes in concentration of NH_4-N and NO_3-N in all trials followed the general trend during composting. During the composting process, NH_4-N concentration decreased from 0.73-0.80% to 0.05-0.31% in all C/N ratios and control (**Table 3**). Higher initial NH_4-N concentration could be due to the conversion of organic nitrogen to NH_4-N through volatilization and immobilization by microorganisms (Huang et al. 2004). It has been noted that the absence or decrease in NH_4-N is an indicator of both high-quality compost (Hirai et al. 1983). NH_4-N concentration of 0.04% recommended as the maximum content in matured compost[21] . In this context C/N 30 provided better compost as compared to other C/N ratios and control. Initial nitrate is almost absent in the cattle manure and sawdust but higher concentration is prevalent in sewage sludge.

Nitrification, as detected by the formation of NO_3-N, occurred only when the temperature of the material was below 40°C[14] , as the intensity of the process being dependent on the quantity of NH_4-N available to the nitrifying bacteria. The concentration of NO_3-N was almost nil during the first six days, due to inhibition by excessive amount of ammonia. The high temperature and excessive amount of ammonia inhibited the activity and the growth of nitrifying bacteria in the thermophilic phase[22] . This seems to suggest that organic nitrogen mineralization is the limiting step in nitrification since such mineralization was extremely low during the last phase of composting, when the supply of ammonium available to the nitrifying bacteria would have been reduced[23] . Therefore, a slight increase was observed in NO_3-N concentration all C/N ratios especially in C/N 30 at the later phase of composting (Table 3). Significant differences in total nitrogen, NH_4-N and NO_3-N were observed between the C/N ratios including control ($P < 0.05$).

Table- 3: Nitrogen dynamics during composting over time

Days	Total nitrogen (%)				
	C/N 15	*C/N 20*	*C/N 25*	*C/N 30*	*Control*
0	1.62±0.21a	1.29±0.14b	1.09±0.02b	0.98±0.00b	1.79±0.09a
3	1.63±0.13a	1.20±0.19b	1.05±0.03b	1.12±0.07b	1.72±0.14a
6	1.51±0.09a	1.21±0.07b	1.17±0.07b	0.95±0.04c	1.60±0.06a
9	1.57±0.47a	1.30±0.21a	1.29±0.02a	1.10±0.10a	1.70±0.07a
12	1.62±0.18a	1.28±0.25ab	1.14±0.09b	1.28±0.02ab	1.72±0.21a
15	1.60±0.30a	1.21±0.29a	1.37±0.13a	1.34±0.00a	1.69±0.19a
18	1.68±0.23ac	1.27±0.18b	1.45±0.04abc	1.35±0.02bc	1.80±0.08a
21	1.66±0.15ac	1.27±0.23b	1.36±0.11ab	1.35±0.08ab	1.80±0.04c
24	1.86±0.33a	1.32±0.11b	1.38±0.01b	1.38±0.04b	1.90±0.15a
27	1.91±0.28a	1.32±0.08b	1.34±0.05b	1.41±0.02b	1.95±0.09a
30	1.92±0.17a	1.31±0.15b	1.45±0.04b	1.54±0.09b	1.97±0.05a
	NH_4-N (%)				
0	0.75±0.11a	0.77±0.01a	0.79±0.02a	0.80±0.09a	0.73±0.04a
3	0.69±0.07ab	0.66±0.02ab	0.61±0.03a	0.75±0.07b	0.71±0.05ab
6	0.61±0.09c	0.57±0.04abc	0.54±0.01ac	0.43±0.02ab	0.65±0.06c
9	0.56±0.25ab	0.51±0.02ab	0.51±0.05ab	0.29±0.01a	0.60±0.02b
12	0.49±0.13a	0.55±0.25a	0.27±0.05a	0.21±0.04a	0.57±0.07a
15	0.37±0.03ab	0.27±0.06ab	0.21±0.07a	0.27±0.12ab	0.45±0.05b
18	0.26±0.08abcd	0.19±0.05ad	0.17±0.01abd	0.17±0.04d	0.34±0.07c
21	0.23±0.03a	0.18±0.01a	0.14±0.03a	0.14±0.01a	0.34±0.07b
24	0.18±0.02a	0.13±0.02a	0.13±0.02a	0.12±0.00a	0.29±0.08b
27	0.16±0.01a	0.10±0.02a	0.10±0.02a	0.08±0.01a	0.33±0.09b
30	0.14±0.01a	0.12±0.01a	0.10±0.04ab	0.05±0.01b	0.31±0.03c
	NO_3-N (%)				
0	ND*	ND	ND	ND	ND
3	ND	ND	ND	ND	ND
6	ND	ND	ND	ND	ND
9	0.000±0.006a	0.000±0.000a	0.002±0.001ab	0.007±0.002ab	0.011±0.007b
12	0.018±0.008ac	0.008±0.000a	0.070±0.010b	0.092±0.004d	0.030±0.005c
15	0.050±0.005ac	0.020±0.010a	0.092±0.020bd	0.110±0.010d	0.058±0.002c
18	0.068±0.006a	0.050±0.010a	0.130±0.030b	0.150±0.020b	0.060±0.018a
21	0.119±0.012ab	0.060±0.020a	0.150±0.020b	0.175±0.060b	0.100±0.011ab
24	0.112±0.010ac	0.090±0.030a	0.171±0.030bc	0.200±0.020b	0.127±0.025ac
27	0.149±0.008ab	0.110±0.050a	0.215±0.015b	0.214±0.030b	0.135±0.037ab
30	0.168±0.012abc	0.130±0.020a	0.205±0.040bc	0.231±0.011c	0.148±0.040ab

Mean value followed by different letters in columns is statistically different (ANOVA; Tukey's test, $P < 0.05$)*ND-Not detected

- ***Phosphorus***

Phosphorous content gradually increased during the composting process. The water solubility of phosphorous decreased with the humification. Phosphorous solubility during the decomposition was subjected to further immobilization by the compost accelerator microorganisms.

Table- 4: TOC, Total phosphorus and Available phosphorus during composting over time

Days	TOC (%)				
	C/N 15	*C/N 20*	*C/N 25*	*C/N 30*	*Control*
0	25.48±0.02a	25.81±0.06b	27.61±0.11c	28.89±0.03d	23.61±0.13e
3	24.73±0.07a	24.33±0.17b	27.24±0.07c	28.11±0.06d	22.12±0.19e
6	22.98±0.02a	22.06±0.11b	24.11±0.26c	25.72±0.68d	21.28±0.05b
9	22.35±0.08a	19.87±0.04b	23.67±0.02c	24.67±0.29d	20.74±0.07e
12	21.72±0.06a	18.99±0.01bc	22.44±0.06a	24.22±0.64d	19.07±0.16b
15	21.13±0.02a	18.88±0.02b	21.94±0.01ac	23.17±1.16c	19.61±0.11b
18	20.44±0.08ac	18.15±0.06b	21.12±0.03a	21.89±1.28a	19.06±0.03bc
21	20.06±0.05a	17.72±0.01b	20.02±0.02ac	20.50±1.28a	18.50±0.06bc
24	19.72±0.02a	17.33±0.05b	19.06±0.09a	19.67±0.96a	17.88±0.05b
27	19.28±0.02a	17.15±0.01b	18.83±0.01a	19.11±0.90a	17.72±0.06b
30	18.99±0.06a	17.07±0.07c	18.39±0.02ab	18.78±0.81a	17.56±0.04bc
	Total phosphorus (%)				
0	2.81±0.08a	2.70±0.13a	1.85±0.13b	2.98±0.11a	1.94±0.24b
3	2.25±0.01a	2.29±0.11a	2.06±0.23a	2.45±0.09a	2.16±0.19a
6	1.96±0.41a	2.12±0.21a	2.21±0.18a	3.03±0.09b	1.88±0.08a
9	1.97±0.01a	1.77±0.17a	2.70±0.12b	3.69±0.13c	1.88±0.13a
12	1.92±0.03a	1.80±0.11a	2.70±0.21b	3.29±0.04b	1.99±0.47a
15	1.70±0.04a	1.82±0.23ab	2.78±0.07c	3.41±0.07d	2.03±0.05b
18	1.76±0.01a	1.93±0.21ab	2.78±0.12c	3.91±0.05d	2.18±0.10b
21	2.30±0.01a	2.43±0.16a	3.32±0.03b	4.56±0.08c	2.48±0.17a
24	2.88±0.30a	3.52±0.24b	4.06±0.04b	4.62±0.01c	2.71±0.22a
27	2.66±0.06a	2.43±0.23a	3.50±0.14b	4.56±0.04c	2.76±0.11a
30	3.23±0.19ac	3.52±0.21a	3.97±0.16b	4.62±0.08d	3.08±0.09c
	Available phosphorus (%)				
0	0.89±0.41ab	0.89±0.41ab	0.89±0.41ab	0.89±0.41ab	0.89±0.41ab
3	1.06±0.01a	1.06±0.01a	1.06±0.01a	1.06±0.01a	1.06±0.01a
6	1.23±0.15ac	1.23±0.15ac	1.23±0.15ac	1.23±0.15ac	1.23±0.15ac
9	1.52±0.12a	1.52±0.12a	1.52±0.12a	1.52±0.12a	1.52±0.12a
12	1.68±0.12a	1.68±0.12a	1.68±0.12a	1.68±0.12a	1.68±0.12a
15	1.80±0.14a	1.80±0.14a	1.80±0.14a	1.80±0.14a	1.80±0.14a
18	2.06±0.03a	2.06±0.03a	2.06±0.03a	2.06±0.03a	2.06±0.03a
21	2.19±0.02a	2.19±0.02a	2.19±0.02a	2.19±0.02a	2.19±0.02a
24	2.14±0.07a	2.14±0.07a	2.14±0.07a	2.14±0.07a	2.14±0.07a
27	2.26±0.01a	2.26±0.01a	2.26±0.01a	2.26±0.01a	2.26±0.01a
30	2.29±0.01a	2.29±0.01a	2.29±0.01a	2.29±0.01a	2.29±0.01a

Mean value followed by different letters in columns is statistically different (ANOVA; Tukey's test, *P* < 0.05)

The change of total and available phosphorus with a gradual increase throughout the composting period (**Table 4**), which was due to the net loss of dry mass and losses of organic carbon, hydrogen, nitrogen and oxygen from piles as CO_2, H_2S and H_2O during composting. Final total phosphorus of C/N 30 (4.62%) was higher than C/N 15 (3.23%), C/N 20 (3.52%), C/N 25 (3.97%) and control (3.08%), indicating the higher microbial activities during C/N 30 resulting in more mineralization as compared to others C/N ratios. Similar observations were found for available phosphorus. On analyzing the results by ANOVA, total and available phosphorus varied significantly between the C/N ratios including control ($P < 0.05$).

- ***Nutrients (Na, K, Ca, and Fe)***

Table 5 illustrates the concentration of the macronutrients; namely total K, Na, Ca and Fe in all C/N ratios including control throughout the composting process. These nutrients are used as mineral fertilizers in the compost. All C/N ratios showed a similar pattern of changes in macronutrients. Macronutrients K, Na, Ca and Fe were gradually increase till the end of the composting due to due to the net loss of dry mass. C/N 30 showed greater amounts of the three macronutrients except sodium throughout the composting process comparison with others could be due to higher amount of cattle manure coupled with sewage sludge which represents comparatively higher concentration of nutrients. On analyzing the results by ANOVA, significant differences in macronutrients were observed between the all C/N ratios including control ($P < 0.05$).

- ***Trace elements***

The total concentrations of regulated trace elements (Ni, Cd, Cu, Zn, Mn, Cr and Pb) in compost are shown in **Table 6 and 7**. Most of the elements are actually needed by plants for normal growth, although in limited quantities. Certain trace elements are not biodegradable and become toxic at some concentration; therefore, measuring the concentration of these elements can provide fertilizer requirements of plants. The increase of total metal content was due to weight loss in the course of composting following organic matter decomposition, release of CO_2, water and mineralization processes[24] . The total metal contents of final compost of all C/N ratios including control were low (except Cadmium) and are considered as soil fertilizer/conditioner with good quality according to the standards to ensure safe application of compost laid down in Municipal Waste Management and Handling Rules notified by the Ministry of Environment and Forest, Government of India[25] and Canadian Council of Ministers of the Environment[26] . Significant differences in trace elements were observed between the all C/N ratios including control ($P < 0.05$).

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- ***C/N ratio***

The change in the C/N ratios reflects the organic matter decomposition and stabilization achieved during composting. The decomposition of organic matter is brought about by living organisms, which utilize the carbon as a source of energy and the nitrogen for building cell structures[17]. Therefore, continuous decrease was observed during all C/N ratios (**Fig. 2**). Significant differences in C/N ratio were observed between the C/N ratios including control ($P < 0.05$). If the C/N ratio of compost is more, the excess carbon tends to utilize nitrogen in the soil to build cell protoplasm. This results in loss of nitrogen of the soil and is known as robbing of nitrogen in the soil. If on the other hand the C/N ratio is too low the resultant product does not help improve the structure of the soil, hence it is desirable to achieve optimum C/N ratio for prepared compost. Higher reduction in C/N ratio was observed in C/N 30 (58.7%) as compared to other C/N 15 (36.9%), C/N 20 (34.9%), C/N 30 (50.0%) and control (32.5%); indicated higher degradation in C/N 30.

Table- 5: Variations in macronutrients during composting over time

Days	Sodium (g/kg)					Potassium (g/kg)				
	C/N 15	*C/N 20*	*C/N 25*	*C/N 30*	*Control*	*C/N 15*	*C/N 20*	*C/N 25*	*C/N 30*	*Control*
0	2.19±0.16a	2.07±0.38a	1.95±0.43a	1.78±0.62a	1.56±0.09a	6.19±0.60a	6.54±0.52a	6.90±0.33ab	7.81±0.19b	6.41±0.28a
6	2.68±0.35a	2.47±0.17ab	2.11±0.08ab	1.96±0.55ab	1.68±0.34b	6.76±0.31a	7.08±0.21a	7.16±0.26ab	8.16±0.54b	6.97±0.53a
12	2.95±0.31a	2.68±0.23a	2.44±0.30ab	2.27±0.28ab	1.79±0.45b	7.14±0.47a	7.79±0.32a	7.86±0.38ab	8.95±0.61b	7.25±0.13a
18	3.24±0.19a	2.93±0.10ab	2.69±0.25ab	2.51±0.37bc	1.94±0.16c	7.91±0.19a	8.25±0.48ab	8.39±0.25ab	9.18±0.78b	7.98±0.09a
24	3.67±0.58a	3.16±0.52ab	2.80±0.23ab	2.77±0.14ab	2.28±0.33b	8.22±0.35a	8.68±0.63ab	8.82±0.37ab	9.84±0.66b	8.23±0.42a
30	3.94±0.34a	3.45±0.47ab	3.13±0.39abc	2.95±0.24bc	2.40±0.22c	8.96±.28a	9.11±0.44a	9.37±0.26ab	10.21±0.46b	8.60±0.35a
	Calcium (g/kg)					Iron (g/kg)				
0	3.35±0.34a	3.71±0.45a	3.06±0.27a	2.94±0.60a	3.91±0.52a	5.30±0.05a	6.32±0.14b	7.90±0.06c	8.67±0.26d	3.39±0.19e
6	3.78±0.51a	3.94±0.63a	3.24±0.55a	3.77±0.17a	4.17±0.47a	6.09±0.08a	7.35±0.03b	8.99±0.02c	9.23±0.09c	4.15±0.17d
12	4.12±0.19a	4.41±0.81a	4.27±0.43a	4.18±0.58a	4.69±0.59a	7.96±0.13a	8.82±0.09b	9.89±0.11c	10.67±0.07d	4.65±0.05e
18	5.09±0.68a	4.98±0.72a	4.95±0.67a	4.92±0.81a	5.17±0.37a	8.45±0.20a	9.62±0.20b	10.75±0.06c	12.32±0.14d	5.56±0.18e
24	5.91±0.71a	5.83±0.48a	5.76±0.38a	5.18±0.66a	5.82±0.41a	9.47±0.39a	10.18±0.15a	12.86±0.02b	14.25±0.62c	7.00±0.05d
30	6.58±0.24a	6.91±0.54a	6.14±0.19a	6.80±0.35a	6.67±0.62a	10.64±0.31a	11.80±0.16b	13.60±0.09c	15.14±0.06d	7.49±0.14e

Mean value followed by different letters in columns is statistically different (ANOVA; Tukey's test, *P* < 0.05)

Table- 6: Variations in trace elements (Nickel, Cadmium, Copper and Zinc) during composting over time

Days	Nickel (mg/kg)					Cadmium (mg/kg)				
	C/N 15	*C/N 20*	*C/N 25*	*C/N 30*	*Control*	*C/N 15*	*C/N 20*	*C/N 25*	*C/N 30*	*Control*
0	259.5±2.0a	232.8±5.8b	215.8±3.3c	200.5±3.0d	230.3±8.8b	37.8±0.8a	50.8±0.8b	48.3±0.8c	53.3±0.8d	32.5±1.0e
6	267.0±2.5a	246.3±3.3b	227.0±4.0c	206.5±5.0d	239.8±2.8b	40.8±0.8a	54.0±0.5b	51.5±1.0c	56.5±1.0d	34.8±0.3e
12	279.8±0.8a	260.8±6.3b	241.5±2.0c	211.8±4.8d	252.0±7.5bc	43.8±0.8a	56.3±1.3b	52.5±0.5c	60.5±1.5d	38.8±0.3e
18	289.3±5.8a	273.0±6.5b	249.3±1.8c	220.8±1.3d	257.8±6.3c	46.0±0.5a	58.3±0.8b	58.0±1.5b	67.8±1.8c	45.3±1.3a
24	305.5±3.0a	281.5±3.0b	258.8±4.8c	229.0±2.5d	283.0±6.5b	48.8±0.8a	60.0±1.5b	63.5±1.0c	71.0±0.5d	50.5±1.0a
30	317.5±7.0a	297.8±3.8b	273.0±3.5c	240.0±4.5d	303.3±3.8b	53.8±1.3a	65.5±1.0b	66.5±1.0b	73.5±1.0c	56.3±1.3a
	Copper (mg/kg)					Zinc (mg/kg)				
0	203.8±1.3a	193.5±4.0b	190.8±1.3b	169.0±1.5c	159.0±1.5d	1020.5±9.0a	937.0±1.5b	845.3±1.3c	719.8±1.8d	1223.3±6.8e
6	215.3±1.8a	213.0±3.5a	203.3±1.3b	175.3±2.3c	162.3±0.8d	1151.8±3.8a	984.8±2.3b	877.5±2.0c	766.8±2.3d	1260.8±3.8e
12	229.8±2.8a	221.3±4.3b	215.0±2.5b	181.3±0.8c	166.3±1.3d	1199.5±5.0a	1102.3±6.3b	908.8±0.8c	790.5±1.0d	1290.8±1.3e
18	240.5±1.0a	239.0±3.0a	230.3±0.8b	195.5±2.0c	170.3±1.3d	1239.8±2.3a	1130.5±2.0b	949.8±1.3c	812.8±1.8d	1348.0±3.5e
24	246.5±2.0a	247.8±3.3a	238.8±1.8b	205.3±4.3c	174.0±0.5d	1293.5±6.0a	1184.3±4.3b	985.8±1.3c	821.5±2.0d	1384.8±3.8e
30	254.8±1.3a	262.5±4.0b	248.0±1.5c	218.3±1.3d	177.8±0.3e	1339.8±4.3a	1217.0±2.5b	1029.5±4.0c	831.5±2.5d	1423.3±4.3e

Table- 7: Variations in trace elements (Manganese, Chromium and Lead) during pile Composting

Days	Manganese (mg/kg)				
	C/N 15	*C/N 20*	*C/N 25*	*C/N 30*	*Control*
0	480.0±5.0a	502.5±12.5b	390.0±5.0c	337.5±7.5d	320.0±5.0d
6	512.5±2.5a	537.5±7.5b	405.0±5.0c	377.5±2.5d	352.5±7.5e
12	577.5±7.5a	587.5±7.5a	457.5±7.5b	397.5±7.5c	382.5±12.5c
18	640.0±10.0a	610.0±5.0b	500.0±5.0c	417.5±2.5d	400.0±5.0e
24	697.5±7.5a	682.5±7.5a	567.5±7.5b	437.5±7.5c	410.0±5.0d
30	727.5±7.5a	717.5±7.5a	600.0±5.0b	500.0±5.0c	427.5±2.5d
	Chromium (mg/kg)				
0	194.0±2.5a	190.3±3.3a	172.5±3.0b	169.0±2.0b	144.0±3.5c
6	199.8±2.8a	196.0±1.5a	181.3±2.3b	174.8±0.3c	151.3±1.8d
12	212.5±2.0a	202.5±1.0b	186.0±1.0c	193.5±4.0d	164.8±3.8e
18	229.3±2.3a	213.8±4.3b	194.5±2.0c	200.3±4.3c	178.5±2.0d
24	233.3±5.8a	226.3±3.3a	204.3±2.3b	206.0±4.0b	185.8±2.3c
30	258.0±3.5a	234.8±2.8b	217.3±3.3c	228.3±3.3b	192.8±1.8d
	Lead (mg/kg)				
0	215.5±2.0a	268.5±4.0b	297.3±3.8c	289.0±1.5d	190.5±1.0e
6	248.3±8.3a	313.8±8.3b	324.5±3.0b	296.8±2.8c	204.8±3.8d
12	275.0±3.5a	362.8±5.3b	353.3±5.8b	311.3±1.3c	230.3±1.8d
18	307.5±4.0a	393.0±4.5b	395.8±1.3b	333.3±3.8c	250.0±5.5d
24	352.3±2.8a	412.0±10.5b	419.5±1.0b	368.5±12.0a	288.5±2.0c
30	399.5±5.0a	476.8±4.8b	467.8±4.8b	452.5±3.0c	309.8±1.3d

Table- 8: Soluble BOD and COD during composting over time

Days	Soluble BOD				
	C/N 15	*C/N 20*	*C/N 25*	*C/N 30*	*Control*
0	996.95±6.18a	894.27±3.66b	789.75±2.40c	905.14±3.18b	1040.16±4.67d
3	846.85±5.33a	762.23±4.28b	636.90±3.21c	647.85±2.72c	897.49±9.84d
6	723.14±4.51a	629.05±8.39b	554.25±1.58c	462.95±8.20d	794.84±10.67e
9	576.05±5.06a	512.90±7.31b	428.92±5.66c	330.91±4.67d	600.71±1.64e
12	488.09±3.89a	402.40±3.52b	308.65±4.48c	194.09±3.55d	577.13±6.49e
15	399.75±4.48a	278.05±6.46b	205.80±6.77c	103.36±4.55d	491.51±5.71e
18	320.20±7.21a	206.01±4.12b	125.82±4.66c	46.05±4.83d	474.38±6.94e
21	224.05±5.13a	147.87±3.61b	77.85±1.31c	46.35±3.47d	331.29±8.64e
24	209.96±4.71a	134.14±5.61b	60.25±4.26c	71.90±1.78c	303.64±9.79d
27	169.01±3.46a	123.80±1.68b	49.14±2.26c	64.10±4.64d	240.16±6.13e
30	136.05±9.16a	88.85±5.57b	31.02±7.42c	46.15±3.61c	189.14±2.97d
	Soluble COD				
0	1463.01±7.33a	1392.10±4.49b	1287.05±6.26c	1438.99±8.42d	1519.84±8.31e
3	1308.50±8.14a	1246.00±3.84b	1217.90±7.55c	1184.01±6.48d	1440.39±6.49e
6	1187.99±10.38a	1129.05±7.80b	1098.01±3.77c	1046.01±7.46d	1291.17±4.63e
9	1196.00±9.13a	1088.96±3.08b	947.11±5.38c	916.10±4.76d	1307.45±10.87e
12	1053.01±4.52a	987.15±8.34b	912.01±6.65c	831.98±5.19d	1188.37±3.09e
15	1021.98±9.85a	960.99±1.39b	846.01±4.62c	711.96±3.49d	1149.11±4.35e
18	934.94±7.07a	875.98±3.40b	764.15±7.69c	647.87±6.61d	1022.89±7.92e
21	744.00±6.89a	783.05±2.09b	690.90±3.52c	594.32±5.49d	1030.09±6.11e
24	633.98±9.14a	724.01±7.43b	563.00±3.13c	506.79±5.70d	990.41±6.57e
27	633.84±7.34a	685.05±4.32b	523.01±2.47c	497.86±4.61d	974.19±4.38e
30	618.01±6.88a	528.95±6.39b	504.04±3.45c	475.00±5.11d	974.81±7.31e

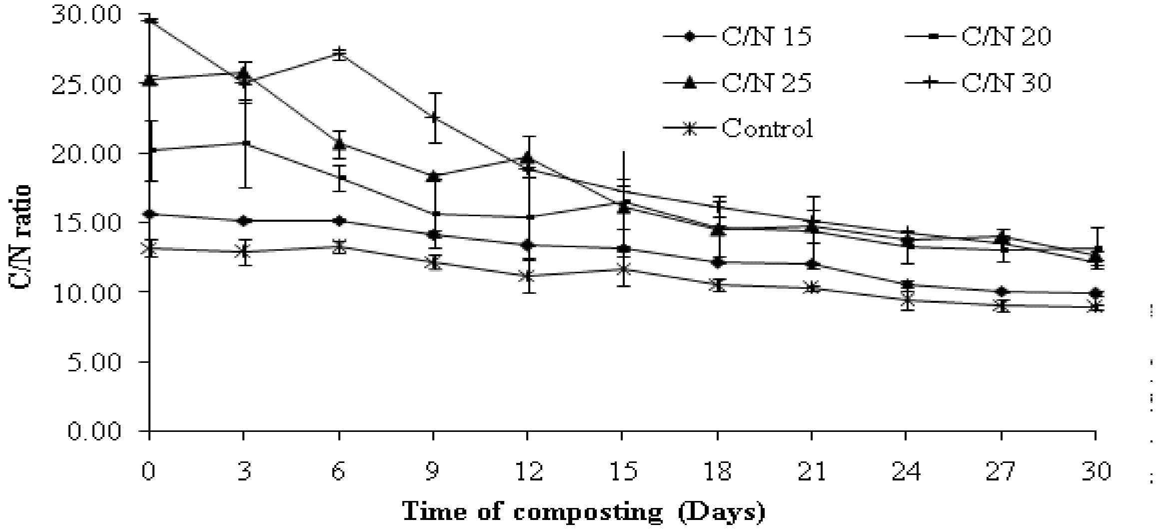

Fig. 2: C/N ratios during composting over time

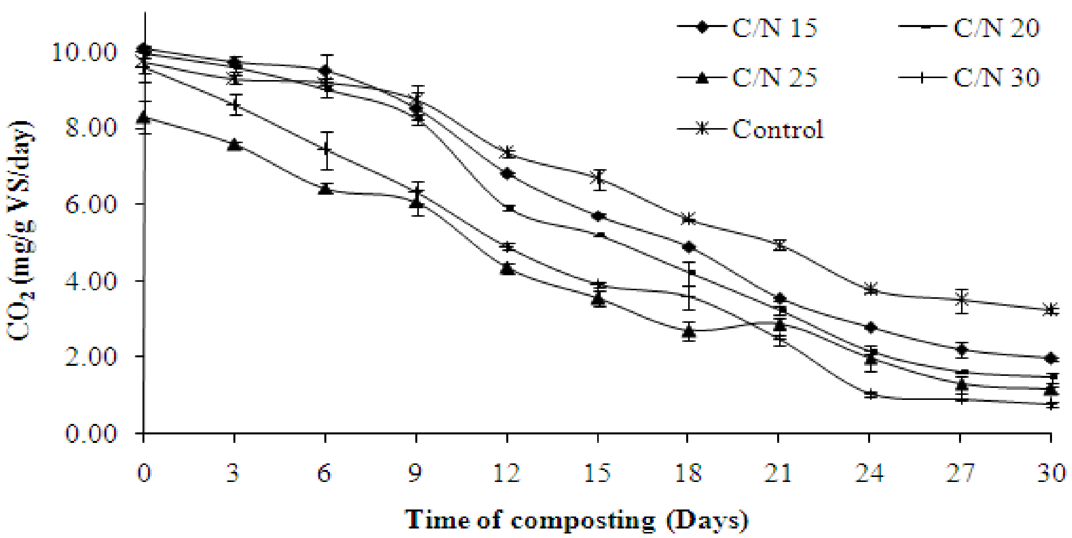

Fig. 3: CO_2 evolution of composting materials over time

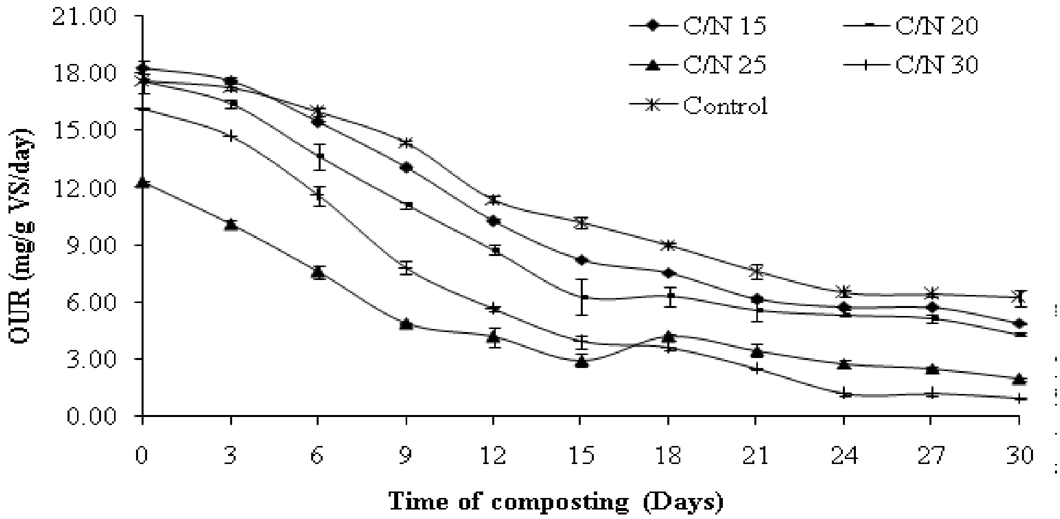

Fig. 4: Oxygen uptake rates (OURs) of composting materials over time

- ***CO_2 evolution and OUR***

CO_2 evolution is the most direct technique of compost stability because it measures carbon derived directly from the compost being tested. Thus CO_2 evolution directly correlates to aerobic respiration. The high CO_2 concentrations indicate elevated microbial respiration of the readily available carbon in the composting mixture. The decrease in the rate of CO_2 evolution with composting time is a result of a reduction in metabolic activity due to the decrease of readily available carbon. The CO_2 evolution rates decreased by 80.4, 85.2, 86.1, 91.9 and 66.8% after 30 days in C/N 15, 20, 25, 30 and control, respectively (Fig. 3). The result showing higher decrease with lower final value of CO_2 evolution in C/N 30 indicated more stabilization as compared to other C/N ratios and control.

Oxygen uptake rate (OUR) is the most accepted method for the determination of biological activity in composts. It evaluates the amount of readily biodegradable organic matter still present in the sample through its carbonaceous oxygen demand. Kalamdhad et al.[17] found OURs to be high in the active stage of composting, as microbes grow rapidly from digesting readily biodegradable substrate. As composting begins, large organic molecules are broken down to smaller, soluble ones and temporarily more substrate may become available. Higher respiration rates were observed in the beginning of the composting in all C/N ratios especially in C/N 30 due to availability of readily degradable cattle manure with the sewage sludge and sawdust.

This was in agreement with Iannotti[16] where OUR was found high in raw material when microbes grow rapidly. The sharp decreased observed in all C/N ratios correlated with the considerable drop in temperature and moisture content. The OUR of C/N ratio 15, 20, 25, 30 and control decreased by 73.1, 75.4, 83.8, 93.8 and 64.6%, respectively (Fig. 4). Higher decrease with lower final OUR value in C/N 30 again enhances our finding indicating more stability of C/N 30. The OUR dropped steadily after the initial sharp decrease in all cases, while after the 2nd week of composting the drop is moderate indicating the compost is approaching stability. On analyzing the results by ANOVA, CO_2 evolution and OUR were vary significantly between the C/N ratios including control ($P < 0.05$).

The Solvita® maturity index was proved to be a good indicator for compost maturity and was more useful at the end of the composting process[15] . The Solvita® maturation index based on CO_2 evolution increased from 3 to 8 in all the experiments. Solvita® results verified that the composts from all the experiments enter into a well stable condition after 30 days especially in C/N 30. While, Solvita® maturation index based on OUR increased from 4 to 8 in case of C/N 25 and 30; and increased from 5 to 7 in case of C/N 15, 20 and control experiments. Therefore, lower final CO_2 evolution and OUR test values in C/N 30 indicated that more stable and highly mature compost without any limitations can be produced from sewage sludge composting by lowering the C/N ratio.

- ***Soluble BOD and COD***

The percentage of readily biodegradable organic matter is supposed to be an important aspect of compost quality[28] . The composting process occurs until the total amount of biodegradable organic material is stabilized, which is odor free and also a poor breeding substrate for flies and other insects. Even if the compost is stable, care should be taken in its application to soil for crops since the biological processes continue, which can strip the soil of its nutrients[29].

The anaerobic condition brought about by the respiration of biodegradable organic matter in the compost is measured as BOD and COD. Soluble BOD values decreased from 996 to 136 mg/l in C/N 15, 894 to 88 mg/L in C/N 20, 789 to 31 mg/L in C/N 25, 905 to 46 mg/L in C/N 30 and 1040 to 189 mg/L in control; while, soluble COD values decreased from 1463 to 618 mg/L in C/N 15, 1392 to 528 mg/L in C/N 20, 1287 to 504 mg/L in C/N 25, 1438 to 476 mg/L in C/N 30 and 1519 to 974 mg/L in control within 30 days of composting. Table 8 shows the rate of decrease of BOD is higher than that of COD. Significant differences in soluble BOD and COD were observed between the C/N ratios including control ($P< 0.05$). As the biological organic content is diminished, BOD and COD are decreased, resulting in decreased emission of CO_2, ultimately indicating stabilization of the compost. Similar trend was also observed by Kalamdhad et al.[17].

CONCLUSION

The effect of C/N ratio was carried out in an agitated pile composting for different C/N ratios (15, 20, 25 and 30 including control) reveals that C/N 30 produced more stable compost after 30 days as compared to others, implying that rigorous decomposition was occurred. Highest moisture loss during C/N 30 justified the higher temperature evaluation. Reduction in pH was observed in all the C/N ratios during 3-4 days but later increased to almost neutral. The high final

EC values observed in C/N 15, 20 and control may be due to higher concentration of sewage sludge as compared to C/N 25 and 30, which are not suited for better compost and also unsafe for plant use. Higher percentage loss in NH4-N and TOC and higher final phosphorus in C/N 30 concluded the paramount waste combination of sewage sludge, cattle manure and sawdust. Higher reductions in C/N ratio, CO_2 evolution, OUR, soluble BOD and COD in C/N 30 demonstrated the stability, resulting the total biodegradable ingredients are stabilized; and a Solvita® maturity index of 8 indicated that the compost was stable and ready for usage as a soil conditioner.

Higher final concentration of nutrients and limited metal content suited the quality of compost prepared from sewage sludge in combination with cattle manure and sawdust. Therefore, it is concluded that the pile composting of sewage sludge at C/N 30 can produce stable compost as compared to all other C/N ratios including control.

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