

Evolution of chemical and biological characterization during agitated pile composting of flower waste

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Abstract

Purpose Flower waste dumping in landfills and other disposal sites is causing major environmental issues due to its highly biodegradable nature. Instead, flower waste can be successfully composted for its higher nutrient value. Therefore, this study evaluated the pile composting of flower waste with different combinations of cow dung and saw dust to produce stabilized compost.

Methods Five agitated piles of flower waste mixture were formed in trapezoidal shape to perform the composting. Pile (P_0) was a control experiment, which contained 100 kg flower waste. The quantity of flower waste mixture with cow dung and saw dust in the other Piles was a total of 100 kg i.e. P_1 (50:40:10) kg, P_2 (60:30:10) kg, P_3 (70:20:10) kg and P_4 (80:10:10) kg, respectively.

Results Temperature above 50 °C was observed in all the piles except in P_0 . Physico-chemical characteristics of compost showed a stabilized compost obtained by proportionate mix of flower waste, cow dung and saw dust. Pile P_2 was observed with pH 7.23 and electrical conductivity 3.98 mS cm⁻¹, total organic carbon 30.9%, total nitrogen 2.31% and C:N ratio 14, thus a good proportion for compost amongst all the piles.

Conclusions Appropriate proportion of waste mixture played an important role in providing favorable conditions for the microbial transformation of flower waste to stabilized compost. Temperature influenced the growth of

microbes and maximum temperature was helpful in fast degradation of organic matter. Finally, flower waste with a combination of cow dung and saw dust was found to be successful during pile composting.

Keywords Agitated pile · C:N ratio · Co-composting · Flower waste · Nutrients

Introduction

In India, flowers are used for various purposes such as an offering to deities in religious places for worship, making garlands and bouquets, as decorative item for various religious ceremonies and social gatherings. As a result, about 300 MT of flower waste is generated per day and it has been found to be one of the major constituents of municipal solid waste (Singh et al. 2013). Most of the flower waste generated is disposed by directly dumping it in open land, water bodies. Alternatively, it is mixed with municipal solid waste for further treatment. Significant increase in leachate formation has been reported when flower waste/organic waste is mixed with municipal waste and is disposed off. Leachate production and percolation into ground water pollutes the ground of nearby landfill area (Varma and Kalamdhad 2014b). Flower waste disposed into rivers causes pollution of river water and is also harmful for both human and aquatic life. Thus, owing to the organic nature of flower waste and the significant presence of macro and micronutrients, composting offers a feasible solution to deal with flower waste.

Composting is defined as the natural biological decomposition of organic matter under self heating, aerobic and moist conditions to produce a stable nutrient enriched product which is used as organic manure (Bustamante et al.

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2009). Organic wastes that have high moisture content generate the leachate during the initial stage of composting and are responsible for decrease in temperature and development of the anaerobic condition. Leachate problem can be solved by addition of bulking agent which also allows free passage of air during the process of composting. Bulking agents also act as buffer against the organic acids produced during the initial stage of decomposition. They also help to maintain the pH 6–8 (Sánchez-Monedero et al. 2001). Typically used bulking agents for composting process are saw dust and dry leaves (Varma and Kalamdhad 2014b), newspaper (Ball et al. 2000), Wheat bran (Wang et al. 2012), Pumice (Wang et al. 2014; Wu et al. 2015) and wood shaving (Adhikari et al. 2009).

Several studies have been reported for agitated pile composting of organic waste such as vegetable waste (Varma and Kalamdhad 2014a), water hyacinth (Singh and Kalamdhad 2015), municipal solid waste (Iyengar and Bhawe 2006), chicken litter (Gao et al. 2010), sewage sludge and pig faeces (Huang et al. 2004), food waste and saw dust (Zhou et al. 2014). However, there is limited literature available on the composting of flower waste with cow dung and saw dust as bulking agent.

Therefore, this study was focused on physico-chemical and biological characterization during composting of flower waste with cow dung and saw dust in different proportions. The best proportion for flower waste composting along with the addition of cow dung and saw dust was evaluated based on maturity and final micro-macronutrient concentration during the different stages of the composting process.

Materials and methods

Feedstock

This study was conducted in Environmental Engineering laboratory, SVNIT, Surat, Gujarat (India). Surat is situated on the bank of the river Tapti. It is located at 21.17°N latitude and 72.83°E longitude. Flower waste was collected from temples in Surat area, India. The debris (plastic, threads, incense sticks, coconut, etc.) was removed from flower waste manually. Large quantities of marigold were found along with rose, lotus, and siroi lily. Fresh cow dung was collected from a dairy farm in a nearby village. Saw dust was collected from a saw mill in Bhatar market. Table 1 shows the initial characteristics of feedstock.

Agitated pile composting

Identical agitated piles of trapezoidal shaped were prepared. The bottom length was 2700 mm, width 450 mm, height 500 mm and top width was 100 mm and L/W ratio

was kept as 6 with 100 kg of total weight. Cow dung and saw dust were mixed thoroughly followed by addition of the flower waste. The mixture was again made to blend properly. Studies were conducted in duplicate and average value was reported. Initially, all the piles were covered with plastic sheets for six days. The proportions of each pile are shown in Table 2.

All piles were manually turned upside down after three days. A sample of one kg was then collected from the top bottom and the centre at various locations of the pile and thoroughly mixed to form a homogenous sample. This process was repeated every three days for the first thirty days and then at an interval of seven days for the next thirty days. The collected samples were dried and crushed into fine powder. They were sieved through a 0.2 mm sieve and kept in desiccator for further analysis.

Analysis of physico-chemical parameters

The temperature was monitored throughout the composting period using digital thermometers. The temperature at different locations of each pile was measured and the average temperature was reported. Moisture content was monitored up to 30 days and after that moisture content was adjusted between 55 to 60%, if needed; water was added on dry weight basis during the turning of piles. Gravimetric method was used for determining the moisture content of the sample after pile turning (BIS, 1982). For determining the pH and conductivity, 10 g dried sieved sample was diluted by 100 mL distilled water (1:10 w/v) and kept through mixing in rotary shaker for 2 h. Then the sample was left to be settled for half an hour for settling and finally filtered through the whatman filter paper no 42 (Singh and Kalamdhad 2016).

Total nitrogen was determined by Kjeldahl method. Ammonical nitrogen ($\text{NH}_4^+\text{-N}$) was determined by KCl extraction method followed by phenate method (APHA 2005). Volatile solids were determined by keeping the oven dried sieved sample in a muffle furnace for 550 ± 5 °C for 2 h. The total organic carbon was calculated by dividing the volatile solids by 1.83 (Adhikari et al. 2009).

Fresh wet samples were used for the presence of CO_2 and determination of germination index. The CO_2 evolution rate was determined as described by Singh and Kalamdhad (2014). The Germination Index test was determined as described by Zhang and Sun (2015).

The macronutrients (P, K, Na, Ca and Mg) and the micronutrients (Fe, Mn, Zn and Cu) present in the compost were analyzed according to Singh and Kalamdhad (2012). The sample was digested before analysis by heating 0.2 g dry sample with a ratio of 5:1 of 10 mL H_2SO_4 and HClO_4 at 300 °C for 2 h. The digested sample was used for determining the total phosphorous present using stannous



Table 1 Initial characteristics of feedstock material

Parameters	Flowers waste	Cow dung	Saw dust
Moisture content (%)	82.01 ± 0.7	80.10 ± 2.1	16.71 ± 0.7
pH	5.26 ± 0.03	7.19 ± 0.04	5.85 ± 0.90
Electrical conductivity (mS cm ⁻¹)	4.51 ± 0.08	3.29 ± 0.08	0.98 ± 0.91
Total organic carbon (%)	44.70 ± 1.5	32.20 ± 1.8	54.20 ± 1.2
Total nitrogen (%)	2.13 ± 0.08	1.39 ± 0.20	0.68 ± 0.09
NH ₄ ⁺ -N (%)	1.80 ± 0.08	0.37 ± 0.08	0.21 ± 0.07
C:N ratio	20.90 ± 0.3	23.10 ± 0.4	79.77 ± 2.1
Total phosphorous (g kg ⁻¹)	3.15 ± 0.08	2.52 ± 0.07	1.25 ± 0.09
Na (g kg ⁻¹)	0.90 ± 0.08	2.49 ± 0.05	0.65 ± 0.07
K (g kg ⁻¹)	13.75 ± 0.50	10.42 ± 0.31	1.31 ± 0.15
Ca (g kg ⁻¹)	6.31 ± 0.95	8.92 ± 0.63	2.94 ± 0.70
Cu (mg kg ⁻¹)	48.62 ± 0.3	36.24 ± 0.2	17.82 ± 0.2
Zn (mg kg ⁻¹)	129.53 ± 1.0	178.22 ± 1.3	6.21 ± 1.3
Mn (mg kg ⁻¹)	98 ± 0.8	258 ± 1.1	56 ± 1.0
Fe (g kg ⁻¹)	1.86 ± 0.57	1.88 ± 0.57	0.47 ± 0.51
Mg (g kg ⁻¹)	2.55 ± 0.19	5.83 ± 0.15	1.23 ± 0.12

NH₄⁺-N ammoniacal nitrogen, C:N ratio carbon to nitrogen ratio, Na sodium, K potassium, Ca calcium, Cu copper, Zn zinc, Mn manganese, Fe iron, Mg magnesium

Table 2 Combination of flower waste, cow dung and saw dust

Name of pile	Flower waste (kg)	Cow dung (kg)	Saw dust (kg)
P ₀	100	–	–
P ₁	50	40	10
P ₂	60	30	10
P ₃	70	20	10
P ₄	80	10	10

chloride method (APHA 2005; Singh and Kalamdhad 2014). The concentrations of Na and K were determined using flame photometer (Systronics 128μ) and the concentrations of calcium (Ca), copper (Cu), zinc (Zn), manganese (Mn), iron (Fe), chromium (Cr) and magnesium (Mg) were determined by Inductively Coupled Plasma Atomic Emission Spectroscopy method.

Statistical analysis

The value of measured Physico-chemical parameters reported for each trial is the mean of duplicate. A one way repeated measure ANOVA was used to test for differences in each of the measured Physico-chemical parameters during composting. SPSS 13.0 was used to perform the analysis of variance (ANOVA $P < 0.05$) for each parameter among five piles. The objective of statistical analysis was to determine the significant differences among the parameters analyzed for different combinations. Table 3 shows the Anova of physico-chemical parameters.

Results and discussion

Initial characteristic of waste material

The initial characteristic of the combination of different waste mixture content piles is shown in Table 1. Flower waste, cow dung and saw dust contained 82.01, 80.10 and 16.71% of moisture content, respectively. Singh and Kalamdhad (2014) reported that bulking agent regulates moisture content and provides free air passage. In pile P₀ (100 kg), flower waste lump formation was observed on the third day and it was possibly due to excess moisture content and lack of air passage between the particles. Leachate production was also observed in pile P₀. The covering of each pile with plastic sheet helped to increase the temperature inside the pile and it reached the thermophilic phase within one day. Due to the presence of moisture and the action of microbes there was an increase in humidity inside the pile. As a result, vapours were seen on the inner surface of the plastic sheets.

The bacterial activity increased due to the temperature inside the pile and presence of moisture (water) converted this heat into steam. Varma and Kalamdhad (2014b) reported that vapour provided was responsible for the breakdown of tough organic material (lignin or tannin). Turning or proper mixing of piles in every three days provided adequate oxygen to the piles, which reduced the stinking and enhanced the temperature.

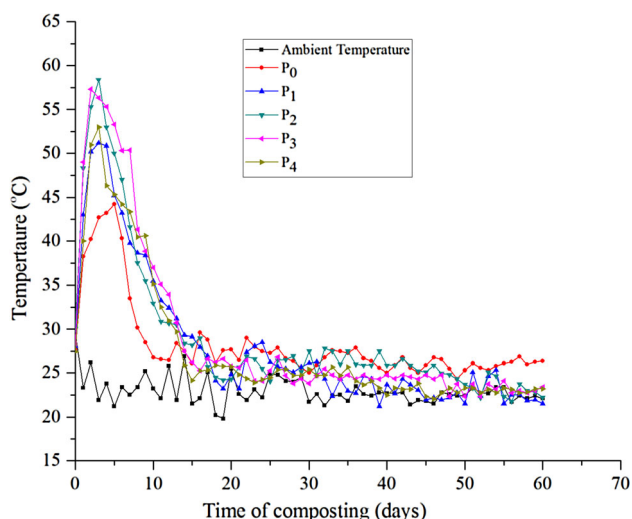


Table 3 Anova of physicochemical parameters

Parameters	Anova	Sum of squares	Degree of freedom (<i>df</i>)	Mean square	<i>F</i> value	<i>P</i> value
Electrical conductivity	Between groups	75.780	4	18.945	209.660	0.0001
	Within groups	6.777	75	0.090		
	Total	82.557	79			
Total organic carbon	Between groups	279.835	4	69.959	5.004	0.001
	Within groups	1048.604	75	13.981		
	Total	1328.439	79			
C:N ratio	Between groups	269.943	4	67.486	4.677	0.002
	Within groups	1082.122	75	14.428		
	Total	1352.066	79			
Ash content	Between groups	937.140	4	234.285	5.004	0.001
	Within groups	3511.670	75	46.822		
	Total	4448.810	79			
Total nitrogen	Between groups	0.785	4	0.196	5.115	0.001
	Within groups	2.878	75	0.038		
	Total	3.663	79			
Sodium	Between groups	15.420	4	3.855	21.046	0.0001
	Within groups	13.737	75	0.183		
	Total	29.157	79			
Potassium	Between groups	205.705	4	51.426	54.613	0.0001
	Within groups	70.623	75	0.942		
	Total	276.329	79			

Temperature

Temperature is one of the key indicators for active microbial biomass. Figure 1 shows variation of temperature in each pile during the composting process. Each pile attained the mesophilic phase (Temp <40 °C), thermophilic phase (>45 °C), cooling and maturation phase. However, pile P_0 could not attain proper thermophilic phase (>45 °C) because of the presence of excess moisture

**Fig. 1** Variation of temperature during the composting period

which was unfavourable for the growth of microbes. Piles P_1 and P_4 remained at temperature >50 °C for three and two days, respectively. Piles P_2 and P_3 remained at >50 °C for 4 and 6 days, respectively. Maximum thermophilic phase was observed in piles P_2 and P_3 due to the proper combination of flower waste and cow dung. The presence of higher and lower proportion of waste mixture was responsible for the duration of thermophilic phase and for achieving maximum temperature. The maximum temperature recorded in piles P_2 and P_3 was 58.40 and 57.32 °C, respectively. Temperature between 50 and 60 °C for two consecutive days kills the pathogens and this sanitizes the compost (Awasthi et al. 2015). For each pile, the observation was that within 15 days the temperature became near to the ambient temperature. Similar variations of temperature were reported by Abdullah et al. (2013), Singh and Kalamdhad (2014), Varma and Kalamdhad (2014b) for the composting of different organic waste.

Moisture content

Figure 2 illustrates moisture content variations in each pile. Initial moisture content of piles P_0 , P_1 , P_2 , P_3 and P_4 were $82.0 \pm 2.68\%$, $72.5 \pm 3.01\%$, $73.7 \pm 2.92\%$, $76.7 \pm 3.21\%$, $81.2 \pm 2.87\%$, respectively. Moisture content decreases linearly in P_1 , P_2 , P_3 and P_4 . Whereas increase in moisture content and formation of leachate was observed in

P_0 , decrease in moisture content was primarily because of the use of saw dust, which absorbed excess moisture, and thus maintained moisture content, whereas in absence of bulking agent, moisture content increased. Simultaneously, with the increase of cow dung, decrease in temperature was observed. Cow dung provides microbial inoculums which enhances microbial activity resulting in increasing the rate of degradation of organic matter. P_1 and P_4 took more time because of the presence of ratio of cow dung and flower waste i.e. 4:5 and 1:8, respectively. This indicates that the ratio of cow dung and flower waste significantly affects the composting and the adequate ratio must be maintained.

pH and Electrical conductivity (EC)

Figure 3 shows the variation in pH and electrical conductivity during composting. The increase in pH value was observed for the first 15 days and later a slight variation in pH value was observed for the next 15 days (15–30 days). After 30 days, pH of compost was stabilized at 7.5 ± 1.2 in each pile. The increase in pH was mainly due to the regular turning process which assists in maintaining adequate oxygen to keep aerobic condition (Awasthi et al. 2015).

The neutral pH value was observed after the 12th day as flower waste contained high water soluble K concentration which reacts with bi-carbonic acid (HCO_3^-) during the degradation of organic matter to form strong base KOH. The buffering capacity of humus and volatilization of ammonia result in a slight decrease in pH value. Similar results were reported for organic waste composting (Kalamdhad and Kazmi 2009; Mena et al. 2003). The final pH value between 6 and 8 shows the maturity of the compost (Varma and Kalamdhad 2014a).

Electrical conductivity represents the salinity of compost. The range of EC into compost is $0.14\text{--}12 \text{ mS cm}^{-1}$ which is

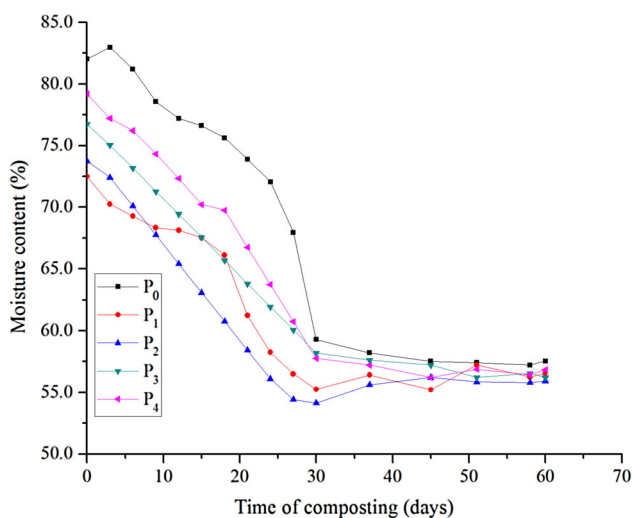


Fig. 2 Variation of moisture content during the composting period

suitable for the growth of plants (Huang et al. 2004). Initial low value in electrical conductivity in waste composition shows the suitability of flower waste for composting. It was observed that the increased electrical conductivity in the beginning of thermophilic phase became stable in cooling phase. However, this behaviour was not observed in pile P_0 where electrical conductivity increased. The degradation of organic matter took place in the beginning of the thermophilic phase which released mineral salts such as ammonium and phosphate and that increased the electrical conductivity. Stabilized electrical conductivity value attributes to the volatilization of mineral salts (Yadav et al. 2013). In spite of electrical conductivity value in between 0.12 and 12.2 mS cm^{-1} in P_0 , it did not indicate quality compost due to the high moisture content and the low temperature which influence the degradation of the organic matter.

Total organic carbon (TOC), ash content and ammoniacal nitrogen ($\text{NH}_4^+\text{-N}$)

Changes in carbon concentration indicate compost maturity. Higher rate of carbon content degradation indicates stabilized compost at the end of the composting. Variation of total organic carbon is shown in Fig. 4a. Reduction of total organic carbon at the end of composting in piles P_0 , P_1 , P_2 , P_3 and P_4 were 13.5, 24.5, 29.6, 30.9 and 22.4%, respectively. The low reduction of total organic carbon in P_0 was due to unavailability of inoculum such as cow dung and the absence of temperature $>50^\circ\text{C}$. Pile P_1 had easily digestible organic substrate for microbes. This reduction in total organic carbon was higher than that of P_4 . The percentage reduction of total organic carbon in P_2 and P_3 was higher due to the availability of thermophilic bacteria which enhances the degradation rate of complex cellulose and protein. A similar result in the reduction of total organic carbon in organic waste was reported in the literature (Awasthi et al. 2015; Zhou et al. 2014). The reduction of the total organic carbon content indicates the mineralization of the organic matter and the maturity of the compost.

Figure 4b shows the variation of ash contents during the composting period. Initially the presence of ash content in pile P_0 , P_1 , P_2 , P_3 and P_4 were 18.65 ± 2.63 , 19.44 ± 3.12 , 19.51 ± 2.75 , 17.26 ± 1.95 and $17.39 \pm 2.75\%$, respectively, which was increased, respectively, to 29.70 ± 3.11 , 39.22 ± 2.42 , 43.37 ± 1.58 , 42.90 ± 1.75 and $35.95 \pm 2.35\%$ at the end of composting period. Higher rate of increase in ash contents was observed in pile P_2 (6:3:1) ratio of waste mixture due to the higher rate of degradation of organic matter at the time of thermophilic phase. In pile P_0 , the increase in percentage of ash content was less as compared to the pile containing cow dung and saw dust due to lower temperature and presence of higher moisture content.

Fig. 3 Variation of pH and electrical conductivity during composting period

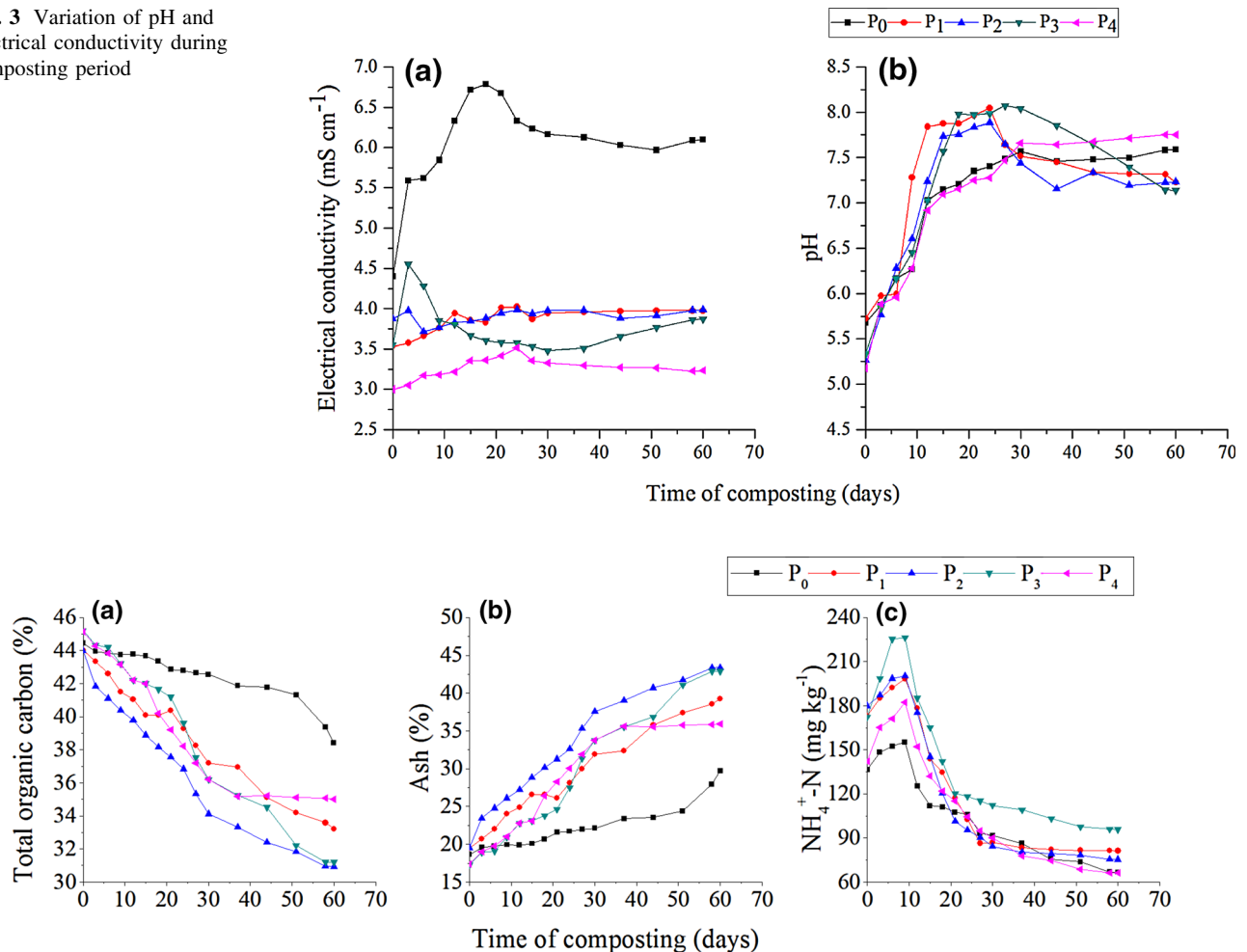


Fig. 4 Variation of total organic carbon ash content and ammoniacal nitrogen during composting period

Figure 4c shows the variation of ammoniacal nitrogen during the composting period. It was observed that in P₀ the ammoniacal nitrogen reduction was high when compared to other piles. This may be due to the low temperature in thermophilic phase and low degradation rate of the organic matter. In piles P₁, P₂, P₃ and P₄ the initial ammoniacal nitrogen were 73.0 ± 21.3 , 179.8 ± 19.5 , 172.3 ± 21.5 and 142.2 ± 16.5 mg kg⁻¹, respectively, which finally decreased to 81.8 ± 23.2 , 75.3 ± 24.5 , 95.8 ± 19.5 and 66.4 ± 18.9 mg kg⁻¹, respectively, during composting. The ammoniacal nitrogen concentration decreased due to the volatilization of NH₄⁺-N by the microbes and the nitrification during the composting process.

Macro nutrients (N, P, K, Na, Ca and Mg) and micro nutrients (Fe, Mn, Zn and Cu)

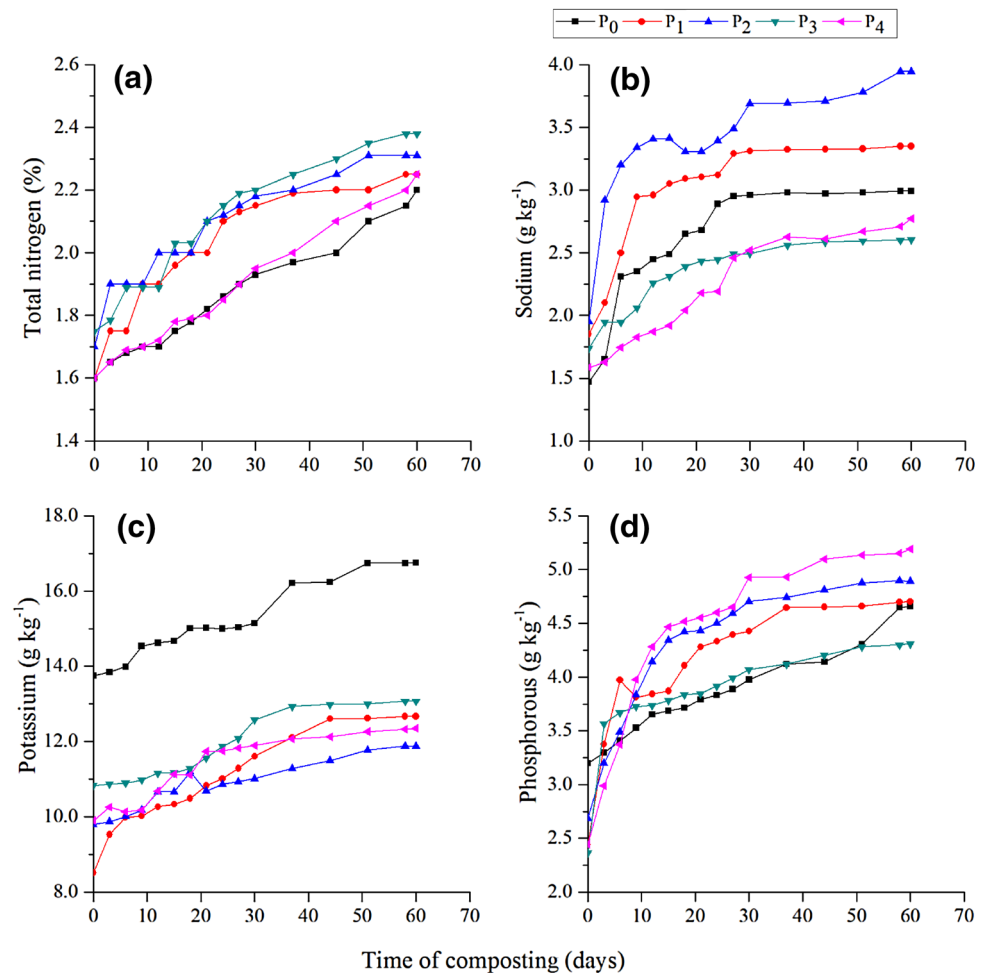
The Macro nutrients in the organic matter are used by the microbes for body metabolism and also for the growth of plants. Figure 5a shows the variation of total nitrogen

content. The initial concentration of total nitrogen in piles P₀–P₄ was between at 1.6 and 1.7% and increased to concentrations of 2.2–2.3% at the end of the composting process. The increasing trends of total nitrogen in this study was found to be similar to results by Jolanun and Towprayoon (2010). Total nitrogen increased due to the degradation of organic matter and loss of carbon in the form of CO₂ and the contribution of nitrogen fixing bacteria which were the responsible for the increase of total nitrogen content (Garcia et al. 1992).

Figure 5b shows the increase in concentration of sodium from the initial to the final day of composting. Initial concentrations of sodium in piles P₀–P₄ were 2.5–3.2 g kg⁻¹ which increased to 5.3–4.9 g kg⁻¹ within the 60 days composting period. The concentration of macronutrients P, K, Na, Ca and Mg increased gradually which indicates the net loss in dry mass due to the degradation of organic matter and the release of CO₂, NH₃ and H₂S during the composting process (Bustamante et al. 2009).



Fig. 5 Variation of total nitrogen, sodium, potassium, phosphorous during composting period



Initial total phosphorous content in the pile P_0 was $3.20 \pm 0.09 \text{ g kg}^{-1}$, which finally increased to $4.65 \pm 1.23 \text{ g kg}^{-1}$. In P_1 , P_2 , P_3 and P_4 the initial content of phosphorous were 2.44 ± 0.32 , 2.69 ± 0.12 , 2.37 ± 0.89 and $2.45 \pm 0.85 \text{ g kg}^{-1}$, which increased, respectively, to 4.70 ± 0.12 , 4.89 ± 0.52 , 4.31 ± 0.74 and $5.19 \pm 0.95 \text{ g kg}^{-1}$ at the end of the composting process. The order of increase of the presence of phosphorous content in the piles was $P_4 > P_2 > P_1 > P_0 > P_3$. The increase in phosphorus concentration during composting can be attributed to the loss of organic matter. Similar increase in phosphorous content was observed by Singh and Kalamdhad (2014), Varma and Kalamdhad (2014b) during the composting of water hyacinth and vegetable waste.

Initial concentration of potassium in pile P_0 was $13.75 \pm 0.50 \text{ g kg}^{-1}$ and it increased to $16.75 \pm 0.82 \text{ g kg}^{-1}$ in 60 days. The concentration of potassium was rich in pile P_0 . It shows the high inherent content in flower waste, suggesting that the compost is rich in potassium. The Initial potassium concentrations in piles P_1 , P_2 , P_3 and P_4 were 13.7 ± 0.54 , 8.5 ± 1.2 , 9.7 ± 0.94 , 10.8 ± 0.63 and $9.9 \pm 0.54 \text{ g kg}^{-1}$, and, respectively, increased to

16.7 ± 0.85 , 12.6 ± 1.25 , 11.8 ± 1.34 , 13.0 ± 1.54 and $12.3 \pm 1.24 \text{ g kg}^{-1}$ at the end of the composting period. The increase in potassium concentration in all the piles is partly due to potassium assimilation and immobilisation by microbes (Singh and Kalamdhad 2012).

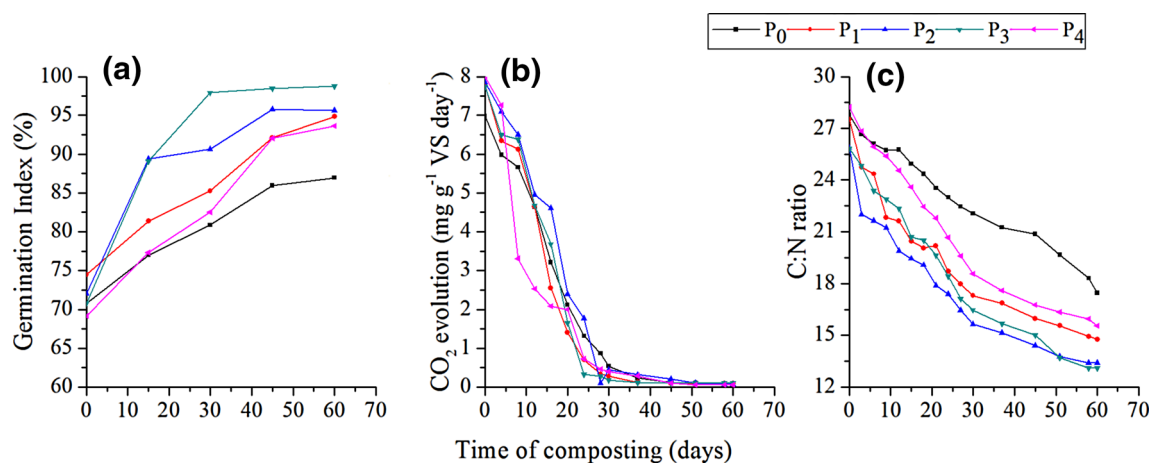
Micronutrients present in small amounts in the compost help in the growth of the plant and in plant reproduction (Wang et al. 2004). Manganese helps in nitrogen assimilation and photosynthesis in plant. Zinc helps in the secretion of enzymes and protein synthesis which regulate the growth of plants. Copper and iron help in the metabolism process of the plants. The initial and final concentration of micronutrient Fe, Mn, Zn and Cu present in the compost is shown in Table 4. In all the piles, an increase in micronutrients contents was observed. The increment order of micronutrient present on the final day of compost was $\text{Fe} > \text{Mn} > \text{Zn} > \text{Cu}$.

The concentration of iron in P_0 $8.6 \pm 0.49 \text{ g kg}^{-1}$ was the highest due to the high iron content in flower waste. Initially the concentration of manganese in pile P_1 was more compared to the remaining piles. The concentration of manganese in cow dung and flower waste was 98 ± 0.8

Table 4 Macro and microelement contents in the initial and final day of the composting period

Elements	Day	Pile 0	Pile 1	Pile 2	Pile 3	Pile 4
Ca (g kg ⁻¹)	0	6.43 ± 0.77	10.66 ± 0.51	9.12 ± 1.37	7.83 ± 0.46	8.11 ± 0.88
	60	16.49 ± 0.76	29.67 ± 1.04	25.98 ± 0.50	18.09 ± 1.85	15.92 ± 1.03
Mg (g kg ⁻¹)	0	2.27 ± 0.02	3.55 ± 0.04	3.2 ± 0.01	2.83 ± 0.03	2.47 ± 0.01
	60	6.86 ± 0.02	6.53 ± 0.01	5.22 ± 0.02	6.05 ± 0.03	5.87 ± 0.02
Fe (g kg ⁻¹)	0	0.92 ± 0.46	1.64 ± 0.46	1.58 ± 0.52	1.57 ± 0.43	1.03 ± 0.20
	60	8.69 ± 0.49	6.8 ± 0.48	4.69 ± 0.33	6.77 ± 0.25	7.53 ± 1.01
Mn (mg kg ⁻¹)	0	99.63 ± 1.63	208.36 ± 0.50	143.17 ± 1.1	126.43 ± 0.70	110.24 ± 1.0
	60	126.36 ± 2.0	244.42 ± 0.50	171.32 ± 1.0	170.1 ± 1.12	152.71 ± 0.5
Zn (mg kg ⁻¹)	0	127.29 ± 1.0	130.76 ± 0.50	177.11 ± 1.1	152.99 ± 0.50	141.78 ± 0.5
	60	163.77 ± 0.7	177.42 ± 0.80	204.88 ± 0.3	192.06 ± 0.50	176.13 ± 0.7
Cu (mg kg ⁻¹)	0	36.42 ± 0.08	39.76 ± 0.11	38.18 ± 0.18	37.12 ± 0.12	35.11 ± 0.11
	60	48.14 ± 0.14	40.6 ± 0.25	42.73 ± 0.15	43.21 ± 0.03	45.26 ± 0.03

Ca calcium, Mg magnesium, Fe iron, Mn manganese, Zn zinc, Cu copper

**Fig. 6** Variation of germination index, CO₂ evolution rate, C:N ratio

and $258 \pm 1.1 \text{ mg kg}^{-1}$, respectively. The increase in magnesium content in pile P_1 was due to increased quantity of cow dung. The concentration of zinc in pile P_2 was comparatively more than the remaining piles. This was due to the availability of zinc content in the flower waste $129 \pm 1 \text{ mg kg}^{-1}$ and cow dung $178 \pm 1.3 \text{ mg kg}^{-1}$. The concentration of copper was more in the flower waste $48.62 \pm 0.3 \text{ mg kg}^{-1}$ whereas in cow dung it was $36.24 \pm 0.2 \text{ mg kg}^{-1}$. The concentration of copper in pile P_0 was observed as $48.14 \pm 0.14 \text{ mg kg}^{-1}$ on the final day of composting. This study showed that the flower waste was rich in macro and micronutrients which are essential for the plants. The addition of cow dung helps in fast microbial activities. In each pile, it was observed that at the end of composting the concentration of micronutrients had increased due to the degradation of organic matter and the release of ammonia.

Germination index (GI), C: N ratio and carbon dioxide (CO₂) evolution

Germination index is necessary for the determination of maturity and phytotoxicity effects of compost (Gao et al. 2010; Huang et al. 2004). Germination index is widely used to check the suitability of compost for agricultural purposes. Figure 6a shows the germination index during the composting process of flower waste. The germination index which was initially 70, 74, 72, 70 and 69% in piles P_0 – P_4 were increased to 86, 94, 95, 98 and 93%, respectively, at the end of the composting period. The germination index was more than 50% which shows that flower waste compost is a good source for the growth of plants. Zhang and Sun (2015) concluded that the optimum percentage of germination index suitable for mature compost is more than 50%. Similar trends of germination index

were observed by Gao et al. (2010) and Singh et al. (2013) during composting of different proportions of organic waste.

CO₂ evolution is one of the best methods to determine the stability of the compost because it measures the carbon derived directly from decomposition or degradation of the organic matter. CO₂ evolution directly synthesizes aerobic respiration, which shows the direct measure of respiration and aerobic microbial activity (Kalamdhad and Kazmi 2009). CO₂ production decreased with time. Figure 6b depicts that the CO₂ production in piles P₁–P₄ was 6.9, 7.7, 7.6, 7.4 and 7.9 mg g⁻¹ VS day⁻¹ which decreased to 0.5, 0.2, 0.4, 0.1 and 0.3 mg g⁻¹ VS day⁻¹, respectively, during the composting process. Similar decreasing trends of CO₂ production rate was observed by Varma and Kalamdhad (2014b) during the rotary drum composting of vegetable waste.

Figure 6c shows the variation of C:N ratio during the composting process. C:N ratio is a widely used parameter to indicate the maturity of the compost (Huang et al. 2004; Jiang et al. 2011). The initial C:N ratio of pile P₀ was 28 which reduced to 18 at the end of the composting period. The reduction in C:N ratio was due to the reduction of total organic carbon and increase of total nitrogen during the composting period. The initial C:N ratio of pile P₁–P₄ was 26–28 and it decreased to 14–16 at the end of composting period. The reduction of C:N ratio was due to the usage of carbon as a source of energy by the microorganisms while nitrogen was used for building the cell structure by the different group of microbes (Adhikari et al. 2009; Yadav et al. 2011; Yadav and Garg 2009). In P₂, due to fast degradation of cow dung, a 24.5% reduction of the C:N ratio was observed without reducing the carbon content, which indicates the quality of the matured compost. In pile P₀, due to rich content of flower waste and the absence of saw dust and cow dung, less reduction in total organic carbon content and an increase in the total nitrogen content was observed, all of which resulted in an increased C:N ratio. This research shows that the addition of cow dung plays an important role in the reduction of the total organic carbon and the duration of composting process.

Conclusions

A conclusion that the study derived is that the agitated pile composting of flower waste with cow dung and saw dust as bulking agent resulted in completely stabilized compost at the end of sixty days. The study also reported the leachate production during the process due to the absence of saw dust. The maximum degradation of organic matter was observed during the first 30 days of the composting process. The addition of the bulking agent helped in

maintaining the aerobic condition, which reduced the excessive formation of leachate and maintained the thermophilic stage for a longer period. Macro and micronutrients contents after composting were observed in suitable ranges for agricultural purposes. The physico-chemical analysis showed that the pile containing 60 kg of flower waste, 30 kg of cow dung, and 10 kg of saw dust would be the most appropriate combination for the composting of flower waste.

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