Application of rotary in-vessel composting and analytical hierarchy process for the selection of a suitable combination of flower waste

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ABSTRACT
The flower waste generated from different sources is either mixed with municipal solid waste or thrown into the river in India. Flower waste is rich in organic contents and can be converted into nutrient-enriched compost. The aim of the present study was to determine the changes in physico-chemical and biological changes during the composting of flower waste by using rotary drum technique. For composting the flower, waste was mixed with cow dung, sawdust, and wheat bran. Four different trials were performed, in which 0.5 wt% of sawdust and wheat bran was added in each trial. From the series of trials 1–4, the different proportions of flower waste and cow dung were 5:4, 6:3, 7:2 and 8:1, respectively. Finally, the compost produced by all the trials were found to have pH 7.23–7.51, electrical conductivity 5.5–6.12 mS/cm, reduction in the percentage of total organic carbon 22–33%, the percentage increase in total nitrogen 2.17–2.66%, C:N ratio 13–17, sodium 2.14–2.60 g/kg and calcium 13.35–15.58 g/kg. The analytical hierarchy process was used for the ranking of the trials to find the best proportions from the different combinations performed in this study.

1. Introduction
The disposal of solid waste is a big challenge both in the rural and the urban areas. The waste generation in India is 400–600 gram/capita/day (Elango, Thinakaran, Panneerselvam, & Sivanesan, 2009). Due to the huge production of waste, the availability of land for landfills is increasing. Landfilling requires a large area of land which is very costly and that land can be used for other purposes. The municipal waste generated contains 70% of organic waste which are the vegetable waste, flower waste, fruit waste, etc. (Rashad, Saleh, & Moselhy, 2010). Most of the municipal waste used for landfilling produces leachate and pollute the groundwater of the surrounding area. Landfilling causes air pollution and is a threat to the environment.

The setting for present study happened to be Surat, one of the fastest growing cities of India in the state Gujarat which is located on the banks of river Tapti. The city is situated at 72.83° east longitude and 21.17° north latitude. Surat alone generates solid waste of 1700 ton/day. Among the wastes, the generation of flower waste is 1500 kg/day (Sharma, Varma, Yadav, & Kalamdhad, 2017). The flower waste contains organic materials which are easily degradable and are a good source of macro and micronutrients. Composting is the best option for degradation of the flower waste. The conversion of organic waste available into compost is an option for disposal. The compost obtained from flower waste is an alternate for the replacement of chemical fertilizers. Chemical fertilizers decrease the fertility of soils whereas compost will increase the organic content of the soil. The compost also increases the water holding capacity of the soil and reduces soil erosion (Elango et al., 2009).

Composting is an aerobic process under the thermophilic condition for transforming organic matter into nutrient-enriched compost. Aeration and moisture content play an important role in maintaining the thermophilic condition. Aeration is also important to maintain the process of aerobic condition. Flower waste contains 75–83% moisture which produces leachate and gives out an unpleasant smell if not managed properly. The moisture content is very important for the composting process to provide proper aeration, increasing the rate of microbial activity and the free air space (Jolanun & Towprayoon, 2010; Sadaka & El–Taweel, 2003). The moisture content and proper aeration can be controlled by the addition of the bulking agent. Numerous researchers had used various types of bulking agents such as leaves (Elwell, Keener, Hoitink, Hansen, & Hoff, 1994), biochar (Dias, Silva, Higashikawa, Roig, & Sánchez-Monedero, 2010), and sawdust (Iqbal, Shafiq, & Ahmed, 2010) to maintain proper moisture content, free airspace, and aeration.
Various methods are available for composting process. Rotary drum is an efficient and decentralized composting technique. It helps in proper mixing, aeration and produces stable and matured compost. The rotary drum can easily be installed on the site of the organic waste generation. Kalamdhad and Kazmi (2008) used the capacity of the 250-litre rotary drum for the composting of cow dung, mixed vegetable waste, sawdust, and compost as bulking agents. Fernández, Sánchez-Arias, Rodríguez, and Villaseñor (2010) used the closed rotary drum reactor with forced aeration of capacity 100-litre using sewage sludge, olive mill waste, and winery waste. The authors concluded that composting was successful when sewage sludge used as the bulking agent. Singh and Kalamdhad (2013) used the rotary drum of capacity 3.5 m³ for the composting of vegetable waste, sawdust, and cattle manure. Studies have been carried out for rotary drum composting of manure and straw co-composting by Rihani et al. (2010) and Rosal, Chica, Arcos, and Dios (2012), and house hold waste using rotary drum by Akinbile and Yusoff (2012). Numerous works had been carried out by rotary drum composting of organic waste using a various bulking agent. There are no studies available for the flower waste composting using rotary drum method.

Analytical hierarchy process (AHP) is very popular and widely used decision-making method to solve the problem of various fields. Curiel-Esparza, Cuenca-Ruiz, Martin-Utrillas, and Canto-Perello (2014) studied the analytical hierarchy method for selecting a sustainable disinfection technique for wastewater reuse projects. Karimi, Mehradadi, Hashemian, Bidhendi, and Moghaddam (2011) used AHP method for selecting the best water treatment process. Ghaitidak and Yadav (2014) used AHP method to check the effect of coagulant in greywater treatment and selected the best coagulant condition. At present, the use of multi-attribute decision method has not used to find the best trials of any method used for the preparation of compost. The present study gives a step-by-step procedure to find the best trials of flower waste, cow dung and bulking agent (sawdust and wheat bran) for rotary drum composting using AHP.

The aim of the present study was to investigate physico-chemical and maturity parameters of compost produced during rotary drum composting of flower waste using cow dung as inoculum, sawdust and wheat bran as bulking agent at various stages of the composting process. The AHP was used to rank the trials by selecting the physico-chemical and maturity indices of the compost.

2. Materials and methods

Flower waste was used as main feedstock. Flower waste contains a variety of flowers such as rose (Rosa), marigold (Tagetes erecta), lotus (Nelumbo nucifera), and siroli lily (Lilium mackliniae). Among these flowers, it was observed that the quantity of marigold flowers was the maximum. Flowers waste was collected from nearby temples and transported to the composting laboratory of Sardar Vallabhbhai National Institute of Technology, Surat, India. Segregation of waste was done manually to remove the unwanted materials (plastic, threads, incense sticks, coconut, etc.) before using it for the experiments. Cow dung was used as microbial inoculum to enhance the microbial biomass and biological activities during the composting process. A dairy farm in village Umra, Surat provided the cow dung for the study. Sawdust and wheat bran were used as bulking agents. Likewise, sawdust was collected from a sawmill in Bharat, Surat and wheat bran was collected from a nearby flour mill in Surat. Bulking agents (sawdust and wheat bran) was used to control the excess moisture and reduce the air space between the material particles. The initial characteristics of waste mixtures are shown in Table 1.

### 2.1. Rotary drum composter

Figure 1 shows the rotary drum composter of capacity 0.6 m³ similar to Kalamdhad and Kazmi (2008) was made to perform the composting process. The dimensions of the drum were length 1.20 m, diameter 0.80 m and thickness of metal sheet 0.3 mm. The anticorrosive paint was used to paint the inner portion of the drum to prevent the drum from rusting. For the rotation of the drum four metal rollers, one handle and a metallic stand were used. For proper mixing of waste mixtures inside the drum 40 mm, angles were welded longitudinally. To drain off the leachate from the drum during the composting periods two holes were made. A plastic bucket was used to fill the waste mixture inside the drum as required for the trials. After daily manual turning, opening up both the half side doors was done.

### Table 1. Initial physico-chemical characteristics and composition of feedstock material.

| Parameters | Flowers waste | Cow dung | Saw dust | Wheat bran |
|------------|---------------|----------|----------|------------|
| MC (%)     | 80.05 ± 0.85  | 79.85 ± 2.5 | 15.84 ± 0.75 | 7.55 ± 1.25 |
| pH         | 5.18 ± 0.02   | 7.2 ± 0.02  | 5.91 ± 0.01  | 5.48 ± 0.03 |
| EC (mS cm⁻¹) | 4.40 ± 0.04  | 33.5 ± 0.01 | 0.93 ± 0.01  | 2.14 ± 0.03 |
| TOC (%)    | 44.78 ± 1.67  | 32.11 ± 1.67 | 53.87 ± 1.02  | 53.44 ± 2.4  |
| TN (%)     | 2.03 ± 0.07   | 1.4 ± 0.14  | 0.63 ± 0.07  | 2.42 ± 0.1   |
| NH₄-N (%)  | 1.79 ± 0.04   | 0.34 ± 0.03  | 0.22 ± 0.05  | 1.24 ± 0.06  |
| CaO (%)    | 22.06 ± 0.34  | 22.94 ± 0.40 | 85.51 ± 2.19  | 22.08 ± 1.98 |
| TP (kg⁻¹)  | 3.18 ± 0.01   | 2.79 ± 0.03  | 1.14 ± 0.04  | 4.21 ± 0.02  |
| Na (kg⁻¹)  | 0.85 ± 0.07   | 2.54 ± 0.03  | 0.62 ± 0.05  | 0.47 ± 0.08  |
| K (kg⁻¹)   | 17.3 ± 0.49   | 10.03 ± 0.21 | 1.21 ± 0.14  | 4.86 ± 0.32  |
| Ca (g kg⁻¹) | 6.43 ± 0.82   | 9.01 ± 0.33  | 2.60 ± 0.69  | 1.15 ± 0.82  |
| Zn (mg kg⁻¹) | 36.17 ± 0.25  | 48.52 ± 0.18 | 8.13 ± 0.14  | 16.50 ± 0.24  |
| Mn (mg kg⁻¹) | 98 ± 0.91     | 258.5 ± 1.25 | 55 ± 1.28  | 103 ± 1.04  |
| Fe (g kg⁻¹) | 1.76 ± 0.47   | 1.98 ± 0.37  | 0.37 ± 0.41  | 0.49 ± 1.51  |
| Mg (g kg⁻¹) | 2.25 ± 0.07   | 5.93 ± 0.02  | 1.03 ± 0.07  | 1.92 ± 0.09  |
| K (g kg⁻¹)  | 179.12 ± 1.24 | 178 ± 1.20   | 6.1 ± 1.27  | 110.5 ± 1.34 |
| Na (g kg⁻¹) | 0.85 ± 0.07   | 2.54 ± 0.03  | 0.62 ± 0.05  | 0.47 ± 0.08  |
| K (kg⁻¹)   | 17.3 ± 0.49   | 10.03 ± 0.21 | 1.21 ± 0.14  | 4.86 ± 0.32  |
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| Fe (g kg⁻¹) | 1.76 ± 0.47   | 1.98 ± 0.37  | 0.37 ± 0.41  | 0.49 ± 1.51  |
| Mg (g kg⁻¹) | 2.25 ± 0.07   | 5.93 ± 0.02  | 1.03 ± 0.07  | 1.92 ± 0.09  |
| K (g kg⁻¹)  | 179.12 ± 1.24 | 178 ± 1.20   | 6.1 ± 1.27  | 110.5 ± 1.34 |
| Na (g kg⁻¹) | 0.85 ± 0.07   | 2.54 ± 0.03  | 0.62 ± 0.05  | 0.47 ± 0.08  |
| K (kg⁻¹)   | 17.3 ± 0.49   | 10.03 ± 0.21 | 1.21 ± 0.14  | 4.86 ± 0.32  |
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Note: Mc – Moisture content; EC – Electrical conductivity; TOC – Total organic carbon; TN – Total nitrogen; CaO – Carbon to nitrogen ratio; TP – Total phosphorous; Na – Sodium, K – Potassium; Ca – Calcium; Cu – Copper; Zn – Zinc; Mn – Manganese; Fe – Iron; Mg – Magnesium.
for maintaining the aerobic condition inside the drum. A sample of about 500–600 g was collected from top, bottom and middle part of the drum at several locations. The sample was collected at intervals of four days. After collecting the sample, it was oven dried at 105 ± 2 °C for 24–72 h then ground and sieved. The sample was kept for further physico-chemical parameters analysis after sieving with a 0.2 mm sieve.

2.2. Sampling and analysis of physico-chemical parameters of compost

During the composting time, the temperature was recorded by using digital thermometers. The temperature at the top, middle and the bottom at starting, centre and end locations were monitored. Gravimetric method (BIS No. 10158, 1982) was used for finding the availability of moisture content into the fresh sample. The moisture content of the collected fresh sample was determined at the time of turning. Fresh sample was used for determining the CO₂ evolution as mentioned by Kalamdhad and Kazmi (2008). For determining the germination index test, the compost sample was taken from the rotary drum at the interval of 7 days. For mixing the compost into water 50-g compost was mixed into 100 mL distilled water and was kept in for shaker for 6 h for the complete mixing. After that, the sample was centrifuged at 8000 rpm for 20 min. Ten Petri dish was having 10 cm diameter lined with fast speed qualitative filter paper. The centrifuged sample of 5 mL quantity was put into each Petri dish, and for control 5 mL deionized water was put into the Petri dish. In each Petri dish, 10 radish seeds were sown with 10 replicates per treatment. The Petri dish was kept in an incubator for 72 h at 25 °C at dark. After seven days the germinated seeds were counted and determined the relative seed germination, relative growth rate, and germination index. The Equations (1) and (2) are used to calculate the relative seed germination and germination index (GI) by the previous researcher Zhang and Sun (2014),

Relative seed germination (%) = \( \frac{\text{Number of seeds germinated extra} \times 100}{\text{Number of seeds germinated in control}} \) (1)

\( GI(%) = \frac{(\text{Relative seed germination}) \times (\text{Relative root growth})}{100} \times 100 \) (2)

pH and the electrical conductivity were determined by using pH and EC metre. In 100 mL distilled water 10 g dried sample (1:10 w/v) was mixed and kept for rotary shaker for a thorough mixture of the sample into the water for two hours. After two hours, the sample was held for settling down for half an hour, and then it was filtered through Whatman filter paper for finding the pH and EC. For determining the total nitrogen, the sieved sample of 0.2 g was digested using heating digester (Cupric sulphate and potassium sulphate in 1:5 ratios and 10 mL H₂SO₄). The digested sample was used for determining the total nitrogen. Pelican Kelplus Distyl ems instrument was used for total nitrogen determination. KCl extraction methods were used for ammoniacal nitrogen estimation and followed the phenate methods (APHA, 2005). Dry solid weighing 10 g was kept at 350 °C for two hours in a muffle furnace to determine the volatile solids of the sample. Carbon content was calculated similar...
2.4. Statistical analysis

ANOVA of physico-chemical parameters is given in Table 3. The average of the equivalent is represented by monitored physico-chemical parameters tested for each trial. One way ANOVA was used to trial those distinctions for every of the measured physicochemical parameters throughout composting. SPSS 13.0 was used for each single parameter in all trials for computing the variance (i.e., ANOVA $p < 0.05$). The aim of statistical analysis was significant variation between all the parameters analysed for distinct combinations.

3. Result and discussion

3.1. Temperature, moisture content, pH and electrical conductivity (EC)

Temperature is the key parameter for the composting process which shows the correlation with microbial activities. Figure 2(a) shows the variation of temperature which indicates that all the trials had reached up to the thermophilic phase within 2 days. Trials 1, 2, 3, and 4 stayed in the thermophilic phase up to 4, 6, 8, and 4 days, respectively. It shows that the rate of microbial activity is higher during the composting period. All trials were achieved the highest temperature of 50.54, 52.65, 55.21, and 52.21 °C, respectively. Temperature > 50 °C up to 3 days shows the sanitization of compost (Awasthi, Pandey, Bundela, & Khan, 2015; Sharma & Yadav, 2017; Zhang, Xiao, Peng, Su, & Tan, 2013). The ambient temperature ranges from 19 to 25 °C. In all the trials the temperature had reached near the ambient temperature after 15 days. Varma and Kalamdhad (2014) and Sharma and Yadav (2017), observed the similar trends of temperature profile during the composting of vegetable waste and flower waste.
The moisture content is a significant parameter for the growth of microbes as well as in the physiochemical properties of the compost. Figure 2(b) illustrates the variations of moisture during the first 30 days. In trial 4, the quantity of flower waste was high. Therefore, the moisture content on the final day of composting was high compared to other trials. The moisture reduction in trial 1 was less due to proportions of 50 kg flower waste and 40 kg cow dung. In trial 2 and trial 3 the reduction of moisture was 58.64 and 60%, respectively. Availability of moisture affects the temperature of the drum it can be understood by comparing Figure 2(a) and (b). Higher the moisture content reduces the rise in the temperature. But with the increase in the quantity of cow dung in the composition, temperature decreases. Cow dung is a good source of microbes which increases the activity and the degradation rate of organic matter. An adequate proportion of flower waste and cow dung is to be used as it significantly affects the rate of composting.

Figure 2(c) shows the variation in pH during composting period. pH plays an important role in the evaluation of the overall efficiency of the composting process. It was observed that initially, the pH of all the trials was below 6, but on the final day, all trials were having pH > 7. The rotation of the drum provides proper aeration which was responsible for increasing the pH value during the degradation process. Aeration helped to release more hydrogen ions, which contributed to the increase in pH value. After the 8th day, neutral pH value was observed because the flower waste was a good source of potassium concentration which reacts to the bi-carbonic acid (HCO$_3^-$) and forms strong base KOH at the organic matter degrades. The initial pH values of trials 1–4 were 5.91, 5.84, 5.74, 5.65 and it increased to 7.31, 7.23, 7.51, and 7.34 on the final day of composting. Awasthi et al. (2015), reported that under aerobic conditions, organic N is transformed into NH$_3$ or NH$_4^+$ during ammonification which was responsible for increasing the pH of the compost. The stable pH value during co-composting is due to the buffering capacity of hummus, which was synthesized during the maturation phase of composting. The range of pH for the matured compost was between 6 and 8 (Wong et al., 2001).

Electrical conductivity is the indicator of the degree of salinity. It indicates the phytotoxicity effect on the growth of the plant. Initial electrical conductivity in all the trials was lower, but it increased after composting. Figure 2(d) shows the initial electrical conductivity of trials 1–4 were 3.61, 3.95, 3.94 and 3.74 mS/cm which after 30 days increased to 5.50, 5.86, 6.02, and 6.12 mS/cm, respectively. The degradation of organic matter in thermophilic phase releases mineral salts such as ammonium, phosphate and thus increases the electrical conductivity. Similar trends of increased electrical conductivity were observed by Awasthi et al. (2014) during the composting of municipal waste. Electrical
because of degradation of organic matter, the loss of carbon as CO$_2$ and the contribution of nitrogen-fixing bacteria. The rate of increasing overall nitrogen in the present study found similar to the previous result obtained by Jolanun and Towprayoon (2010), Awasthi et al. (2014) and Sharma et al. (2017) for the organic waste composting.

The compost maturity can be determined when the ammoniacal nitrogen concentration decreases at the end of the composting period. It was observed that the biological decomposition slowed down and the compost had become mature. Figure 3(c) indicates the variation of ammoniacal nitrogen. It was observed that initially up to 12 days ammoniacal nitrogen was increased and after that, it started decreasing and stabilized within 30 days. It was also observed that the change in ammoniacal nitrogen also depended on the variation of pH. The concentrations of ammoniacal nitrogen were 101.23, 96.85, 102.57 and 104.54 mg/kg which were decreased to 53.92, 73.60, 78.87 and 75.21 mg/kg in trial 1, 2, 3 and 4, respectively. Huang, Wong, Wu, and Nagar (2004) and Rashad et al. (2010) also observed similar decreasing trends of ammoniacal nitrogen during the organic waste composting. ANOVA analysis indicates the significant difference (p < 0.05) in the variation of total organic carbon, total nitrogen and ammoniacal nitrogen in all the trials.

3.2. Total organic carbon (TOC), total nitrogen and ammoniacal nitrogen (NH$_4^+$ – N)

Total organic carbon (TOC) is generally used to check the stability of compost. TOC reduction in trials 1, 2, 3, and 4 were 33, 29, 26, and 22%, respectively. Reduction of total organic carbon with time is shown in Figure 3(a). The maximum TOC reduction was observed in trial 1 which was possibly due to the presence of more quantity of cow dung. Elango et al. (2009) and Adhikari et al. (2009) also observed the similar trend of reduction in total organic carbon while composting the municipal solid waste and food waste.

Figure 3(b) indicates the variation in the overall nitrogen. It was observed that there was a rise in the overall nitrogen at the time of composting. The initial concentration of total nitrogen in trials 1–4 was 1.54–1.75% and increased to 2.17–2.66% at the final day of the composting period. The total nitrogen raises concentration because of degradation of organic matter, the loss of carbon as CO$_2$ and the contribution of nitrogen-fixing bacteria. The rate of increasing overall nitrogen in the present study found similar to the previous result obtained by Jolanun and Towprayoon (2010), Awasthi et al. (2014) and Sharma et al. (2017) for the organic waste composting.

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As per conclusion of Sun, Wang, Lu, and Wang (2012), the optimum percentage of germination index appropriate for mature compost are greater than 80%. A similar trend of germination index was observed by Sharma et al. (2017) during the agitated (windrow) pile composting of flower waste.

CO2 evolution is one of the best methods for determining the maturity and stability of the compost as it measures the carbon derived directly from the compost. CO2 evolution directly synthesizes to aerobic respiration, which shows the direct measure of respiration and aerobic biological activity. CO2 evolution decreased with time. Figure 4(c) shows the CO2 evolution in trials 1–4 were 7.99, 7.86, 7.74, and 7.99 mg/g VS/day which decreased to 0.27, 0.44, 0.17 and 0.39 mg/g VS/day during the composting process. Similar decreasing trends of CO2 evolution rate during the rotary drum composting of vegetable waste was observed by Varma and Kalamdhad (2014).

### 3.3. Carbon to nitrogen ratio (C:N), germination index (GI) and carbon dioxide (CO2) evolution

The C:N ratio is a very useful criterion for evaluating the maturity rate, the intensity of microbial growth, the compost quality, and presence of nutrients in the final compost. The living organisms present in the compost utilize the carbon as a source of energy and the nitrogen for building cell structures. The maturity of the compost was linearly dependent on the preliminary C:N ratio. Figure 4(a) indicates that the preliminary C:N ratio of trials 1–4 was 28.84–30.30 which decreased linearly to 13–17. C:N ratio 10–15 indicates the compost maturity. Similar values (13–17) of C:N ratio was observed during the composting of organic waste by several researchers (Guo et al., 2012; Zhang & Sun, 2014).

Germination index is one of the widely used tools for checking the maturity and phytotoxicity effects of the compost during the composting period. Germination index assesses the fittingness of compost for agricultural purposes. Initially, the germination indexes were 75, 73, 74, and 68% in trials 1–4 which increased to 91, 94, 98, and 91%, respectively (refer Figure 4(b)). It was observed that in all trials the germination index was found to be greater than 80% which displays that for the plant growth, the flower waste compost is suitable.

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### 3.4. Macro and micronutrients

The presence of nutrients in the compost shows the compost quality as macro and micronutrients are indispensable for the growth of plants. Table 4 indicates the
3.5. Rank of drum composting using AHP

The hierarchy structure used for ranking of the trials is shown in Figure 5. Seven important criteria suitable for the maturation of compost had been taken for deciding the rank of the trials by using AHP method. (1) No of days the trials stay in thermophilic phase (2) pH (3) EC (4) TOC (5) germination index (6) C:N and (7) CO₂ evolution rate. The final after (30 days) composting value had been taken for ranking from each trial. Keeping these parameters as the source of quality of good compost, the ranking of the trials has been optimized using AHP. Alternatives and attributes are significant for the decision-making (refer matrix A1). After the decision of hierarchy, the weight criteria are calculated by using AHP method. The acceptance of weights depends on the consistency ratio. The normalized value of the quantitative data is shown below. The normalized data with the weight of attributes show the ranking of alternatives. Equations (3) and (4) show the steps for the calculation of consistency ratio by using AHP.

Table 4. Presence of macro (P, K, Na, Ca and Mg) and micronutrients (Fe, Mn, Zn and Cu) at initial and final day into compost.

| Parameter | Day | Trial 1 | Trial 2 | Trial 3 | Trial 4 |
|-----------|-----|---------|---------|---------|---------|
| P (g kg⁻¹) | 0   | 8.65 ± 0.06 | 7.02 ± 0.01 | 4.96 ± 0.03 | 5.58 ± 0.02 |
|           | 30  | 13.06 ± 0.05 | 12.01 ± 0.03 | 11.25 ± 0.06 | 10.22 ± 0.04 |
| K (g kg⁻¹) | 0   | 9.37 ± 0.01 | 10.87 ± 0.04 | 11.33 ± 0.02 | 11.54 ± 0.03 |
|           | 30  | 17.01 ± 0.02 | 18.61 ± 0.01 | 17.69 ± 0.01 | 18.34 ± 0.04 |
| Na (g kg⁻¹) | 0   | 1.57 ± 0.05 | 1.49 ± 0.07 | 1.52 ± 0.03 | 1.47 ± 0.04 |
|           | 30  | 2.44 ± 0.06 | 2.60 ± 0.08 | 2.52 ± 0.02 | 2.14 ± 0.01 |
| Ca (g kg⁻¹) | 0   | 7.92 ± 0.08 | 8.15 ± 1.36 | 6.95 ± 0.97 | 7.53 ± 1.22 |
|           | 30  | 14.84 ± 1.07 | 15.58 ± 1.36 | 13.86 ± 0.51 | 13.35 ± 1.31 |
| Mg (g kg⁻¹) | 0   | 3.66 ± 0.02 | 3.36 ± 0.04 | 2.96 ± 0.02 | 2.51 ± 0.01 |
|           | 30  | 6.38 ± 0.01 | 6.94 ± 0.05 | 5.25 ± 0.04 | 7.03 ± 0.01 |
| Fe (g kg⁻¹) | 0   | 1.95 ± 0.57 | 1.84 ± 0.48 | 1.96 ± 0.14 | 1.21 ± 0.37 |
|           | 30  | 4.25 ± 0.63 | 4.63 ± 0.41 | 4.894 ± 0.38 | 3.83 ± 0.25 |
| Mn (mg kg⁻¹) | 0   | 103.09 ± 1.1 | 94.37 ± 54.5 | 85.13 ± 48.26 | 75.76 ± 41.09 |
|           | 30  | 211.45 ± 1.1 | 186.64 ± 0.99 | 160.31 ± 0.93 | 158.76 ± 0.89 |
| Zn (mg kg⁻¹) | 0   | 142.33 ± 0.8 | 161.27 ± 1.06 | 159.51 ± 0.61 | 144.74 ± 0.5 |
|           | 30  | 186.66 ± 1.3 | 197.41 ± 0.83 | 190.45 ± 1.9 | 178.2 ± 1.32 |
| Cu (mg kg⁻¹) | 0   | 45.39 ± 0.15 | 43.4 ± 0.15 | 42.51 ± 0.15 | 41.29 ± 0.04 |

The presence of an initial and final concentration of nutrients in the compost. The concentration of potassium content was high in all the trials. It shows the presence of high inherent content in flower waste, pointing that the compost might be the good source of potassium. The concentration of sodium and calcium gradually increased which means the net loss in dry mass because of the degradation of organic matter and the release of CO₂ mineralization during the composting period. Calcium and sodium are essential nutrients for plant growth. When the compost is mixed with soil, it increases the soil acidification and makes the nutrient easily available to the plant. The order of concentration of macro and micronutrients in the flowers waste composting is K > Ca > Mg > Na and Fe > Mn > Zn > Cu and these concentrations of nutrients are suitable for plant growth. Similarly, it was observed in the literature that the quantity of nutrients increases in the compost due to the degradation of organic matter (Awasthi et al., 2014; Singh & Kalamdhad, 2014).
3.5.2. Selection index

Selection index shows the ranking of the piles. The higher values of SI indicate the better alternative. Selection index was obtained by multiplying normalized data by weight (MAT A2). The normalization of the alternative and attributes used for the ranking of the piles are shown below.

| Attributes | Temp | pH | EC | TOC | GI | C/N ratio | CO2 |
|------------|------|----|----|-----|----|-----------|-----|
| Trial 1    | 0.5000 | 0.9863 | 1.0000 | 1.0000 | 0.9286 | 0.9286 | 0.6296 | 0.4096 | 0.7475 |
| Trial 2    | 0.5000 | 0.9600 | 0.9016 | 0.6667 | 0.9286 | 0.7647 | 0.4359 | 0.1654 | 0.6592 |
| Trial 3    | 0.5000 | 0.9730 | 0.9167 | 0.6999 | 0.9286 | 0.7647 | 0.4359 | 0.1654 | 0.5890 |
| Trial 4    | 0.5000 | 0.9863 | 1.0000 | 1.0000 | 0.9286 | 0.9286 | 0.6296 | 0.0702 | 0.9072 |

Calculation of consistency ratio and the result obtained using AHP.

\[ \text{CI} = \left( \lambda_{\text{max}} - M \right) / \left( M - 1 \right) \]  \hspace{1cm} (3)

where \( \lambda_{\text{max}} \) = maximum eigenvalue of the matrix, \( A \).

\( A \) = Average of matrix A4 (see matrix A2 section) and M = order of matrix (Here, \( \lambda_{\text{max}} = 7.748 \) and \( M = 7 \)).

The consistency ratio (CR) was calculated as Equation (4).

\[ \text{CR} = \text{CI} / \text{RI} \]  \hspace{1cm} (4)

where RI = random index. RI depends upon the size of the relative importance matrix (Here, RI = 1.35).

The value of CR should be less than 0.1, which satisfies the pairwise comparison matrix for criteria and validates the weights. In this case, CR = 0.092; which is CR < 0.1; hence the matrix satisfies the consistent and validated resultant weights. Matrix A1 shows the pair wise comparison matrix for the criteria shown below.

3.5.1. Normalized data

Normalized data of the attributes are shown below. Attributes temp was the main effects of composting. Hence, temp was the beneficial attribute and was the case of maximization. The attributes pH, electrical conductivity, total organic carbon, germination index, C:N and CO2 evolution rate increases or decreases due to the variation in temperature. Hence, these attributes are minimized. For instance, piles stay in no of days in thermophilic phase was 8 in alternative trial 3. Therefore, all temp value was divided by 8 so that the normalized temp value at trial 3 will be 1 and that in another alternative will be <1 (refer normalized data and selection index), respectively. The minimum value of pH was 7.2 in alternative trial 2 and normalized as 1, and the other normalized value of pH was obtained by dividing 7.2 by each pH (7.2/7.3 = 0.986). Alternatives and attributes used for ranking of the piles are shown below. Temperatures mentioned in days indicate that the piles stayed in that particular number of days in the thermophilic phase.
The ranking of the piles as per AHP methods are as follows: Trial 3-Trial 2-Trial 1-Trial 4. Trial 3 achieved the first rank practically among the trials 1–4. Trial 3 stayed up to 8 days in thermophilic phase. At the end period of the composting pH was 7.5, EC was 6 mS/cm, TOC reduction was 26%, germination index was 98%, and C/N ratio was 13, and CO₂ evolution rate was 0.17 mg/g/VS/day.

4. Conclusions

Flower waste composting using rotary drum produces stable, matured and nutrient-enriched compost within thirty days of the composting period. The bulking agent (sawdust and wheat bran) helped to maintain the prolonged thermophilic condition and also helped in maintaining the moisture content. The bulking agent helped in controlling the leachate and maintaining the aerobic condition during the composting process. Trial three (70 kg flower waste + 20 kg cow dung + 5 kg sawdust and 5 kg wheat bran) was achieved the first rank among all the trials using AHP. The variations of pH was 7.5, electrical conductivity was 6 mS/cm, total organic carbon was 26%, C:N ratio was 13, Na was 2.52 g/kg, K was 17.69 g/kg, and Phosphorous was 11.25 g/kg in trial 3 at the end of 30 day during the rotary drum composting of flower waste. In trial 3 the germination index was 98% and CO₂ evolution rate was 0.17 mg/g/VS/day which shows the maturity and stability of the compost.

Disclosure statement

No potential conflict of interest was reported by the authors.

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