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ORIGINAL ARTICLE

Bioconversion of garden waste, kitchen waste and cow dung into value-added products using earthworm *Eisenia fetida*

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Abstract Solid waste management is a worldwide problem and it is becoming more and more complicated day by day due to rise in population, industrialization and changes in our life style. Transformation of industrial sludges into vermicompost is of double interest: on the one hand, a waste is converted into value added product, and, on the other, it controls a pollutant that is a consequence of increasing industrialization. Garden waste, kitchen waste and cow dung were subjected to recycle through vermicomposting by using the epigeic earthworm *Eisenia fetida* under field conditions. The pH, moisture content, total organic carbon, humus, nitrogen, phosphorous and potassium in vermicompost was analysed. It was found that moisture content, total organic carbon, humus, nitrogen, phosphorous and potassium was high in cow dung, followed by kitchen waste and garden waste. This study clearly indicates that vermicomposting of garden waste, kitchen waste and cow dung can not only produce a value added produce (vermicomposting) but at the same time reduce the quantity of waste.

1. Introduction

The problem of efficient disposal and management of organic solid wastes has become more rigorous due to rapidly increasing population, intensive agriculture and industrialization, over the last few years. The various types of environmental and disposal problems caused by the production of large quantities of organic waste all over the world requires sustainable approach in a cost effective manner (Edwards and Bater, 1992) and this has become a very important issue for maintaining healthy environment (Senapati and Julka, 1993).

Vermicomposting is being considered as a potential option in the hierarchy of integrated solid waste management that involves the stabilization of organic material by the joint action of earthworms and microorganisms. Although microbes are responsible for the biochemical degradation of organic matter, earthworms are the important drivers of the process by conditioning the substrate and altering the biological activity (Aira et al., 2007). However, the processing time and quality of the end product vary according to the composition of the initial mixture being processed (Singh et al., 2010). The various

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industrial wastes which have been already vermicomposted and turned into nutrient rich manure include paper waste (Elvira et al., 1998; Kaur et al., 2010), textile mill sludge (Garg and Kaushik, 2005), guar gum industrial waste (Suthar, 2006), sugar industry wastes (Sen and Chandra, 2007), distillery sludge (Suthar and Singh, 2008), leather industry (Ravindran et al., 2008) and beverage industry sludge (Singh et al., 2010), agroindustrial sludge (Suthar, 2010), primary sewage sludge (Hait and Tare, 2011), and tannery industries (Ravindran and Sekaran, 2011). Vermicomposting has also shown impressive effects on the growth of different crops under field conditions (Mamta et al., 2012) Various physical, chemical and microbiological methods of disposal of organic solid wastes are currently in use, these methods are time consuming and involve high costs. Therefore, there is a pressing need to find out cost-effective alternative methods of shorter duration particularly suited to Indian conditions. In this regard, vermicomposting has been reported to be a viable, cost-effective and rapid technique for the efficient management of the organic solid wastes (Hand et al., 1988; Raymond et al., 1988; Harris et al., 1990; Logsdson, 1994). Several other research studies have demonstrated the ability of some earthworm species to consume a wide range of organic wastes such as sewage sludge, animal dung, crop residues and industrial refuse (Mitchell et al., 1980; Chan and Griffiths, 1988; Hartenstein and Bisesi, 1989; Edwards, 1998). Earthworms fragment the waste substrate and accelerate the rate of decomposition of the organic matter, leading to a composting effect through which unstabilized organic matter becomes stabilized. The vermicompost has more available nutrients per kg weight than the organic substrate from which it is produced (Buchanam et al., 1988). The biological activity of earthworms provides nutrient rich vermicompost for plant growth thus facilitating the transfer of nutrients to plants (Ismail, 2000).

Keeping in view the above facts, the present study was conducted to assess the potential of *Eisenia foetida* in composting the different types of organic substrates (i.e. garden waste kitchen waste and cow dung).

2. Methods

Eisenia fetida, cattle dung and garden waste, and young non-clitellated *E. fetida* were randomly picked from the stock culture maintained in the vermicomposting unit of the Department of Zoology, Jiwaji University, Gwalior, India. Cattle dung was arranged from the nearby dairy farm situated in the vicinity of the University. Cattle dung was spread for 15 days for air-drying, so that unwanted gases and heat were removed which may cause harm to earthworms. Garden waste and kitchen waste were procured from the Jiwaji University, Gwalior, India and households around the University. The collected organic waste was crushed into very fine particles so that it can become easier for worms to consume.

3. Experimental design

The work was carried out at the Department of Indira Gandhi Academy of Environmental Education Research and Ecoplanning, Jiwaji University, Gwalior (India).The experiments were conducted in the perforated vermicomposting pits of the size 10×8 ft. The temperature in the experimentation pits was maintained at 25 ± 1 °C which is the optimum temperature range for *E. foetida* (Reinecke et al., 1992). Approximately 500 g (~100–120 in numbers) of earthworms, both clitellated and juvenile, were inoculated in the bedding for the acclimatization of the earthworms to the new environment. The mixed cultures were prepared using the earthworm species in equal proportions and one control was also kept for degradation without any worms.

4. Chemical analysis

The pH of the vermicompost was determined in double distilled water suspension of each concentration in the ratio of 1:10 (w/v) using digital meter-LNK-VI-8611 SYSTRONICS. Total kjeldahl nitrogen (TKN) was measured by Micro-Kjeldhal method of Bremner and Mulvaney (1982) after digesting the sample in digestion mixture ($H_2SO_4 + K_2-$ So_4:$CuSo_4$: SeO_2 in 10:4:1). Method of John (1970) was used for measuring total potassium (TK), and total available phosphorous (TAP) using Systronics Flame photometer-128 and UV–Visible Spectrophotometer, respectively after digesting the samples in diacid mixture ($HClO_4$:HNO_3 in 4:1 ratio). Total organic carbon (TOC) was measured after igniting the sample in a Muffle furnace at 550 °C for 60 min by the method of Nelson and Sommers (1996).

5. Statistical analysis

Pearson's coefficient of correlation was used to correlate the relationship between different parameters. Results of all experiments were analyzed by one way analysis of variance (ANOVA) with Duncan's multiple range test for comparison of the significance level (P) between the means of different wastes. A $P \leqslant 0.05$ value was considered a significant difference between the values compared.

6. Results and discussion

6.1. pH

The vermicompost from garden waste, kitchen waste and cow dung showed a similar pattern of change in pH that falls in the range of 6.34 ± 0.06 and 8.13 ± 0.06, respectively, which is within the optimal range for plant growth (Goh and Haynes, 1977) which shows a shift from the initial acidic condition toward neutral condition (Table 1). A significant difference ($P > 0.05$) in the values of pH was found between the values of garden waste and kitchen waste, garden waste and cow dung, kitchen waste and cow dung. The mineralization of nitrogen and phosphorus into nitrites/nitrates and orthophosphates and bioconversion of the organic material into intermediate species of organic acids may have decreased the pH (Ndegwa and Thompson, 2000).

The pH of the garden compost showed significant negative correlation with moisture content (−0.3958), total organic carbon (−0.3314), humus (−0.7035), total nitrogen (−0.4642), total phosphorus (−0.4770), and potash (−0.2470). however, the pH of the kitchen compost showed a significant positive correlation with moisture content (0.5958), total organic carbon (0.6504), total phosphorus (0.4535) and potash (0.1092)

Table 1 Nutrient content and different physio-chemical parameters in garden waste, kitchen waste and cow dung.

Waste	pH	MC	TOC	Humus	Nitrogen	Phosphorus	Potassium
Garden waste	6.3 ± 0.06[a]	2.7 ± 0.10[a]	11.7 ± 0.24[a]	68.7 ± 0.91[a]	1.02 ± 0.07[a]	0.37 ± 0.03[a]	0.60 ± 0.02[a]
Kitchen waste	7.2 ± 0.04[b]	3.1 ± 0.08[b]	13.3 ± 0.31[b]	63.9 ± 1.99[b]	1.30 ± 0.02[b]	0.50 ± 0.02[b]	1.01 ± 0.18[b]
Cow dung	8.1 ± 0.06[c]	2.6 ± 0.04[b]	18.4 ± 1.16[b]	64.1 ± 0.94[c]	1.97 ± 0.07[c]	0.62 ± 0.03[c]	0.88 ± 0.18[c]

All values are in mean ± 1 S.E. Values bearing different superscripted alphabets differ from each other at $P \leqslant 0.05$ (based on Duncan's multiple range test). Data are expressed as $M \pm 1$ *SEM*; values with different superscripts differ from each other at $P \leqslant .05$, values with the same superscripts do not differ from each other at $P \leqslant .05$ (based on Duncan's multiple range test).

whereas it exhibited a negative correlation with humus (−0.0859), total nitrogen (−0.2589) and the pH of cow dung compost showed significant positive correlation with moisture content (0.5618), total organic carbon (0.8563), humus (0.1006), and potash (0.6395) whereas it exhibited negative correlation with total phosphorus (−0.1595), and total nitrogen (−0.1432).

6.2. Moisture content

The earthworm growth rates are not unusual, it is assumed that moisture was appropriate for earthworm growth. However, the moisture content was 2.70 ± 0.10, 3.10 ± 0.08, 2.61 ± 0.04, in the garden waste, kitchen waste and cow dung, respectively, as shown in Table 1. A significant difference ($P > 0.05$) in the values of moisture content was found between the values of garden waste and kitchen waste and garden waste and cow dung, however, no significant difference ($P > 0.05$) was found between the values of kitchen waste and cow dung. The growth rate of earthworms has been related to moisture. The optimal humidity range for *E. fetida* has been reported to be between 60% and 90%, with the fastest growth rate at 80–90% humidity. Low moisture conditions may also delay sexual development; it was found that earthworms of the same age developed clitella at different times under different moisture conditions (Dominguez et al., 2001). The moisture content of garden compost showed a positive correlation with total organic carbon (0.3563), humus (0.4943), total nitrogen (0.0734), total phosphorus (0.2113), whereas it exhibited a negative correlation with potash (−0.0284). The moisture content of the kitchen compost showed a positive correlation with total organic carbon (0.2585), total phosphorus (0.5525), potash (0.4864).whereas it exhibited a negative correlation with humus (−0.2416), total nitrogen (−6954) and the moisture content of cow dung compost showed a positive correlation with total organic carbon (0.2864), humus (0.0657), potash (0.8900).whereas it exhibited negative correlation with total nitrogen (−0.4814), and total phosphorus (−0.3818).

6.3. Total organic carbon (TOC)

The consumption of the available carbon as a source of energy by the earthworms and the microorganisms may have decreased the large fraction of TOC in the form of CO_2. However, the TOC content was 11.75 ± 0.2410.15%, 13.31 ± 0.31, 13.31 ± 0.31, in the garden waste, kitchen waste and cow dung, respectively, as shown in Table 1. A significant difference ($P > 0.05$) in the values of TOC was found between the values of garden waste and kitchen waste, garden waste and cow dung, kitchen waste and cow dung. The reduction of TOC into CO_2 during vermicomposting of municipal or industrial wastes has also been observed by (Kaviraj and Sharma, 2003). The total organic carbon of the garden compost showed a significant negative correlation with humus (−0.1498), total nitrogen (−0.2453), and total phosphorus (−0.3731), whereas it exhibited a positive correlation with potash (0.7332). The total organic carbon of the kitchen compost showed a significant positive correlation with total phosphorus (0.7896), potash (0.3988), whereas it exhibited a negative correlation with humus (−0.3075), total nitrogen (0.0260) and the total organic carbon of cow dung compost showed a significant positive correlation with total nitrogen (0.2148), potash (0.3906), whereas it exhibited negative correlation with humus (−0.1865), total phosphorus (−0.2361).

6.4. Humus

Humus content was highest in the garden waste (68.75 ± 0.91) followed by cow dung (64.18 ± 0.94) and kitchen waste (63.93 ± 1.99). A significant difference ($P > 0.05$) in the values of humus was found between the values of garden waste and kitchen waste and garden waste and cow dung, however, no significant difference ($P > 0.05$) was found between the values of kitchen waste and cow dung. The prolific activity of earthworms ingested organic matter up to 12 tonnes/ha/year soil or is by this population, leading to the upturning of 18 tons of soil/year (Bhawalkar and Bhawalkar, 1993). About one-fourth of the organic matter is converted into humus. Humic acid has a very good impact on plant growth (Atiyeh et al., 2002). Colloidal humus acts as 'slow release fertilizer' in the soil (Tomati et al., 1983). The humus of the garden compost showed significant positive correlation with total nitrogen (0.4293), total phosphorus (0.8147), whereas it exhibited a negative correlation with potash (−0.2612). The humus of the kitchen compost showed a significant positive correlation with total nitrogen (0.3820), whereas it exhibited a negative correlation with total phosphorus (−0.3882), potash (−0.4357). The humus of cow dung compost showed a significant positive correlation with potash (0.0550), whereas it exhibited a negative correlation with total nitrogen (−0.3612), total phosphorus (−0.3011).

6.5. Total nitrogen (TN)

TN consists of the inorganic forms of nitrogen NH_4–N and NO_3–N. TN content was higher (1.97 ± 0.07) in cow dung followed by kitchen waste (1.30 ± 0.02) and garden waste (1.02 ± 0.07), respectively (Table 1). A significant difference ($P > 0.05$) in the values of nitrogen was found between the

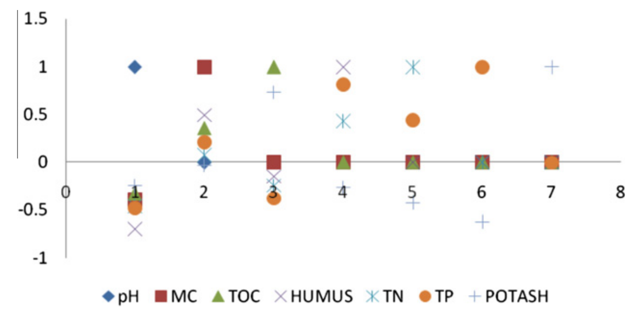

Figure 1 scattered diagram of garden compost.

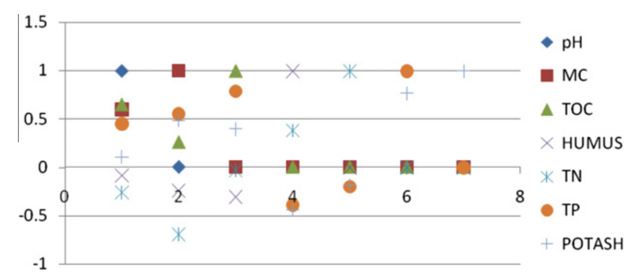

Figure 2 scattered diagram of garden compost.

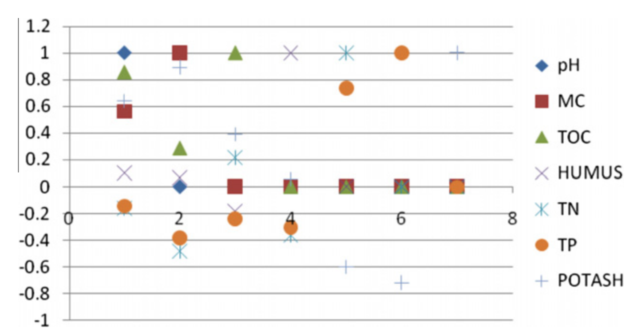

Figure 3 scattered diagram of cow dung compost.

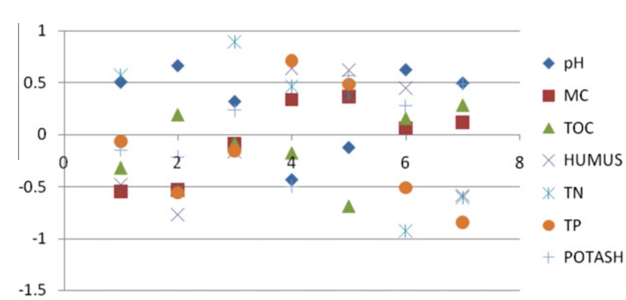

Figure 4 scattered diagram of garden compost and kitchen compost.

values of garden waste and kitchen waste, garden waste and cow dung, kitchen waste and cow dung. Increase in nitrogen content in the final product in the form of mucus, nitrogenous excretory substances, growth stimulating hormones and enzymes from earthworms have also been reported (Tripathi and Bhardwaj, 2004). The loss in organic carbon might be responsible for nitrogen enhancement Viel et al. (1987). The mineral nitrogen may be retained in the nitrate form by nitrogen transformations by earthworms in manure, by enhancing nitrogen mineralization, Atiyeh et al. (2000). It has been found that the final N content of the compost is dependent on the initial N present in the waste and the extent of decomposition (Crawford, 1983; Gaur and Singh, 1995). The total nitrogen of garden compost showed significant positive correlation with total phosphorus (0.4432), whereas it exhibited negative correlation with potash (−0.4222). The total nitrogen of kitchen compost showed significant negative correlation with total phosphorus (−0.1916), potash (−0.1827) and the total nitrogen of cow dung showed a significant positive correlation with total phosphorus (0.7339), whereas it exhibited negative correlation with potash (−0.1827).

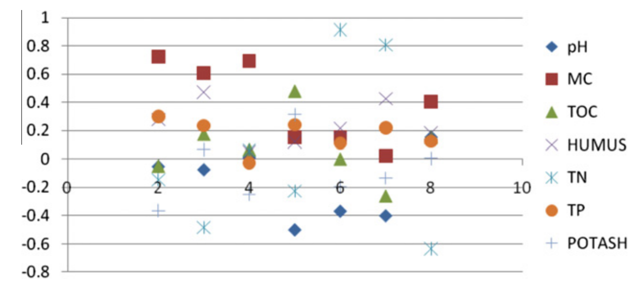

Figure 5 scattered diagram of garden compost and cow dung compost.

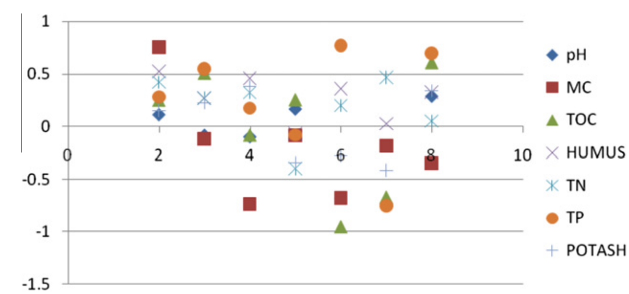

Figure 6 scattered diagram of kitchen compost and cow dung compost.

6.6. Total phosphorous (TP)

The TP was higher in cow dung (0.62 ± 0.33) as compared to kitchen waste (0.50 ± 0.02) and garden waste (0.37 ± 0.03) during the study period. A significant difference ($P > 0.05$) in the values of phosphorus was found between the values of garden waste, kitchen waste and cow dung. Increase in TP during vermicomposting is probably through mineralization and mobilization of phosphorus by bacterial and phosphatase activities of earthworms (Edwards and Lofty, 1972). Mansell et al. (1981) observed that plant litter was found to contain more available P after ingestion by earthworms, which may be due to the physical breakdown of the plant material by worms. Satchell and Martein (1984) also found an increase of 25% in P of paper waste sludge, after worm activity. They attributed this increase in P to the direct action of worm gut enzymes and indirectly by stimulation of the microflora. Increase in TP during vermicomposting is probably due to mineralization and mobilization of phosphorus as a result of bacterial and fecal phosphatase activity of earthworms (Edwards and Lofty, 1972). The total phosphorus of garden compost showed negative correlation with potash (−0.6245) and the total phosphorus of the kitchen compost showed positive correlation with potash (0.7694) however, the total phosphorus of cow dung compost showed negative correlation with potash (−0.7201).

6.7. Total potassium

Data reveal that total potassium increase was significantly higher (1.01 ± 0.18) in kitchen waste as compared to cow dung (0.88 ± 0.18) and garden waste (0.60 ± 0.02) during our study. A significant difference ($P > 0.05$) in the values of potassium was found between the values of garden waste and kitchen waste, however, no significant difference ($P > 0.05$) was found between the values of garden waste and cow dung, kitchen waste and cow dung. The available Micro-nutrients like potassium (K) are required for assimilation by earthworms during the vermicomposting, although the quantity required is very low as compared to the initial content present in the parent feed material. The production of acids by the microorganisms and enhanced mineralization rate through increased microbial activity during the vermicomposting process play a key role in the solubilizing of insoluble potassium (Kaviraj and Sharma, 2003; Khwairakpam and Bhargava, 2009) (see Figures 1–6).

7. Conclusion

The use of earthworms for the conversion of different types of wastes into vermicomposting can truly bring in ‘economic prosperity’ for the farmers and the nations with ‘environmental security’ for the earth. The use of *E. foetida* (epigeic species) for vermicomposting of garden waste, cow dung and kitchen waste on the basis of nutrient content is an important indication that this technology will reduce the burden of synthetic fertilizers. Experimental data provide a sound basis that vermicomposting is a suitable technology for the conversion of garden waste, cow dung and kitchen waste into organic fertilizer. This study clearly demonstrates that the conversion of different types of wastes into vermicompost may not only reduce the burden of synthetic fertilizers but may also act as good soil conditioners and a source of plant nutrients in agriculture.

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