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RESEARCH ARTICLE

A Chemometric study during vermicomposting of organic wastes by employing *Eisenia fetida*

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ABSTRACT

The decomposition efficiency of *Eisenia fetida* for vermicomposting was evaluated by using a variety of wastes such as Domestic waste, Agricultural waste, Sago waste, cow dung and poultry dropping in different compositions. This paper reports the recycling of nutrients by vermicomposting of employing earthworm (*Eisenia fetida*). A total of six vermicomposting units were established and dynamics of chemical and biological parameters has been studied for 42 days. The waste mixture containing domestic waste + cow dung in 1:1 ratio and mixed crop residues +Domestic waste + cow dung in 1:1:2 ratio had better fertilizer value among studied waste combinations. At the end of experiment, vermicomposts showed decrease in pH and organic C, but increase in total Kjeldhal N, total available P and total K contents. The C:N ratio of final vermicomposts also got reduced to 10.7–12.7 from 22.8 -56 in different waste combinations.

INTRODUCTION

Much attention has been paid in recent years to manage different organic waste resources at low-input as well as eco-friendly basis. Vermicomposting, utilizing earthworms, is an eco-biotechnological process that transforms energy rich and complex organic substances into a stabilized humus-like product (Benitez *et al*., 2000). Vermitechnology has been proposed globally as potential tool to stabilize the natural and anthropogenic wastes, such as sewage sludge, industrial sludge, plant-derived wastes, agro-industrial solid waste, household waste, animal dung, etc. Vermicomposting is bio-oxidation and stabilization of organic material involving the joint action of earthworms and microorganisms. Although microbes are responsible for the biochemical degradation of the organic matter, earthworms are the important drivers of the process, conditioning the substrate and altering biological activity (Aira *et al*., 2002). Several epigeic earthworms have been identified as detritus feeders which can be reared on large numbers in organic waste resources. Some of these epigeics, e.g. *Eisenia fetida* (Savigny), *Perionyx excavatus* (Perrier), and *Eudrilus eugeniae* Kinberg, have been observed as the key candidates for organic waste recycling practices (Gajalakshmi *et al*., 2002; Loh *et al*., 2005; Garg and Kaushik, 2005). These species are highly adaptable and can tolerate varying degrees of moisture. Vermicomposting could be an appropriate technology for the transformation of organic wastes into valuable products. Several kinds of waste can be used such as solid organic waste, sewage sludge, agricultural waste, animal manure and some sorts of industrial waste as sources of organic matter. Earthworm accelerates composting process, controls potential environmental risks, improves soil structure and physico-chemical and biological properties of the soil (Stewart and Scullion,1988). The result of the composting process through earthworms (vermicomposting) is a high quality humic product (earthworm casting) used as soil organic amendment (Malathi and Anitha Subash, 2010). *Tapioca or cassava* is a widely cultivated cash crop of South India (Tamil Nadu). More than 1000 small and large scale sago industries function in Namakkal District alone. The generation and accumulation of the sago waste in and around sago processing industries pose threat to the environment (Malathi and Anitha Subash, 2010). At the same time, intensive livestock farming and poultry farms generate huge quantities of organic solid wastes, which have the potential for being recycled on agricultural land. These wastes are among the major under-utilized resources and their disposal is the major concerns for municipalities and industries in and around Namakkal District.

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Fresh organic waste materials cannot be applied to soil until they have been sufficiently iostabilized, because application of immature organic materials to soil may affect plant growth due to nitrogen starvation and production of toxic metabolites (Zucconi *et al*., 1981). These wastes have not been fully exploited due to nonavailability of a viable technology for their economical recycling. Under these circumstances, vermicomposting may be an ecofriendly and economically viable technology for converting these wastes into organic manure. (Aira *et al*., 2002). Cow dung is considered as an efficient bulking agent for rapid decomposition of waste through vermicomposting. It contains a variety of microbes which may accelerate mineralization process through enzyme synthesis. This paper reports the feasibility of vermicomposting for the management of Domestic waste, Agricultural waste, Sago waste, cow dung and poultry dropping in different compositions. The objective of the present paper is to produce nutrient-rich vermicompost using locally available wastes in and around Kollihills, Namakkal District using earthworm *Eisenia fetida*.

MATERIALS AND METHODS

Vermicomposting experiment: preparation of vermibeds

Five different types of organic wastes e.g. Domestic waste, Agricultural waste, Sago waste, cow dung and poultry dropping have been used in this study. Agriculture waste was the mixture of Bark (hardwoods and softwoods), Sawdust, Shrub trimmings, Hardwood chips shavings, Softwood chips shavings, Leaves (dry, loose) collected in Kolli hills, Namakkal District and Sorghum Silage, Straw, Sorghum stalks, and Sorghum cobs collected from the plain around the hills. Sago industry waste and poultry manure were collected from a sago factory and a poultry farm in Rasipuram, Tamil Nadu (India). Fresh cow dung (CD) was procured from a live-stocked farm at Rasipuram, India. *E. fetida* a composting worm was used in the experiments due to its well established potential for vermicomposting of compostable organic materials such as agricultural wastes and animal manures (Edwards *et al*., 1998). Unclitellated hatchlings weighing 100–150 mg (live weight) were used for the experiment. A total of six vermicomposting units containing different waste mixture compositions were established. Each unit contained 2.5 kg waste mixtures on dry weight basis. Circular plastic containers of appropriate size were used for experiment. Triplicates were prepared for each unit. All the used waste mixtures were predecomposed for 4 weeks, for semi-decomposition and thermal stabilization to have optimum action of earthworms and microorganisms. After 4 weeks, 100 unclitellated hatchlings of *E. fetida* were randomly picked from stock culture and introduced in each unit. All the containers were kept in dark at a laboratory temperature of 22 ± 3℃. The moisture content was maintained at 60–80% by periodic sprinkling of water throughout the study period.

The substrates (vermibeds) were prepared by using different waste material amended with animal wastes (dry weight proportion) in different ratio. Six type of the vermibeds were prepared as given below:

Vermicomposting unit no. 1:– 100% cattle farmyard manure
Vermicomposting unit no.2:– poultry dropping + cow dung in 1:1 ratio
Vermicomposting unit no. 3: – Sago waste + cow dung in 1:1 ratio
Vermicomposting unit no. 4: – mixed crop residues (mixing of all types crop residue used in this study) + cow dung in 1:1 ratio
Vermicomposting unit no. 5: – Domestic waste + cow dung in 1:1 ratio
Vermicomposting unit no. 6: – mixed crop residues + Domestic waste + cow dung in 1:1:2 ratio

Earthen pots size of 52cm height and 50cm diameter, each have capacity of 4Kg waste, with a hole at the bottom. Experimental beddings were kept in triplicate for each treatment, and same setup without earthworm was also maintained, which acted as the control. All beddings were kept for fifteen days prior to experimentation for thermal stabilization, initiation of microbial degradation and softening of waste. At the start of the experiment, about 6 weeks old 20 clitellated earthworms were rinsed from stock culture, pre-weighed and placed in the different Earthen pots having 2000 g (on dry weight basis) of experimental material. The moisture level of containers was maintained about 50–60% throughout the study period by periodic sprinkling of adequate quantity of tape water. To prevent moisture loss, the experimental pots were covered with paddy straw. At the start of the experiment, the material of all six beddings and the vermicompost produced at the end of 42 days during the course of experiment were measured for their chemical parameters (organic C, total N, available P, and exchangeable K content).

Chemical analysis

The chemical parameters of bedding material and vermicompost produced during experiment were analyzed by using standard methods. Organic carbon was determined by the partially-oxidation method (Walkley and Black, 1934). Total Kjeldhal nitrogen was measure after digesting the sample with digestion mixture (20 g sodium sulphate + 0.833 $CuSO_4$ + 0.1249 HgO + 0.0418 sodium metal powder) and 35 ml concentrated H2SO4 (Jackson, 1975). For extractable phosphorous determination, 5.0 g of air-dried sample was taken into a conical flask and 25 ml of sodium bicarbonate and 1.0 g activated charcoal was added and the mixture was shaken for 30 min. After this, the solution was filtered through a Whatmann No. 42 filter paper and the filtrate was used for the determination of phosphorous using Tecator Model Enviroflow- 5012 autoanalyser (Anderson and Ingram, 1993). Potassium was determined after extracting the sample using ammonium acetate extractable method; analyzed by Perkin–Elmer model 3110 double beam atomic absorption spectrophotometer.

Statistical analysis

All the results reported in the text are the mean of three replicates. One-way ANOVA was used to analyze the significant differences among different vermicomposts for studied parameters. Tukey's t-test as a post hoc was also performed to identify the homogeneous type of vermicomposts for the various parameters. The probability levels used for statistical significance were $P < 0.05$ for the tests.

RESULTS AND DISCUSSION

Nutrient quality of vermicomposts

The earthworms in composting process modify the physical, biological and chemical properties of the waste materials. The final vermicomposts were odour free, granular, darker and homogeneous than initial waste mixtures. The manurial value of vermicompost depends on several factors viz., nature of feed substrate, aeration, moisture, temperature and earthworm species used in the process. Hence it is essential to specify various physicochemical characteristics, pH, total organic carbon, total Kjeldhal nitrogen, total available phosphorus, exchangable potassium, etc. to quantify the dynamics of vermicomposting process. Physico-chemical characteristics of

Table 1: Nutrient content (g kg-1) of initial material used for experimentation (mean ± SD, n = 3)

Vermibeds	pH	Organic C	Total N	Available P	Exchangeable K	C:N ratio
Cattle farmyard manure	9.6 ± 0.06	8.5±0.06	0.20±0.04	0.09±0.01	0.5±0.04	57.55±0.05
Poultry dropping + cow dung	7.57 ± 0.03	8.4±0.01	0.15±0.03	0.01±0.00	0.04±0.01	48.01±0.05
Sago waste + cow dung	8.60 ± 0.06	5.8±0.08	0.16±0.07	0.04±0.00	0.03±0.06	51.40±0.06
Mixed crop residues + cow dung	7.73 ± 0.07	10.6±0.09	0.31±0.09	0.06±0.00	0.05±0.04	53.02±0.12
Domestic waste + cow dung	7.3 ± 0.00	11.01±0.09	0.28±0.08	0.01±0.00	0.07±0.07	52.43±0.07
Mixed crop residues +Domestic waste + cow dung	7.57 ± 0.09	9.8±0.04	0.18±0.06	0.07±0.00	0.06±0.02	59.02±0.12

Table 2: Nutrient content (g kg-1) of final material used for experimentation (mean ± SD, n = 3)

Vermibeds	pH	Organic C	Total N	Available P	Exchangeable K	C:N ratio
Cattle farmyard manure	8.83 ± 0.03	5.5±0.0 6	0.50±0.06	0.21±0.01	0.10±0.03	37.06±0.02
Poultry dropping + cow dung	6.77 ± 0.09	5.8±0.08	0.42±0.12	0.05±0.00	0.07±0.08	25.30±0.02
Sago waste + cow dung	8.00 ± 0.06	2.05±0.04	0.26±0.03	0.05±0.01	0.53±0.03	33.46±0.02
Mixed crop residues + cow dung	6.80 ± 0.01	7.12±0.012	0.84±0.07	0.11±0.00	0.10±0.06	33.35±0.04
Domestic waste + cow dung	6.70 ± 0.00	7.60±0.08	0.78±0.08	0.15±0.00	0.15±0.03	32.14±0.06
Mixed crop residues +Domestic waste + cow dung	6.75 ± 0.90	5.95±0.02	0.89±0.07	0.09±0.07	0.12±0.01	32.15±0.03

the initial feed mixtures and vermicomposts are given in Table 1. pH of vermicomposts was significantly different than initial pH. The pH of all the feed combinations decreased from alkaline (7.7–9.6) to slightly acidic (6.7–6.9) except cattle farmyard manure and sago waste. Similar observations have been reported by other scientists for vermicomposting process. Khwairakpam and Bhargava (2009) reported a decrease in pH during the vermicomposting of sewage sludge. The difference in pH of different waste mixtures can be attributed to difference in physicochemical characteristics of wastes used in the process. Ndegwa and Thompson (2000) have reported that shift in pH values may be due to N and P mineralization and conversion of the organic material into intermediate of organic acids. Pramanik *et al.* (2007) have postulated that decomposition of organic matter leads to the formation of ammonium (NH^+4) and humic acids. The combined effect of these two oppositely charged groups actually regulates the pH of vermicompost leading to a shift of pH towards neutrality or acidity. Mean pH of vermicomposts produced from different vermicomposting units was 6.4 ± 0.2, which is within the optimal range for plant growth (Goh and Haynes, 1977). The pH for all the vermicomposting units was not different significantly ($P < 0.05$). Total organic carbon (TOC) content was lesser in all the vermicomposts than initial TOC. Maximum decrease in TOC was recorded in mixed crop residues +Domestic waste + cow dung and . The Minimum decrease in TOC was recorded in cattle farmyard manure. Combined action of earthworms and microorganisms may be responsible for TOC loss from the initial feed waste in the form of CO_2. Kaviraj and Sharma (2003) have reported 20–45% reduction of TOC as CO_2 during vermicomposting of municipal or industrial wastes.

Inoculation of earthworms in decomposing organic waste material promotes biochemical degradation, and their activity also promoted the colonization of decomposer communities of waste system, this is due to stable biological as well as chemical environmental conditions. Dominguez and Edwards (2004) has reported that earthworm fragments and homogenizes the ingested material through muscular action of their foregut and also adds mucus and enzymes to ingested material and thereby increases the surface area for microbial action, while microorganisms perform the biochemical degradation of waste material providing some extra-cellular enzymes within the worm's gut. Thus combined action earthworms and microorganisms bring about C loss from the substrates in the form of CO_2. Total Kjeldhal nitrogen (TKN) content in the vermicomposts was higher than initial waste mixture. The final TKN content of the waste mixtures had increased 2.5-4.5 fold (Table 2). Kaushik and Garg (2004) have reported 2.0–3.2-fold increase in TKN during vermicomposting of textile mill sludge mixed with cow dung and wheat straw. Plaza *et al.* (2007) have reported that the nitrogen content of vermicomposts increases due to mineralization of C-rich materials and, possibly, due to the action of N-fixing bacteria. Decreases in pH may be another important factor in nitrogen retention by vermicompost which otherwise may be lost as ammonia at higher pH values. There was about 12–51% increase in total available phosphorus in vermicomposts compared with phosphorus content in initial waste mixtures (Table 2). Sangwan *et al.* (2010) have also reported a 1.3–1.5-fold increase in phosphorus content in the vermicomposting of press mud. Le Bayon and Binet (2006) have reported that some amount of phosphorus is converted to more available forms partly by earthworm gut enzymes, i.e., acid phosphatases and alkaline phosphatases. Actions of phosphorus-solubilizing microorganisms present in earthworm's casts may also be responsible for the release of phosphorus in vermicomposting (Prakash and Karmegam, 2010). The potassium (K) content was greater in all the vermicomposts than initial waste combinations (Table 2). The increase in potassium content was from 0.01 - 0.09 to 0.05- 0.21 in the vermicomposts as compared with K content in initial waste mixtures. The differences in the results can be attributed to the differences in the chemical nature of the initial raw materials.

Suthar (2008) has reported 104– 160% increase in potassium content during vermicomposting. Sangwan *et al.* (2010) have also reported an increase in K in vermicomposts after bioconversion of sugar industry waste. Kaviraj and Sharma (2003) have reported that enhanced number of micro-flora present in the gut of earthworms might have played an important role in the process and increased potassium content during vermicomposting process. Initial C:N ratio was in range of 57.55–59.02 (at 0 day), but after 42 days there was a significant decrease in the C:N ratio in all the vermicomposting units. Final C:N ratio was in the range of 37.06–32.14. The C:N ratio indicates the degree of stabilization of a waste, as carbon is lost as CO_2 during vermicomposting whereas nitrogen content is enhanced during this process and these factors contributes to the lowering of C:N ratio. The decrease in C:N ratio and relative increase in the TKN of vermicomposts may also be due to the loss of dry mass in terms of CO_2 as well as moisture loss by evaporation during vermicomposting (Viel *et al*., 1987). So, a high degree of organic matter stabilization of waste material was achieved in all the vermicomposters which prove that *E. fetida* can promote decomposition and mineralization of organic matter.

Conclusions

This work was undertaken to explore the use of vermicomposting technology in food industry waste management. Various combinations of CD with PD and Sago with Mixed crop residue were vermicomposted using an epigeic earthworm (*E. fetida*) and the vermicompost qualities were estimated in different waste mixtures. The final vermicomposts was rich in important plant nutrients (nitrogen, phosphorus and potassium) and their C:N ratio was below 37 in 42 days which indicate their agronomic importance. The quality of initial feed substrates determined the physico-chemical characteristics of vermicomposts prepared after vermicomposting. The results suggest that using locally available wastes found in and around Kolli hills can be used effectively to produce vermicompost as a value added products.

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