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Stabilization of anarobic digestor sludge through vermicomposting

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Abstract: In this study, efficiency of vermitechnology in stabilizing sludge without pre-treatment was studied. The sludge was directly introduced in the vermicomposting reactors after their withdrawal from the bio-methanation reactor installed for experimentation on domestic waste. One Liter (5% TS) sludge was loaded after every fourth day and it was discontinued after sixteen days. However, the chemical analysis of the compost was done till twenty-fourth day. The present study also evaluated the potential of one indigenous *Perionyx excavates* (*P.e.*) and one exotic epigeic earthworm species *Eisenia fetida* (*E.f*). The results clearly elucidate that vermireactor with indigenous earthworms (*P.e*) gives over all comparable similar results with world wide known exotic species (*E.f*). The results of the study show a significant reduction in initial C/N ratio from an initial value of 19 to 9 for all reactors with earthworms, total organic matter (TOC) reduced by 50% and pH also reduced nearer to neutral, but increase in, total nitrogen (TN) 95%, NH_4^+-N reduced from 0.52% to 0.31% and NO_3^-N increased from 0 to 0.13%, total phosphorus (TP) increased from the initial concentration of 0.76% to 1.31%., However, removal efficiency of Fecal coliforms (indicator organism) in the prepared vermicompost through *P.e* and *E.f* was in the 6 log and 7 log (MPN/gm) respectively.

Keywords: Earthworm, *Eisenia fetida*, *Perionyx excavatus* and Sludge vermitechnology

INTRODUCTION

Vermitechnology is a bio-oxidation and stabilization of organic material involving the joint action of earthworms and microorganisms. Although microbes are responsible for biochemical degradation of organic matter, earthworms are the important drivers of the process, conditioning the substrate and altering biological activity (Dominguez *et al.*, 2001; Rajpal *et al.*, 2011). During the process of vermicomposting the earthworm acts as the carriers of microorganism, they feed on the organic matter and convert them into stable casting (ejected matter), which are rich in plant nutrients like nitrogen, phosphorous and potassium. The chemical analysis of the casting shows two times available magnesium, fifteen times available nitrogen and seven times potassium when compared to the surrounding soil.

Sludge from bio-methanation is residual solid wastes generated in the bio-methanation process which is sent to sludge drying bed and once dry, sold as manure. The fertilizer properties of the dry sludge are limited as the concentration of nitrate is comparatively low. In good fertilizer the concentration of nitrate is high, as this form of nitrogen is readily absorbed by plant roots. Also dry sludge may contain fraction of heavy metals, which is toxic to soil. Therefore, the effluent sludge from digesters must be subjected to further stabilization or other supplementary processes with a simple technology, easy operation, and of higher efficiency. Vermicomposting involves bio-oxidation and stabilization of organic material by the joint action of earthworms and mesophilic microorganisms under aerobic conditions. Although several studies have evaluated the efficiency of the combined composting and vermicomposting for biosolids stabilization (Ndegwa and Thompson, 2001; Alidadi *et al.*, 2004; Nair *et al.*, 2006; Tognetti *et al.*, 2007; Lazcano *et al.*, 2008; Monson and Murugappan, 2010; Mupondi *et al.*, 2010), there are no studies addressing the optimization of the integrated system. Vermitechnology has now a day attracted much attention as a method of sludge stabilization worldwide due to simple, natural and needs low cost equipments (Ndegwa and Thompson, 2000; Gupta and Garg, 2008; Suthar and Singh, 2008; Suthar, 2009; Khwairakpam and Bhargava, 2009).

In the present study, the efficiency of Vermitechnology in stabilizing sludge without pre-treatment is studied. The changes in TOC, TKN, COD, BOD, ammonical nitrogen, nitrate nitrogen, total phosphorous, and micro nutrient were monitored to determine the efficiency of the system. Also comparative study between one exotic species (*E. fetida*) and indigenous species (*P. excavatus*) was performed to determine the potential of native species vis-a-vis the exotic species in vermicomposting of sludge.

MATERIALS AND METHODS

Collection and culturing of earthworms: The earthworms

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P. excavates (*P.e.*) and *E. fetida* (*E.f.*) were collected from earthworm pits of environmental laboratory, IIT Roorkee, India.

Substrate for experiment: Sludge for vermicomposting was obtained from bio-methanation reactor installed for experimentation on vegetable waste at Indian Institute of Technology, Roorkee (IITR). The sludge was directly introduced for vermicomposting after its withdrawal from the bio-methanation reactor. The initial physico-chemical characteristic of the sludge is given in Table 1.

Experimental setup: The experiment was conducted in controlled condition created inside laboratory where temperature was maintained between 22±3^{0}C. The experiment was conducted in plastic container of 6L capacity. The container was punched with 2mm holes on bottom and side for leaching of extra water and aeration. A total of three containers was used for the study, with each having *P. excavatus* (R_1), *E. fetida* (R_2) and the last acting as the control (R_3). Half depth (15cm) of each container was filled with fully stabilized compost free of earthworm, which acted as the initial habitat of earthworms. In each container 30 gram of respective type of earthworm was added, which were counted before introducing them to the reactor. One Litre (5% TS) sludge was loaded every fourth day and it was discontinued after sixteen days. However the chemical analysis of the compost was done on every eighth day and was continued till twenty- fourth day.

Chemical analysis: The chemical analysis was done on every eighth day and the parameters monitored (APHA, 2005) where pH using pH meter, total organic carbon (TOC) determined by Shimadzu (TOC-Vcsn) solid sample module (SSM-5000A), total kjeldahl nitrogen (TKN) using Kjeldahl method, ammoniacal nitrogen (NH_4^+-N) and nitrate nitrogen (NO_3^--N) using KCl extraction (Tiquia and Tam, 2000), total potassium (TK), chemical oxygen demand (COD) by spectrophotometer, biochemical oxygen demand (BOD), were analyzed through azide modified method In addition the temperature of the composting bed was monitored on daily basis.

Statistical analysis: All the reported data are the mean of four replicates. One way analysis of variance (ANOVA) was used to determine any significance among the parameters analyzed ($p<0.05$).

RESULTS AND DISCUSSION

pH: The initial pH of the sludge was 6.85 which increased for all the reactors as shown in Fig. 1. Maximum and minimum increase in pH was observed for *E. fetida* (LT_3) and control, respectively.

Total phosphorous (TP): Total Phosphorous increased during vermicomposting because of the mineralization of the organic matter. The initial value was 0.76% which had subsequently increased to 1.31%for R_1, 1.41% for R_2 and 1.07% for R_3 (Fig. 1). The maximum increase was observed in R_2 with 85% higher than the initial value. Increase in TP during vermicomposting is due to mineralization and mobilization of phosphorus by bacterial and fecal phosphates activity of earthworm (Edwards and Bater,1992). A high significance was observed for TP as per the ANOVA ($F=4.3953$, $p< 0.013$).

Total organic carbon (TOC): The total organic carbon had reduced during the process of vermicomposting. A large fraction of TOC is lost as CO_2 and due to consumption of available carbon as an energy source by earthworms and microorganisms. The maximum reduction was for R_2 from 36.4% to 32.8% and the minimum reduction was observed in case of R_3 from 36.4% to 34.7% (Fig. 2). Kaviraj and Sharma, 2003 had reported 20-45% loss of carbon as CO_2 during vermicomposting of municipal or industrial waste. A non significant variation ($F= 2.42$, $p< 0.0061$) was observed for all the reactors as per the ANOVA .

C/N ratio : The role of organic carbon and inorganic nitrogen for cell synthesis, growth, and metabolism is important in all living organisms. Plants cannot assimilate N unless the C/N ratio is less than 20 (Edward *et al.*, 1996). To provide proper nutrition for earthworms during vermicomposting, carbon and nitrogen must be present in the substrates at the correct ratio. The usual practice is to arbitrarily add either a rich nitrogenous material or a rich carbonaceous material to the feed substrate to correct for C/N imbalance.

The initial C/N value of the substrate was 19, which had subsequently reduced during vermicomposting to 9.2 for R1, 10.1 for R_2 and 16 for R_3 (Fig. 3). The maximum reduction in C/N ratio was observed in case of R_2 and the minimum reduction was observed in case of R_3. The decrease in C/N ratio over time is attributed to rapid decrease in organic carbon due to increase in oxidation of the organic matter. A low significance was observed for C/N as per the ANOVA ($F=.6212$, $p< 0.6543$).

Macro-nutrients (potassium, sodium, calcium): The initial concentration of Potassium in the substrate was 0.62% which had subsequently increased for all reactors. The maximum increase was observed for rector R_2 to 0.72% and the minimum increase was for R_3 to 0.64% (Fig.3). Acid production by the microorganisms is the major mechanism for solubilization of insoluble potassium. The enhanced number of micro flora present in the gut of earthworms in the case of vermicomposting plays an important role in this process and results in increased potassium over the control (Kaviraj and Sharma, 2003; Khwairakpam and Bhargava, 2009). However the increase in concentration is nominal when compared to the results reported earlier. This is attributed to leaching of the soluble elements by excess water that drained through the mass. Some researchers had reported

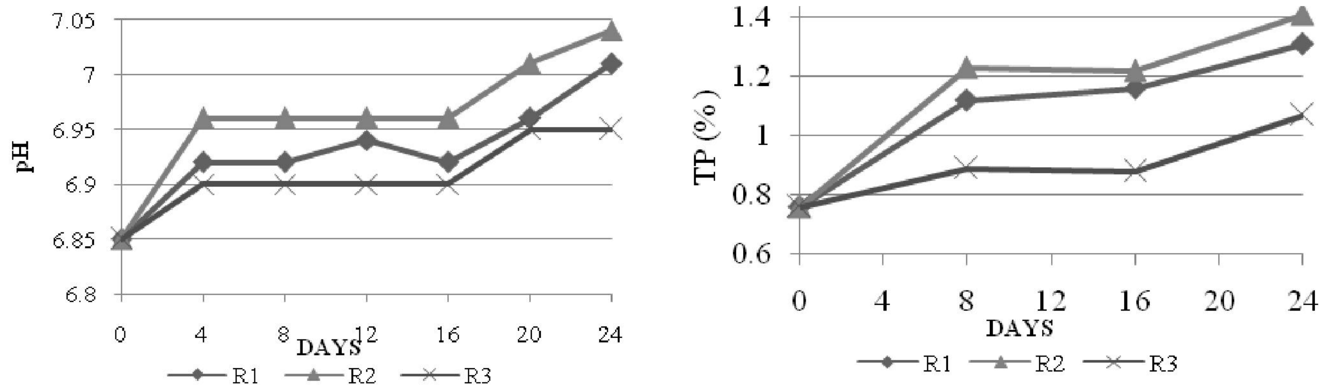

Fig. 1. *pH and TP profile during vermicomposting.*

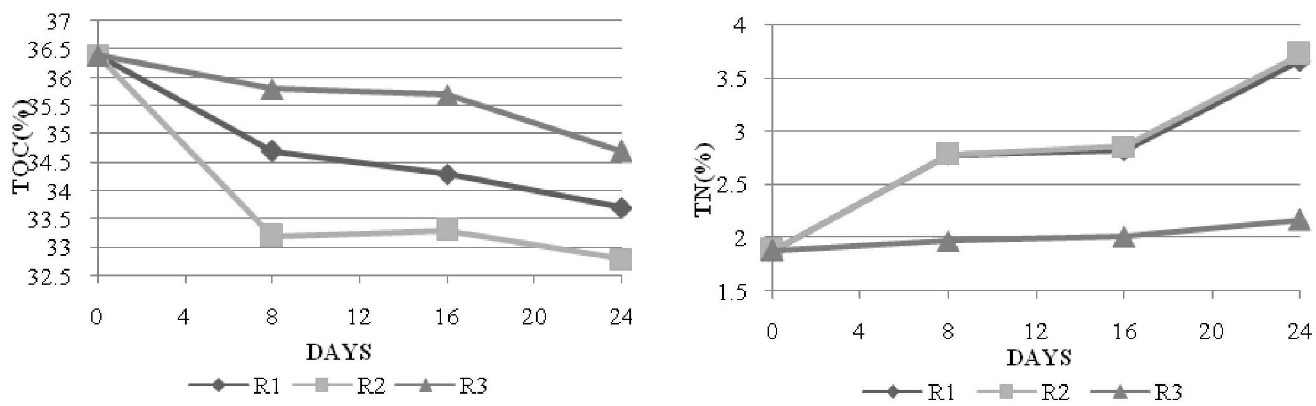

Fig. 2. *TOC and TN profile during vermicomposting.*

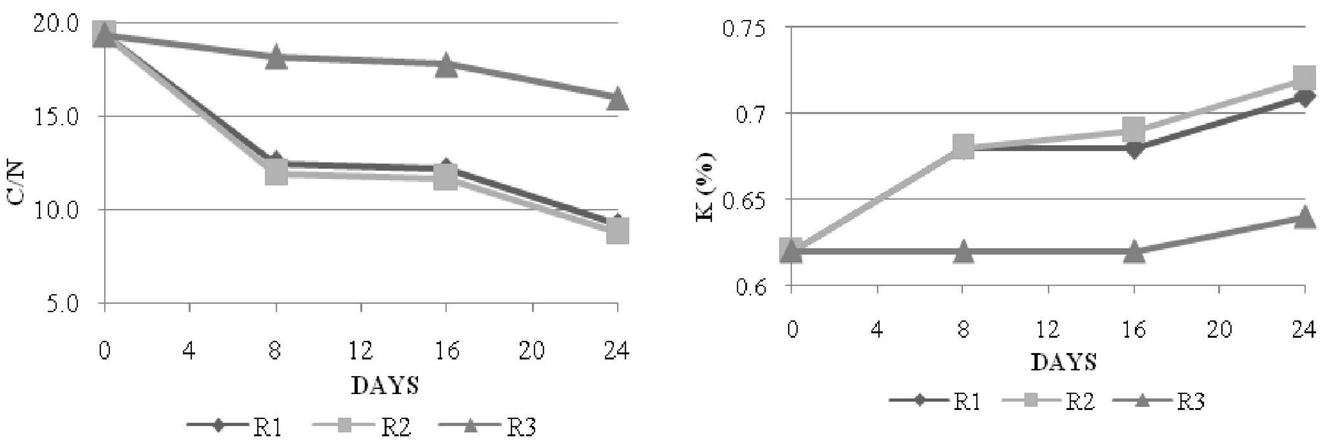

Fig. 3. *C/N and potassium profile during vermicomposting.*

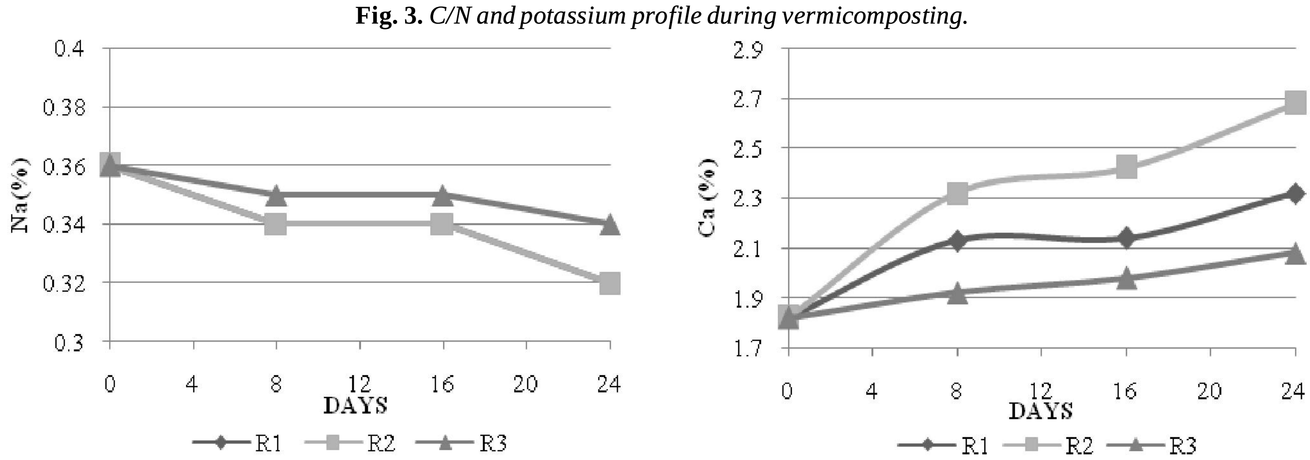

Fig. 4. *Sodium and calcium profile during vermicomposting.*

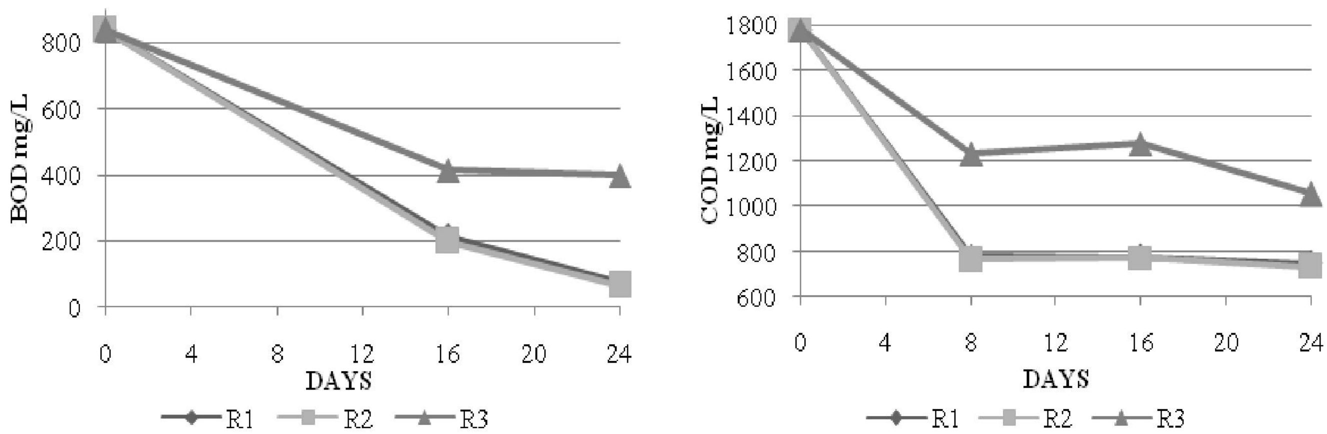

Fig. 5. *BOD and COD profile during vermicomposting.*

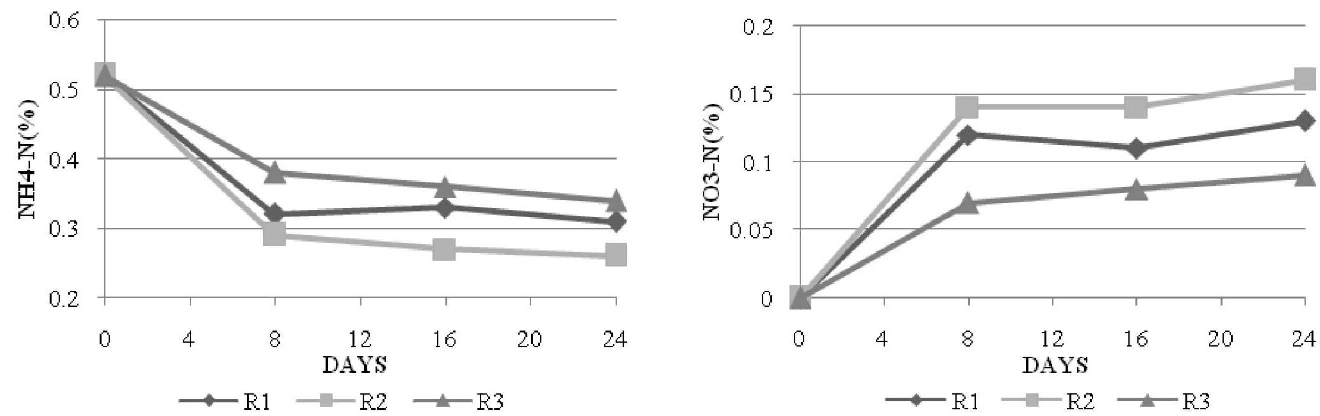

Fig. 6. *NH_4-N and NO_3-N profile during vermicomposting.*

that the leachate collected during vermicomposting process had higher potassium concentrations (Benitez *et al.*, 1999). A decrease in potassium and a non significant increase in calcium have been reported in the vermicomposting process where excess water was used that drained through the mass (Elvira *et al.*, 1996). A high significance was observed for K as per the ANOVA analysis of variance ($F=4.8216$, $p < 0.0105$). The initial concentration of Na was 0.36%, which had decreased for all reactors. The maximum decrease of was observed in case of R_2 and R_1 to 0.32% and a minimum decrease was observed for R3 to 0.34% (Fig. 4). A high significance was observed for Na as per the ANOVA ($F=5.0961$, $p < 0.0085$).

The initial concentration of Ca was 1.82 %, which had subsequently increased for all reactors, the increased to 2.32% for R_1, 2.68% for R_2 and 2.08% for R_3 (Fig. 4). A high significance was observed for Ca as per the ANOVA ($F=3.1868$, $p < 0.00278$).

COD and BOD: The composting potential of a substrate is directly proportional to the quantity of biodegradable organic matter contained in the substrate. The substrate will not stabilize till all the biodegradable organic content is converted to stabilized form, which is odorless, pathogen free and is a poor breeding ground for flies and other insects. Even if the compost is stable, care should be taken while applying to soil for crop use because the biological processes will continue and can strip the nutrients of soil (Wang *et al.*, 2004). In all reactors BOD and COD had shown a trend of reduction during the course of vermicomposting. The initial COD of the substrate was 1781 mg/l, which had reduced to 748 mg/l for R_1, 733 mg/l for R_2 and 1056 mg/l for R_3. Similarly the BOD had reduced for all reactors from initial value of 837mg/l to 75 mg/l for R_1, 65mg/l for R_2 and 398 mg/l for R3 (Fig. 5). ANOVA showed high significance level for COD and BOD in all reactor ($p<0.05$).

Total nitrogen (Tn), ammonical nitrogen (NH_4^+), nitrate nitrogen (NO_3^{-2}): The total nitrogen content was increased (Fig. 2) for all the reactors, the maximum increase of 97% was observed for reactor R_2. The minimum increase of 15% was observed for control. For R_1 the increase was in the order of 95%. The reduction in organic carbon due to substrate utilization by microbes and earthworm, water loss by evaporation, and mineralization of organic matter leads to relative increase in nitrogen (Viel *et al.*, 1987; Rajpal *et al.*, 2011).

The exchangeable NH_4^+-N in the vermicompost was always greater than the NO_3^{-2}-N during the course of experiment. A decrease in NH_4^+-N was observed in correspondence with an increase in NO_3^{-2}-N at the end of the vermicomposting process. However, the rapid

Table 1. Initial physico-chemical characteristics of the sludge.

Parameter	Values	F value	p-value
pH	6.85±0.21	2.433	0.143
TOC (%)	62.8±1.8	2.421	0.006
COD (mg/l)	1781±76.74	137.919	9.251
BOD (mg/l)	837±7.21	39.035	0.037
TN (%)	1.88±0.11	5.105	0.050
Ammonical Nitrogen (%)	0.52±0.03	6.880	0.027
Nitrate Nitrogen (%)	0.0±0.0	7.290	0.024
Total Phosphorous (%)	0.76±0.02	4.395	0.013
Na (%)	0.36±0.02	5.0961	0.008
K (%)	0.62±0.15	4.821	0.010
Ca (%)	1.82±0.06	3.1868	0.002
C/N (%)	19±.61	3.621	0.654

All values ±SD represent average of three replicates.

decrease in NH_4^+-N during composting did not coincide with a rapid increase in NO_3^{-2}-N. The difference between various forms of N would be either due to immobilization / denitrification or both (Fig. 6). High significance was observed for NH_4^+-N as per the ANOVA ($F=5.06814$, $p< 0.008711$). Similarly a high significance was observed for NO_3^{-2}-N as per ANOVA ($F=5.325992$, $p< 0.007137$).

Conclusion

The present study inferred that the vermicomposting of sludge stabilizes the sludge rapidly and converts it into vermicompost. The C/N ratio is brought down which assist the plants in assimilate N easily. There is a overall increase in concentration of TKN and nitrate nitrogen which can easily be fixed by plants. In previous studies on vermicomposting of sludge, the sludge was dried in the sludge drying bed and later applied for vermicomposting. However with the provision of an adequate depth of matured compost the sludge can directly be applied on the reactor. Matured compost act as a secured habitat for the earthworms, from where they can migrate and feed on the bio solid of the sludge under favorable conditions. The integrated vermicomposting system has potential to stabilize and converts the organic waste into quality organic manure for agronomic applications without any adverse effects.

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