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Growth and Reproduction of *Eisenia fetida* in Vermicomposting of Organic Fraction of Municipal Solid Wastes

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The objective of this reseach is to investigate the growth and reproduction of *Eisenia fetida* during vermicomposting of organic fraction of municipal solid waste (OFMSW). Furthermore the research was intended to assess the applicability of vermicomposting as an alternative recycling process for conversion of OFMSW to a useful stabilized nutrient rich end product. This research was performed in 24 L containes (as experimental units) and in a complete randomized design with five level of substrate mixture consisting of pretreated OFMSW and cow manure (CM) in per cent ratios of: 20:80, 40:60, 60:40, 80:20 and 100:0, respectively, on the basis of total dry matter. The units with 100 % OFMSW were considered as control ones. The experimental period lasted 80 days. The change in number and biomass of adult earthworms, measured at the beginning and at the end of the experimental work was used to evaluate the difference in growth and reproduction of *Eisenia fetida* under various experimental conditions. Other parameters such as temperature, pH, moisture content and C/N ratio were measured regularly to observe the change in environmental and operational conditions. Statistical assessment of the results was done using SPSS software. The results of the research indicated that a pretreatment step (*e.g.*, undergoing conventional composting for a period of 21 days) was required for OFMSW prior to its use as a substrate in vermicomposting process. The results also showed a considerable increase in the number and biomass of *E. fetida* in all the experimental units. However, the rate of increase varied significantly ($p < 0.05$) between different units. The growth and reproduction of *E. fetida* was found to be significantly affected by the proportion of OFMSW in the substrate mixture; increasing as the amount of OFMSW was increased. The best result (211 % increase in number and 468 % increase in weight of the earthworms) occured in the units with only pretreated OFMSW as substrate indicating that, without the need for any additives, the process of vermicomposting can be used as an alternative method in management and recycling of organic fraction of municipal solid waste.

Key Words: Vermicompost, Earthworms, *Eisenia fetida*, Municipal Solid Waste, Cow manure.

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INTRODUCTION

Production and disposal of large quantities of municipal solid wastes has imposed major environmental problems (*e.g.* offensive odours, soil and ground water contamination) all around the world. As a result, the use and implication of correct managemental methods in processing and disposal of different types of wastes including municipal solid wastes are of fundamental issues in maintaining healthy environment.

During last decade, the issue of efficient disposal and management of organic fraction of municipal solid wastes (OFMSW) has become more vigorous due to rapidly increasing population, urbanization and industrialization. At the present time, various physical, chemical and biological methods are used for disposal of OFMSW. However, many of them are highly costly, time consuming, site specific and/or may need specific conditions. As a result there is a pressing need to find out cost-effective, easy to operate alternative methods. 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[1-4].

The prefix "vermi" is Latin for worm. Vermicomposting refers to the process in which earthworms are used to make compost. During this process earthworms fragment their substrate, digest and stabilized organic matter. The process has two end-products; both with economic values. One is vermicompost which has more available nutrients per kg weight than the organic substrate from which it is produced[5]. This nutrient rich end-product can be utilized for plant growth, thus facilitating the transfer of nutrients to plants[6]. Another product is biomass of earth worms which has high nutritional value and can be used as a source of proein in diets of fishing industries, birds, *etc*.

Due to the biological nature of vermicomposting, the growth and reproduction of earthworms as well as process efficiency is affected by many environmental and operational parameters such as pH, temperature, moisture content, type and composition of substrate.

In general, there are about 3000 known species of earthworms with the size in the range of 0.6 to 330 cm. Of the known species, the two species of *Eisenia fetida* and *Lumbricus rubellus* are the most common types used in vermicomposting process due to their high growth rate, high performance efficiency and ease of operational control[7-9].

Various organic wastes can be used as substrate in vermicomposting. The effects of different types of substrate such as sewage sludges[10-12], paper mill industry sludge[13], pig waste[14,15], water hyacinth[16], paper waste[17], brewery yeast[13], crop residues[18], cow slurry[1], cattle manure[19] and textile mill sludge[20] on vermicomposting process were tested and reported by different investigators. Tripathi and Bhardwaj[21], compared biomass production and effectiveness of two species of earthworms; *Eisenia fetida* and *Lampito mauritii* in vermicomposting under semi-arid conditions of Jodhpur, India. They found *Eisenia fetida* with higer growth and reproduction rate to be

more tolerant to such harsh environment. Their work showed that the optimom pH and moisture content for *Eisenia fetida* were 6.5 and 70 %, respectively while for *Lampito mauritii*, the coreponding values were 7.5 and 60 %. Reinecke *et al.*[22] investigated the effects of temperature on growth and reproduction of three epigeic species of earthworms included *Eudrilus eugeniae, Perionyx excavatus* and *E. fetida*. The results of their research indicated that *E. fetida* tolerates a wider range of temperature change (5 to 43 ºC) than other two species, thus it can be used in both hot and cold regions.

This research was performed to investigated: (a) The growth and reproduction of *E. fetida* during vermicomposting of OFMSW and (b) the applicability of recycling of OFMSW to a compost product through vermicomposting process.

EXPERIMENTAL

The experimental work was done on the basis of complete randomized design with five different substrate mixture and three replica for each mixture. The mixtures included pretreated OFMSW and cow manure (CM) in per cent ratios of 20:80, 40:60, 60:40, 80:20 and 100:0, respectively (on the basis of total dry matter). Plastic containers with approximate volume of 24 L were used as experimental units. The containers with 100 % pretreated OFMSW were considered as control units.

Initial work of current research demonstrated that OFMSW could not be used in its original composition as substrate for *E. fetida*. The worms would not remain in the containers even in the units with the lowest percentage of OFMSW in the sybstrate. After trying several alternatives, it was finally realized that a pretreatment step including conventional composting of OFMSW for a period of 21 days could provide the suitable substrate and conditions for the activities of *E. fedida*. During this pretreatment period, partial decomposition of organic matter prevents accumulation of byproducts that may otherwise be undesirable for the worms. It also prevents exposure of worms to high temperature that occurs during the initial stage composting process.

Fig. 1 reperesents the change in temperature of the compost pile of OFMSW during the pretreatment stage. The results of analysis of physical and chemical characteristics of pretreated OFMSW and cow manure used in this work are shown in Table-1.

Each container was filled with 2 kg substrate (on the basis of total dry matter) consisting different percentages of pretreated OFMSW and cow manure, as was designed. The labling of different treatment units with their substrate contents are showed in Table-2.

All the units were seeded with 100 healthy earthworms (species of *E. fetida*), each with an average weight of 250 to 400 mg.

Temperature, pH and per cent moisture content of the units were measured regularly (temprature and per cent moisture at 5 days interval and pH at 10 days interval) to ensure the suitable conditions for the growth and reproduction of the earthworms. The moisture level of substrates was maintained in the range of 60-70 %

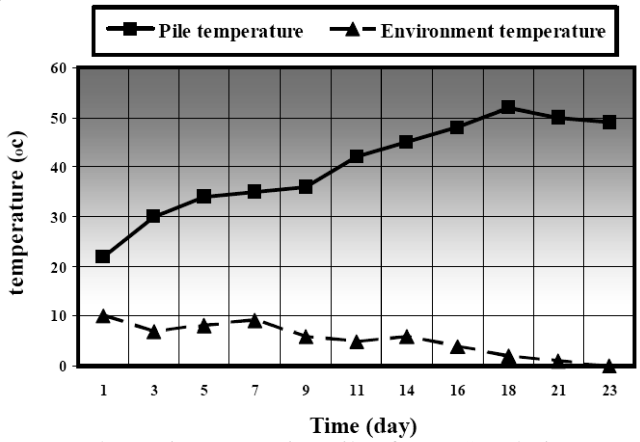

Fig. 1. Temperature change in composting pile of OFMSW during pretreatment step

TABLE-1
PHYSICO-CHEMICAL CHARACTERISTICS OF PRETREATED OFMSW AND COW MANURE

Parameter	Unit	Content	
		OFMSW	Cow manure
pH	-	7.60	7.90
EC	ms/cm	0.45	1.32
TVS	kg of D.S.	684.70	521.60
TOC	kg of D.S.	340.10	276.84
TKN	kg of D.S.	12.30	14.40
TP	kg of D.S.	7.10	13.35
TK	kg of D.S.	7.15	19.00
C:N	-	27.65	19.23
C:P	-	47.90	20.74

TABLE-2
PERCENTAGE OF PRETREATED OFMSW AND COW MANURE IN DIFFERENT EXPERIMENTAL UNITS

Treatment	OFMSW (%DW*)	Cow manure (%DW*)
A (Control)	100	0
C	80	20
E	60	40
G	40	60
I	20	80

*Per cent of dry weight.

during the experimental period by addition of adequate quantity of tap water if needed. The measurements of TOC, TKN and C/N ratio were carried out at the start up of the units (before seeding earthworms), at 30 day and at the end of research period (80 day). The analytical methods used for measurements of pH, moisture content, TOC and TKN content were in accordance with the standard methods[23].

The number and biomass of *E. fetida*, measured in all the units at the beginning and at the end of the experimental work, were used to assess the growth and reproduction of the earthworms under different tested conditions. Statistical analysis of the results was performed using SPSS software.

RESULTS AND DISCUSSION

Temperature and pH: The results of measurements, shown in Figs. 2 and 3, indicated that the variation in pH and temperature of different experimental units during the course of study remained within the ranges suitable for the growth and activities of *E. fitida* worms[24]. As it can be seen in the figures, the ranges of change in pH and temperature were limited to 7.2-8.5 and 13-24 ºC, respectively.

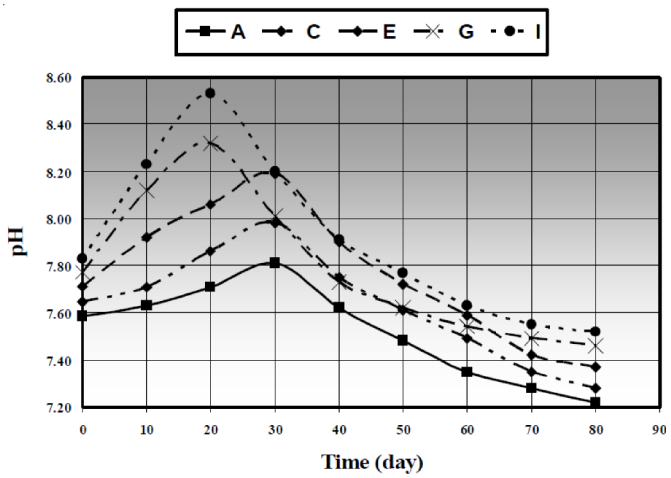

Fig. 2. pH change in different experimental units during the course of study

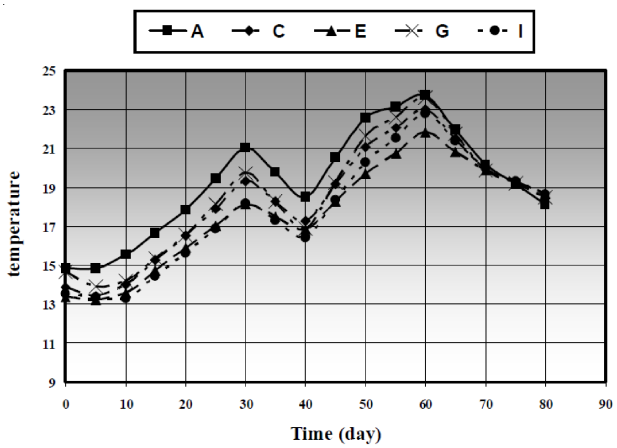

Fig. 3. Temperature change in different experimental units during the course of study

C/N Ratio: This ratio is one of the most important indices used for assessment of: (a) the quality of substrate as food for earthworms and (b) the finishing point of composting process. The optimum C/N ratio of substrate in vermicomposting was found[25,26] to be in the range of 20 to 25, while the C/N ratio indicating the complete stabilization of organic matter and maturity of composted product was reported[27,28] to be around 15. The average C/N ratios of the substrates in different experimental units at the beginning, at day 30 and at the end of the experimental period, are shown in Fig. 4. From the results it can be observed that the C/N ratio of the substrates in all the units were in the range of optimum for the activities of the worms. The C/N ratio of the composted material in different units also decreased to the range of 14 to 17 after 60 days and did not change significantly until the end of the experimental period (80 day).

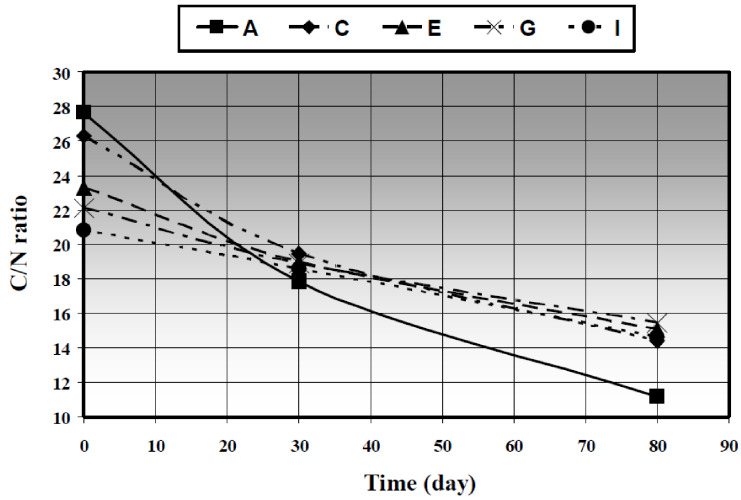

Fig. 4. C/N ratio change in different experimental units during the course of study

Biomass of adult earthworms: The change in biomass of earthworms is considered to be the best index of their growth and reproduction conditions. Table-3 shows the average increase in total biomass of *E. fetida* in different units at the begining and at the end of the experimental period, as well as their specific growth rate. The average per cent increase in total biomass of adult earthworms in each treatment unit is also presented in Fig. 5.

The results indicated that in all the experimental units, the biomass of *E. fetida* increased considerably. However, the differences observed in per cent increase in biomass of *E. fetida* in different units were significant ($p < 0.05$). The maximum increase in biomass (468 %) occurred in unit A which had only OFMSW as the substate (100 % OFMSW + 0 % CM). In contrast, unit I with the lowest per cent of OFMSW (20 % OFMSW + 80 % CM) showed the minimum increase in biomass (132 %).

TABLE-3
AVERAGE INCREASE IN BIOMASS OF *E. fitida* AND THEIR SPECIFIC GROWTH RATES IN DIFFERENT EXPERIMENTAL UNITS (MEAN ± SD, n = 3)

Treatment	Initial stage		Final stage		Increase in biomass (%)	Net individual weight gained (mg/worm)	Growth rate (mg/worm. day)
	Total biomass (g)	Mean individual weight (mg)	Total biomass (g)	Mean individual weight (mg)			
A	33.40	334	189.71	610	468	276	3.45
C	35.00	350	162.40	560	364	210	2.63
E	36.70	367	145.52	545	296	178	2.23
G	34.10	341	95.71	523	181	182	2.28
I	32.10	321	74.40	496	132	175	2.19

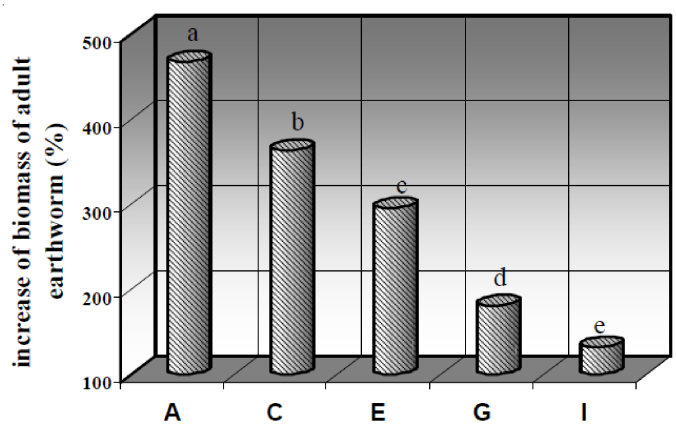

Fig. 5. Average per cent increase in biomass of *E. fetida* in different experimental units

The statistical analysis of the data on specific growth rate of *E. fetida* also indicated a significant difference ($p < 0.05$) between the experimental units. The results presented in Table-3 shows that the worms in unit A had the highest average specific growth rate (3.45 mg/worm.day) indicating the best growth condition, while in unit I, the specific growth rate of the worms was the lowest (2.19 mg/worm.day) indicating the worst growth condition between the units.

The differences observed in the average specific growth rate and biomass increase of the earthworms in different units can be related to differences in: a) the amount and availability of substrate as energy source in each unit, b) physico-chemical characteristics of the beding materials (substrate) in each unit, and c) the extend of activity of microorganisims. Suthar[29], experimetely proved that both physico-chemical characteristics of beding materials and the amount of microbial biomass, have effective roles in the growth and reproduction of earthworms during vermicomposting process.

Number of adult earthworms: The change in number of adult earthworms (*E. fetida*) in experimental units is presented in Table-4. The average percent increase in the number of worms in each unit is also shown in Fig. 6.

TABLE-4
CHANGE IN AVERAGE NUMBER OF *E. fetida* IN DIFFERENT EXPERIMENTAL UNITS (MEAN ± SD, n = 3)

Treatment	Number of adult earthworm (initial stage)	Number of adult earthworm (final stage)	Per cent increase in number
A	100	311	211
C	100	290	190
E	100	267	167
G	100	183	83
I	100	150	50

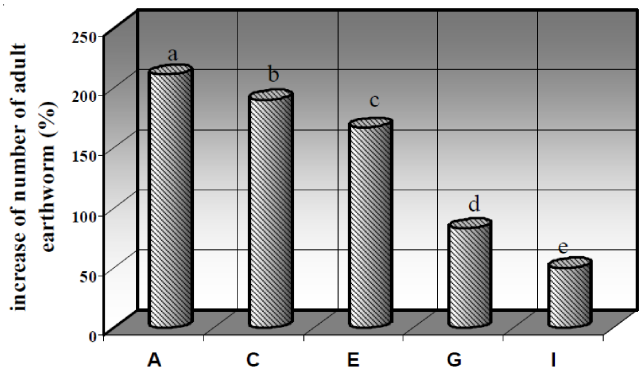

Fig. 6. Average per cent increase in number of *E. fetida* in different experimental units

From the present results it can be seen that in all the units, the number of *E. fetida* increased significantly. The maximum and minimum per cent increase in the number of earthworms occured in units A (211 %) and I (50 %), respectively. The differences observed between different units in this regard, resulted from differences in the substrate mixtures, were significant ($p < 0.05$).

Conclusion

From the results obtained in this research it can be concluded that the type and composition of the substrate used in vermicomposting process, can significantly affect the growth and reproduction of *E. fetida*. In present experimental work the best results from the view point of number, biomass and the growth rate of *E. fetida* was obtained from the substrate consisted of 100 % OFMSW. Furthermore, the results clearly showed that the activities of *E. fetida* diminished as the per cent of OFMSW in the initial mixture of substrate was reduced. In another word, the worst performance of *E. fitida* in regard to the growth and reproduction occured in the substrate with the lowest percentage of OFMSW (20 % OFMSW + 80 % CM). This implies that the OFMSW organic fraction of municipal solid waste had been

more readily available for the use by the earthworms than the organic fraction of cow manure. In general the results give to the conclusions that: a) the organic fraction of municipal solid waste (if properly pretreated) can be used succesfuly, without any need for additives, as a reliable substrate for the growth and reproduction of *E. fetida* and b) the process of vermicomposting in applicable to OFMSW and can be used as an alternative method in recycling and reuse of this type of waste.

REFERENCES

1. P. Hand, W.A. Hayes, J.C. Frankland and J.E. Satchell, *Pedobiologia*, **31**, 199 (1988); P. Hand, W.A. Hayes, J.C. Frankland and J.E. Satchell, The Vermicomposting of Cow Slurry, Earthworms in Waste and Environmental Management, pp. 49-63 (1988).
2. C.L. Raymond, J.H. Martein Jr. and E.F. Neuhauser, Stabilization of Liquid Municipal Sludge using Earthworms, In: Earthworms in Waste and in Environment Management, SPB Academic Publishing, The Netherlands, pp. 95-110 (1988).
3. R.C. Harris, K. Knox and N. Walker, Strategies for the Development of Sustainable Land Fill Design, In: IWM Proceeding, pp. 26-29 (1990).
4. G. Logsdson, *Biocycle*, **35**, 63 (1994).
5. M.A. Buchanam, E. Rusell and S.D. Block, in eds.: C.A. Edwards and E.F. Neuhauser, Chemical Characterization and Nitrogen Mineralization Potentials of Vermicompost Derived from Differing Organic Wastes, Earthworms in Environmental and Waste Management, SPB Academic Publishing, The Netherlands, pp. 231-240 (1988).
6. S.A. Ismail, Organic Waste Management, In: Technology Appreciation Programme on Evaluation of Biotechnological Approaches to Waste Management Held on 26th October 2000, Industrial Association-Ship of IIT, Madras, pp. 28-30 (2000).
7. G.W. Dickerson, Vermicomposting. Extention Horticulture Specialist, Cooperative Extension Service, College of Agriculture and Home Economic, Guide H-164 (2001).
8. S. Sharma, K. Pradhan, S. Satya and P. Vasudevan, *J. Am. Sci.*, **1**, 4 (2005).
9. L. Rees, Vermicomposting: A Brief Guide, Soil Association, Food and Farming Department (2007).
10. M.A. Diaz-Burgos, B. Ceccanti and A. Polo, *Biol. Fertil. Soil*, **16**, 145 (1992).
11. M. Delgado, M. Bigeriego, I. Walter and R. Calbo, *Turrialba*, **45**, 33 (1995).
12. E. Benitez, R. Nogales, C. Elvira, G. Masciandaro and B. Ceccanti, *Bioresour. Technol.*, **67**, 297 (1999).
13. K.R. Butt, *Bioresour. Technol.*, **44**, 105 (1993).
14. P.L.S. Chan and D.A. Griffiths, *Biological Wastes*, **24**, 57 (1988).
15. U. Reeh, *Soil Biol. Biochem.*, **24**, 1327 (1992).
16. S. Gajalakshmi, E.V. Ramasamy and S.A. Abbasi, *Bioresour. Technol.*, **80**, 131 (2001).
17. S. Gajalakshmi, E.V. Ramasamy and S.A. Abbasi, *Indian J. Chem. Technol.*, **9**, 306 (2002).
18. S. Bansal and K.K. Kapoor, *Bioresour. Technol*., **73**, 95 (2000).
19. A. Mitchell, *Soil Biol. Biochem.*, **29**, 763 (1997).
20. P. Kaushik and V.K. Garg, *Bioresour. Technol.*, **90**, 311 (2003).
21. G. Tripathi and P. Bhardwaj, *Bioresour. Technol.*, **92**, 275 (2004).
22. A.J. Reinecke, S.A. Viljoen and R.J. Saayman, *Soil Biol. Biochem.*, **24**, 1295 (1992).
23. A.L. Page, R.H. Miller and D.R. Keeney, Methods of Soil Analysis, Chemical and Microbiological Properties, American Society of Agronomy, Soil Science Society of America. Publisher: Madison, Wiscosin, USA, Part-2, edn. 2 (1982).
24. R. Sherman, Raising Earthworm Successfully, North Carolina Cooperative Extension Service (2003).
25. N.B. Handricsen, *Biol. Fertility Soil*, **10**, 17 (1990).
26. P.M. Ndegwa and S.A. Thompson, *Bioresour. Technol.*, **75**, 7 (2000).
27. R.P. Poincelot, *Compost. Sci.*, **15**, 24 (1974).
28. C.G. Goluke, *Biocycle*, **22**, 36 (1981).
29. S. Suthar, *Bioresour. Technol.*, **98**, 1608 (2007).

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