International Journal of Agricultural Technology 2013 Vol. 9(3): 529-539
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Sustainable management of different organic waste by vermicomposting technology

Parveen Fatemeh Rupani[1*], Mohd Fadhil Md Din[2], Zelam D. Kanhere[3]

[1]School of Industrial Technology, Universiti Sains Malaysia, 11800, Pulau Pinang, Malaysia, [2]Department Skudai, Johor, Malaysia of environmental engineering, Universiti Technology Malaysia, 81310, Malaysia, [3]Department of Environmental sciences, University of Pune, 41107 Pune, Maharashtra, India.

Parveen Fatemeh Rupani, Mohd Fadhil Md Din and Zelam D. Kanhere (2013). Sustainable management of different organic waste by vermicomposting technology. International Journal of Agricultural Technology 9(3):529-539.

Abstract A study was carried out to evaluate the efficiency of earthworm (*Eisenia foetida*) for decomposition of different types of organic substances (kitchen waste, garden waste, newspaper, hair and eggshell) into valuable vermicompost. It was found that vermicomposting significantly modified the nutrient properties (N, P and K) of different waste namely- kitchen waste, garden waste, newspaper, eggshell, hair and mixture of them. The growth patterns of earthworm in terms of juvenile, young and mature earthworm's in different feed mixtures has also been affected by types of waste. The study showed that the typical conditions of composting (e.g. pH, temperature, moisture) during the study were favorable throughout the period of experimentation for the earthworm's growth. It was also showed that earthworm's growth varies with type as well as nature of feed material.
The data reveals that vermicomposting (using *E. foetida*) is a suitable technology for decomposition of different types of organic wastes into value added material.

Key words: Vermicomposting; *Eisenia foetida*; Kitchen waste; Garden waste; Newspaper

Introduction

Over the last few decades, the problem of efficient management and disposal of organic solid wastes has become more rigorous due to rapidly industrialization, increasing population and intensive agriculture. Among the waste leaves, lawn chipping and restaurant food waste have been more problematical because of their bulky nature. In India, daily per capita of municipal solid waste generated ranges from about 100 g in small towns to 500 g in large towns (Singhal and Pandey, 2001). It has been estimated that in cities and rural area of India nearly 700 million tones of organic waste is generated

* **Corresponding author:** Parveen Fatemeh Rupani; **e-mail:** pfr09_tec090@student.usm.my

annually which is either burned or land filled. The municipal authorities spend about 5-25% of their budget on solid waste management, which is Rs. 75-250 per capita per year (Kumar and Gaikwad, 2004). Therefore, the disposal of different types of wastes has become very important issue for maintaining healthy environment (Senapati and Julka 1993). Various studies have been focused on the use of earthworms in the stabilization of organic residues such as sewage sludge (Vigueros, and Camperos, 2002), food waste and paper waste (Arancon, 2008), municipal solid waste (Kaviraj, and Sharma, 2003), Agricultural and industrial waste (Suthar, 2009, 2006) etc.

Vermicomposting has been identified as one of the potential management technology of several waste since it is a natural process, cost effective and only shorter duration is required to accomplish; one to two weeks. According to Nair et al. (2006), 9-day thermo composting prior to vermicomposting helped in mass reduction, moisture content and pathogenic problems. The most favourable factor of earthworms performance in the vermicomposting may attribute from the substrate aeration, mixing, grinding, fragmentation, enzymatic digestion and also microbial decomposition of substrate in intestine of earthworms (Hand et al., 1998; Sharma et al., 2005). Under favorable conditions, wastes are converted into a homogeneous mass i.e. castings which may form a suitable soil conditioner with high nutritional value for plants. In addition of providing soil organic carbon and NPK, which composting does, vermicompost additionally provides enzymes and hormones which stimulate plant growth (Abbasi and Ramasamy, 1999; Atiyeh et al., 2001; 2002; Doube et al., 1997; Chaoui et al., 2003).Vermicompost is also believed to be more pathogen-free than compost itself (Szczech, 1999; Slocum, 2002).

Experimental evidence on vermicomposting using animal dung such as cow dung (Kale et.al 1982; Reinecke et al. 1992; Edwards et al. 1998), sheep dung (Kale et al. 1982), poultry manure (Kale et al 1982) as substrate showed efficient conversion of the waste into vermicast. For large scale vermiculture practices, the chemical as well as biological composition of the substrate material is always of primary importance. Furthermore, as reported by Edwards (1998), the quality as well as quantity of organic wastes is a vital role for determining the rates of earthworm’s growth. The biological behaviour of the earthworm’s species in decomposing organic material is still a priority in recent study of vermiculture biotechnology. However, different earthworm species are impacted differently by the nutritional status of feeding material (Suthar, 2007a), but a comprehensive study in scientific literature is still required.

The objective of the present study was to evaluate potential of *Eisenia foetida* in composting of different types of organic wastes (i.e. kitchen waste, garden waste, newspaper, eggshell and hair) that commonly found in India.

Thus, the aim of present study was also to find correlation between the earthworms growth and organic material quality.

Materials and methods

Collection of Organic wastes

The organic solid waste selected in this study i.e. kitchen waste, garden waste, newspaper, eggshell were obtained from the canteen , Pune University Campus and hair was from the barber shop around University, while the cow dung was obtained from the farmer in Pune.

Collection of earthworms

The earthworms (*E. foetida)* were obtained from the Institute of Natural Organic Agriculture, Pune, India.

Experimental setup

All experiments were conducted in earthen pots of size (21cm height and 25 cm diameter), with a hole at the bottom. The bedding layer (5-7 cm) of coconut coir and 12 cm of dry leaves was taken in each pot to provide initial favorable condition for the growth of earthworms (Figure 1).

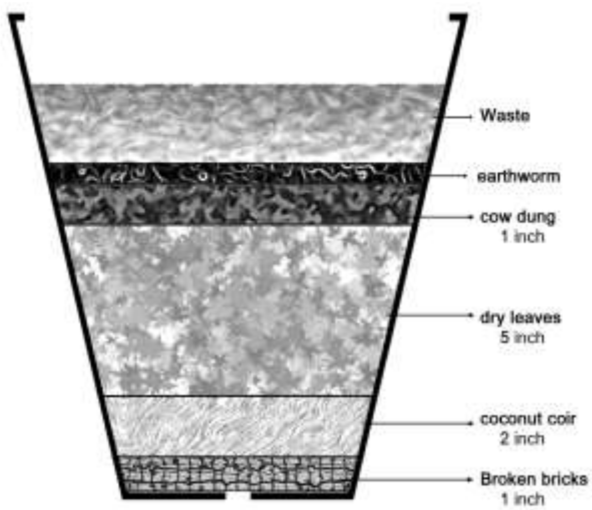

Fig. 1. Example of vermicomposting experimental set-up

A total of six vermireactors were maintained having different kinds of waste mixed individually with cow dung. One pot was prepared in order to mixture of all the wastes prior to transfer to the six vermireactors. In each pot, twelve earthworms with different size were introduced. A 500 g of waste were added with a duration of 8 interval days except to hair and eggshell pot due to slow degradation. Water was sprinkled daily on all pots to maintain the moisture level of 40-60%. All the reactors maintained in triplicate. The duration of experiment was conducted up to 100 days. The experimental pots were kept under shade at 23-28^0 C, 70 ± 10% moisture and covered with the gunny bags to avoid direct sunlight on the terrace of the Department of Environmental Science, University of Pune. After 100 days, the earthworms were removed manually and the total number and biomass of the earthworms were measured.

Four days before the determination, all the treatments were not watered to make the sifting of the compost easier. All the vermicompost produced were taken out from the pots individually and left under room temperature for a couple of hours when all the earthworms have moved down the heap. Thus, sorting process became easier.

Chemical analysis

The vermicompost and the earthworms were taken out manually at the end of the experiment. Carefully total numbers of earthworm in each pot were counted. Total nitrogen was estimated by Kjeldhal digestion. Total phosphorus was detected using colorimetric method and total potassium was estimated by Bray and Krutz method (1945) using Flame emission technique.

Statistical Analysis

The data was collected and analyzed statistically by using statistic computer software PSAW (Predictive analysis software) 18. Values of all the parameters were presented as the mean.

Results and discussions

Data of N, P and K of different vermicomposted waste has been given in Table 1. Vermicomposting significantly modified the nutrient properties (N, P and K) of different waste namely- kitchen waste, garden waste, newspaper, eggshell, hair and mixture of them. Result showed that the values of total P (TP) and total K (TK) of Kitchen waste were highest, however hair shows the lowest P and K percentage (Table 1). The percentage of total P and K were 1.30 and 0.93, respectively in vermicomposted kitchen waste. However, the percentage of P and K in hair was 0.50 and 0.15, respectively. The percent total nitrogen (TN) was highest in vermicomposted hair (2.61), whereas it was lowest in egg shell. (1.18%) (Table 1).

Table 1. Percentage of Total P, K and N in different types of vermicomposted wastes

Different Types of Waste	Total P (%)	Total K (%)	Total N (%)
Kitchen Waste	1.30	0.93	2.32
Garden Waste	0.73	0.64	2.49
Hair	0.50	0.15	2.61
Eggshell	0.73	0.27	1.18
Newspaper	0.69	0.28	1.47
Mixed	0.83	0.46	2.12

The trend of percent total N in vermicomposted waste was Hair > Garden Waste > Kitchen Waste > Mixed > Newspaper > Eggshell, respectively (Figure 2). However, the trend of percent total P in vermicomposted waste was Kitchen Waste > Mixed > Garden Waste ≈ Eggshell > Newspaper >Hair, respectively. The trend of total K percent in vermicomposted waste was reported to be Kitchen Waste > Garden Waste >Mixed > Newspaper > Eggshell >Hair, respectively in the present study (Figure 1). Kaushik and Garg (2004) reported increase in TKN (2–3.2-fold) in textile mill sludge along with cowdung and agricultural residues. Increase in N content in the final vermicomposted product in the form of mucus, nitrogenous excretory substances, growth stimulating hormones and enzymes from earthworms have also been reported by Tripathi and Bhardwaj (2004). According to Viel et al. (1987) loss in organic C might be responsible for nitrogen enhancement.

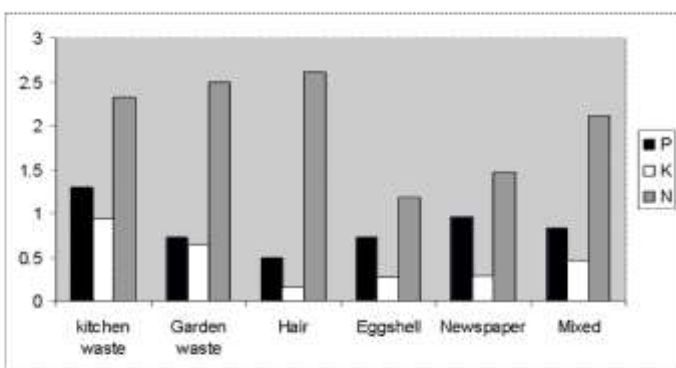

Fig. 2. Percentage of N, P and K in different types of vermicomposted waste

According to Atiyeh et al. (2000), earthworms also have an enormous impact on nitrogen transformations in manure, by enhancing N mineralization, thus allowing mineral nitrogen to be retained in the form of nitrate. Generally, the final N content of the composted material is dependent mostly on the initial N present in the waste and the extent of its decomposition (Crawford, 1983; Gaur and Singh, 1995). Mansell et al. (1981) reported that plant litter contains more available P after ingestion by earthworms, which may be due to the physical breakdown of the plant material by worms during vermicomposting process. An increase of 25% in P of paper waste sludge was also reported by Satchell and Martein (1984) due to worm activity. Satchell and Martein (1984) attributed this increase in P to direct action of worm gut enzymes and indirectly by stimulation of the microflora. According to Edwards and Lofty (1972), increase in TP during vermicomposting is probably due to mineralization and mobilization of phosphorus as a result of bacterial and faecal phosphatase activity of earthworms.

The presence of large number of microflora in the earthworm's gut might play an important role in increasing P and K content in the process of vermicomposting. Higher TK in the final product indicates that the microbial flora also influences the level of available potassium. Acid production by the microorganisms seems to be prime mechanism for solubilising the insoluble potassium (K). According to Kaviraj and Sharma (2003), acid production during organic matter decomposition by the microorganisms is the major mechanism for solubilisation on insoluble P and K. Also the presence of large number of microflora in the gut of the earthworms might play an important role in increasing P and K content in the process of vermicomposting. The same is reflected in the results of present study.

As we know proteins are made up of amino acids, arranged in a linear chains, with the general formula of $H_2NCHRCOOH$. Therefore, the hair waste which contains 'Keratin' as its structural component, showed the highest percentage of nitrogen content after vermicomposting. Tripathi and Bharadwaj (2004) reported 156%, 41% and 38% increase in nitrogen, phosphorus, and potassium as compared to control after 150 days of earthworm (*E. foetida*) inoculation. In addition, the researchers also reported the increase of 102%, 33% and 42% in nitrogen, phosphorus and potassium, respectively as compared to control after 150 days due to vermicomposting with *Lampito mauritii*. They also reported positive correlations between composting period of *E. foetida* and amounts of N and K. Finding of the present study was found to be similar as reported by Tripathi and Bharadwaj (2004). The increases in amounts of N, P and K in the vermicomposts of present study indicated that the enhanced mineralization of these elements was due to the microbial and enzyme activity in the gut of the earthworms (Parthasarathi and Ranganathan, 2000). Several studies have also reported that earthworm casts contain more carbon and N than non-ingested soil (Lee, 1985; Fragoso et al., 1993). This indicates that N is localized in worm castings.

The variations in degree of decomposition and mineralization may be because substrate quality also highly influences the decomposition and the composition of the decomposer community (Swift et al., 1979). Ponnuraj et al. (1998) studied vermicomposting of cow dung, biogas slurry and kitchen waste by *L. mauritii* and *P. excavatus*. In many western temperate countries, *E. foetida* is the preferred species for vermicomposting and it also preferred by

Indian researchers for vermicomposting together with *E. eugeniae* (Kale, 1997). Earthworm species E. *foetida* produced a faster change in the kitchen waste plus cowdung vermicompost with moderate mineralization and higher decomposition rates with moderate breeding (Tripathi and Bharadwaj, 2004).

This suggests that *E. foetida* is a better adapted species for arid environments.

The patterns of earthworm growth in terms of juvenile, young and mature earthworm's in different feed mixtures are illustrated in Table 2. Most of the waste showed positive results. The calculated number of young earthworms was reached the highest record in Kitchen Waste (115) followed by Newspaper waste (108), with the lowest was depicted in Hair Waste (61). Juvenile stage was found to be highest in Newspaper followed by Hair, Kitchen Waste, Garden Waste, Eggshell and lowest in Mixed Waste. Meanwhile the numbers of mature earthworm was found to be highest in Eggshell followed by Garden Waste, Mixed waste, Kitchen Waste, Newspaper and lowest in Hair waste.

Table 2. Initial and Final number of Earth worms (*Eisenia foetida*) in different types of waste

Different types of waste	**Initial no. of E.W**	**Final no. of E.W**		
		Juvenile	Young	Mature
Kitchen Waste	12	32	115	35
Garden Waste	12	30	92	69
Hair	12	42	61	21
Eggshell	12	25	64	92
Newspaper	12	62	108	33
Mixed	12	16	81	38

Gunadi and Edwards (2003) reported the death of *Eisenia foetida* after 2 weeks in the fresh cattle solids although all other growth parameters such as moisture content, pH, electrical conductivity, C: N ratio, $NH_4{}^{+}$ and $NO3^{-}$ contents were suitable for the growth of the earthworms. They attributed the deaths of earthworms to the anaerobic conditions which developed after 2 weeks in fresh cattle solids. Gunadi and Edwards (2003) studied the growth, fecundity and mortality of *E. foetida* in a range of different wastes (cattle manure solids, pig manure solids and super market waste) for more than one year. They concluded that worms could not survive in fresh cattle solids, pig solids, fruit wastes and vegetable wastes. The growth of *E. foetida* was found faster in pig wastes than in cattle waste. The multiple additions of substrates prolonged the fecundity of worms, but there was a tendency of decreasing of the weight by worms after 60 weeks of the experiment (Gunadi and Edwards, 2003).

According to Garg et al (2005), the waste materials strongly influenced the biology of *E. foetida.* Trend in the number of cocoons produced per earthworm per day in different animal waste was monitored apparently from the most contributor to the lowest one; sheep > cow ≈ horse ≈ goat > cameinl > donkey > buffalo. Similarly, in the present study juvenile stage had the trend of Newspaper > Hair > Kitchen Waste> Garden Waste> Eggshell > Mixed waste. However, mature earthworm followed the trend of Eggshell > Garden Waste > Mixed waste > Kitchen Waste > Newspaper > Hair waste. Figure 3 shows that the number of juvenile earthworm are more in Newspaper pot rather than the others, while the number of young earthworms are more in Kitchen waste pot ,meanwhile the population of full grown earthworm as in has shown in the graph is maximum in eggshell pot. This shows that the conditions (pH, temperature, moisture) for the earthworms are favorable throughout the period of experimentation.

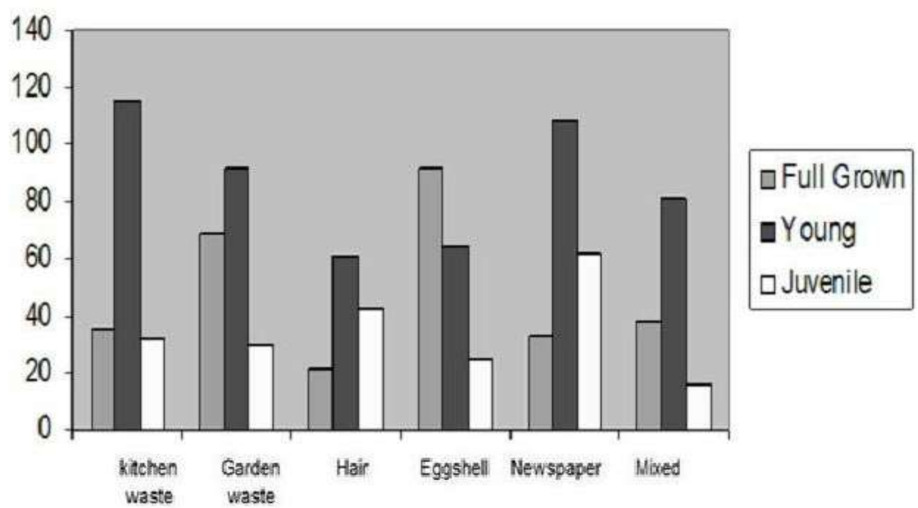

Fig.3. Growth response of earthworm (*Eisenia foetida*) in different types of vermicomposted waste

The nitrogen content of the substrate influences the growth patterns of the composting earthworms (Edwards, 1998; Suthar, 2007b). Suthar (2007a) summarised that the physiochemical and nutrient characteristics of feed stocks might be considered as an important factor related to earthworm growth. The nitrogen content and/or C:N ratio of the feed stock can influence the earthworm growth patterns in vermicomposting system (Suthar, 2007b). Earthworms biomass and cocoon production rate is directly related to the type of earthworm species as well as nature of worm feedstuff (Suthar and Ram, 2008).

Conclusion

Different types of organic waste showed different ability of degradation and producing valuable vermicast. *E. foetida* showed different ability to consume and convert the waste into vermicast. The different types of wastes show variation in their final compost characteristics. The hair waste shows the highest percentage of Nitrogen and the kitchen waste shows highest percentage of P and K. Study also shows that earthworm's growth is also dependent on nature of feed material. Analyzing vermicompost obtained from different organic waste clearly indicates that it is a sustainable way for the management of biodegradable organic wastes. It helps in reducing the load on the landfill. Additionally, vermicomposting has a good potential for the organic farming in future.

References

Abbasi, S.A. and E.V. Ramasamy (1999). Biotechnological Methods of Pollution Control, Orient Longman (Universities Press India Ltd.), Hyderabad, India pp. 168.

Arancom, N.Q., Edwards, C.A., Babenko, A., Cannon, J., Galvis, P. and Metzger, J.D. (2008). Influence of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse. Appl. Soil Ecol. 39:91-99.

Atiyeh, M.S., Lees, C.A., Edwards, N.Q. Arancon and J.D. Metzger (2002). The influence of humic acids derived from earthworm-processed organic wastes on plant growth, Bioresource Technology 84:7-14.

Atiyeh, R.M., J. Dominguez, S. Subler and C.A. Edwardsn (2000). Changes in biochemical properties of cow manure during processing by earthworms (*Eisenia andrei* Bouche) and the effects on seedling growth. Pedobiologia 44:709-724.

Chaoui, H.I., L.M. Zibilske and T. Ohno (2003). Effects of earthworm casts and compost on soil microbial activity and plant nutrient availability. Soil Biology and Biochemistry 35:295-302.

Crawford, J.H. (1983). Review of composting, Process Biochem. 18:14-15.

Doube, B.M., P.M.L. Williams and P.J. Willmott (1997). The influence of two species of earthworm (*Aporrectodea trapezoides* and *Aporrectodea rosea*) on the growth of wheat, barley, and faba beans in three soil types in the greenhouse, Soil Biology and Biochemistry 29:503-509.

Edwards, C.A. (1998). 'The use of earthworms in the breakdown and management of organic wastes', Earthworm Ecology, St. Lucie Press, Boca Raton, pp. 327-351.

Edwards, C.A. and Lofty, J.R. (1972). Biology of Earthworms. Chapman and Hall, London.

Fragoso, C., Barois, I., Gonzalez, C., Arteaga, C. and Patron, J.C. (1993). Relationship between earthworms and soil organic matter levels in natural and managed ecosystems in the Mexican tropics. In: Mulongoy, K., Merckx, R. (Eds.), Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture. A Wiley-Sayce Co. Publication, New York, pp. 231-239.

Garg, V.K., S. Chand, A. Chhilar and A. Yadav (2005). Growth and reproduction of Eisenia Foetida in various animal wastes during vermicomposting. Applied Ecology and Environmental Research 3(2):51-59.

Gaur, A.C. and G. Singh (1995). Recycling of rural and urban waste through conventional and vermicomposting. In: H.L.S. Tondon, Editor, Recycling of Crop, Animal, Human and Industrial Waste in Agriculture, Fertilizer Development and Consultation Organization, New Delhi pp. 31-49.

Gunadi, B. and Edwards, C.A. (2003). The effect of multiple applications of different organic wastes on the growth, fecundity and survival of *Eisenia foetida* (Savigny) (Lumbricidae). Pedobiologia 47(4):321-330.

Hand, P., Hayes, W.A., Satchell, J.E., Frankland, J.C., Edwards, C.A. and Neuhauser, E.F. (1998). The vermicomposting of cow slurry earthworm. Waste Environment Management pp. 49-63.

Kale, R.D. (1997). Earthworms and soil. Proc. Natl. Acad. Sci. 67:13-24.

Kale, R.D., Bano, K. and Krishnamoorthy, R.V. (1982). Potential of *Perionyx excavatus* for Utilization of Organic Wastes, Pedobiologia 23:419-425.

Kaushik, P. and V.K. Garg (2004). Dynamics of biological and chemical parameters during vermicomposting of solid textile mill sludge mixed with cowdung and agricultural residues, Bioresour. Technol. 94:203-209.

Kaviraj Sharma, S. (2003). Municipal solid waste management through vermicomposting employing exotic and local species of earthworms. Bioresource Technology 90:169-173.

Kumar, S. and Gaikwad, S.A. (2004). "Municipal Solid Waste Management in Indian Urban Centres: An Approach for Betterment", Urban Development Debates in the New Millennium, Edited by K.R. Gupta, Atlantic Publishers & Distributors, New Delhi, pp.100-111.

Lee, K.E. (1985). Earthworms: Their Ecology and Relationships with Soils and Land Use. Academic Press, London. pp. 411.

Mansell, G.P., J.K. Syers and P.E.H. Gregg (1981). Plant availability of phosphorous in dead herbage ingested by surface-casting earthworms, Soil Biol. Biochem**.** 13:163-167.

Nair, J., Sekiozoic, V. and Anda, M. (2006). Effect of pre-composting on vermicomposting of kitchen waste. Bioresource Technology 97:2091-2095.

Parthasarathi, K. and Ranganathan, L.S. (2000). Chemical characteristics of mono and polycultured soil worms cast by tropical earthworms. Environ. Ecol. 18:742-746.

Ponnuraj, M., Murugesan, A.G. and Sukumaran, N. (1998). Effect of different organic wastes on fecundity of two earthworms *Lampito mauritii* (Kingberg) and *Perionyx excavatus* (Perrier). J. Environ. Biol. 19:57-61.

Reinecke, A.J., S.A. Viljoen and R.J. Saayman (1992). The suitability of *Eudrilus* eugeniae, *Perionyx excavatus* and *Eisenia fetida* (Oligochaeta) for vermicomposting in Southern Africa in terms of their temperature requirements. Soil Biol. Biochem. 24:1295-1307.

Satchell, J.E. and Martein, K. (1984). Phosphate activity in earthworm feaces. Soil Biology Biochemistry 16:191-194.

Senapati, B.K. and Julka, J.M. (1993). Selection of suitable vermicomposting species under Indian conditions. In: Earthworm Resources and Vermiculture. Zoological Survey of India, Culcutta, pp. 113-115.

Sharma, S., Pradhan, K., Satya, S. and Vasudevan, P. (2005). Potentially of earthworms for waste management and in other uses a review. The Journal of American Science 1(1):4-16.

Singhal Shaleen and Suneel Pandey (2001). Solid waste management of India: Status and future directions. TERI information monitor of Environmental Science 6(1):1-4.

Slocum, K. (2002) Pathogen reduction in vermicomposting, Worm Digest 23:27-28.

Suthar Surindra and Setha Ram (2008). Does substrate quality affect earthworm growth and reproduction patterns in vermicomposting systems? A study using three popular composting earthworms. Int. J. Environment and Waste Management 2(6):584-600.

Suthar, S. (2006). Potential utilization of guar gum industrial waste in vermicompost production, Bioresource Technology 97:2474-2477

Suthar, S. (2007a). 'Vermicomposting potential of *Perionyx sansibaricus* (Perrier) in different waste materials', Bioresource Technology 98:1231-1237.

Suthar, S. (2007b). Nutrient changes and biodynamics of epigeic earthworm *Perionyx excavates* (Perrier) during recycling of some agricultural wastes, Bioresource Technology 98:1608-1614.

Swift, M.J., Heal, O.W. and Anderson, J.M. (1979). Decomposition in Terrestrial Ecosystems. Blackwell, Scientific Publication, Oxford, Great Britain.

Szczech, M.M. (1999). Suppressiveness of vermicompost against *Fusarium* wilt of tomato, Journal of Phytopathology Phytopathologische Zeitschrift pp. 155-161.

Tripathi, G. and Bhardwaj, P. (2004). Decomposition of kitchen waste amended with cow manure using an epigeic species (*Eisenia foetida*) and an anecic species (*Lampito mauritii*). Bioresource Technology 92:215-218.

Viel, M.D. Sayag and L. Andre (1987). Optimization of agricultural, industrial waste management through in-vessel composting. In: M. de Bertoldi, Editor, Compost: Production, Quality and Use, Elsevier Appl. Sci., Essex, pp. 230-237.

Vigueros, L.C. and Camperos, E.R. (2002). Vermicomposting of sewage sludge: a new technology for Mexico, Wat. Sci. Tech. 46(10):153-158.

(Received 22 October 2012; accepted 30 April 2013)