Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 1008-1013

AENSI Journals

Journal of Applied Science and Agriculture

Journal home page: www.aensiweb.com/jasa/index.html

Evaluating the Use of Cow, Sheep and Poultry Manure and Leaf for Vermicomposting with Eisenia fetida: A Comparative Study

[1]Mehdi Rashtbari, [2]Hossein Ali Alikhani

[1]*Researcher of Research and Development Center of Etka Organization, Tehran, Iran.*
[2]*Associate professor, Department of Soil Science Engineering, Campus of Agriculture and Natural Resources, The University of Tehran, Karaj,Iran P.O. Box 4111, Iran.*

ARTICLE INFO

Article history:
Received 19 October 2013
Received in revised form 16 January 2014
Accepted 22 January 2014
Available online 3 February 2014

Keywords:
Bedding, Cow Manure, Eisenia Fetida

ABSTRACT

Background: The disposal of increasing amounts of bio-degradable solid wastes from domestic agriculture and industrial sources has raised environmental and economic problems. **Objective:** Here we evaluated the efficiency of Eisenia fetida at converting four organic substrates (Cow, sheep and poultry manure and leaf) into vermicompost. **Results:** Results of our four-month-long study showed that vermicomposting resulted in significant increase of nitrogen (N), phosphorous, potassium, electrical conductivity (EC), calcium, iron, manganese, and zinc and earthworm numbers. Organic carbon (C), C/N ratio and pH decreased. These changes were most rapid during the initial 12 weeks of the experiment, slowing afterwards. E. fetida decomposed cow manure more efficiently than other substrates examined. Results also showed that combining of cow, sheep and poultry manure can result in a high-quality vermicompost compared to bedding consisting of only sheep and poultry manure and leaf, in terms of nutrient content. **Conclusion:** Poultry manure resulted in high EC final product which is not appropriate for using as a bio fertilizer. However, overall results showed that purely cow manure could result in best quality of produced vermicompost.

To Cite This Article: Mehdi Rashtbari, Hossein Ali Alikhani., Evaluating the Use of Cow, Sheep and Poultry Manure and Leaf for Vermicomposting with Eisenia fetida: A Comparative Study. ***J. Appl. Sci. & Agric.,*** *8(6): 1008-1013, 2013*

INTRODUCTION

The disposal of increasing amounts of bio-degradable solid wastes from domestic agriculture and industrial sources has raised environmental and economic problems. The growth of industries and ever-increasing human population has resulted in accumulation of waste materials (Joshi and Chauhan, 2006). Organic-waste recycling has important roles in sustainable agriculture, reducing environmental pollution, and nutrient enrichment of soils. Vermitechnology has been proposed globally as a tool to reduce organic wastes, including animal manure, industrial wastes, kitchen and agricultural wastes, as well as municipal organic wastes (Keihl, 2001). Vermicomposting is a non-thermophilic process that involves using earthworms to alter physical, chemical and biological reactions in organic wastes such that soil quality is improved. During the vermicomposting process organic materials are converted to stable compounds (humus) and the final product, vermicompost (VC) is rich in humus and available phosphorous.

Although vermicomposting holds tremendous promise as a means of reducing quantities of organic wastes, and improving the quality of agricultural soils, the nutritional value of VC depends on numerous factors including the bedding material being used, aeration, humidity, pH, temperature, and the earthworm species used during vermicomposting (Pramanik *et al*., 2007). Bedding material should ideally be absorbent, have good bulking potential, and have low protein and/or nitrogen content (i.e., a high Carbon: Nitrogen ratio). Selection of appropriate bedding materials is essential for successful vermicomposting process. Golchin *et al*. (2006) reported that vermicomposted animal manures tend to have a higher nutritional status, compared with VC derived from organic municipal waste. For example, vermicompost produced from cattle and pigs manure, as well as food wastes, increased the rate of germination, growth and flowering of a range of ornamental and vegetable seedlings compared with vermicompost from other sources (Atiye *et al*., 2000). Compared with farm-yard manure, VC has been reported to have between 40 to 60% greater levels of humic substances and is superior in quality to conventional composts (Campitelli and Ceppi, 2008).

Several epigeic earthworms have been identified as detritus feeders which can be cultured on large numbers in substrates consisting of organic waste. Some of these epigeics, for example, *Eisenia fetida*, *Perionyx excavatus*, and *Eudrilus eugeniae*, have been appeared as key candidates for large-scale organic-waste recycling

Corresponding Author: Mehdi Rashtbari. Researcher of Research and Development Center of Etka Organization, Tehran, P.O. Box 4111.Iran.
E-mail: Mehdi_Rashtbari@ut.ac.ir. Tel: +989371684968

(Grag and Kaushik, 2005; Loh *et al*., 2005). Recent studies have also revealed that some epigeics show excellent results in beddings amended with sheep manure (Grag *et al*., 2005).

Here we explore the efficiency of Eisenia fetida at vermicomposting by comparing the chemical properties of different organic wastes: cow, sheep and poultry manure and plant leaves. We hypothesized that the addition of different bedding materials to cow manure would improve VC quality.

MATERIALS AND METHODS

2.1. Collection of organic wastes:

The four organic solid wastes selected for this study were cow manure (M), sheep manure (S) and poultry manure (P) obtained from the dairy farm of Etka organization (obtained from cattle, sheep and poultry yard, mainly consisted of animal excreta, discarded animal feed stock, etc.), dry leaves of orchard trees (L) procured from orchard of Etka organization, Humand Absard, Iran.

2.2. Collection of earthworms:

The earthworms (*E. fetida*) were obtained from the research and education station of vermicompost, Tehran University, Iran.

2.3. Experimental setup:

The experiments were conducted in plastic bins (15-cm tall, 20-cm wide and 30-cm length), each with a capacity to contain 1 kg of waste. All bins had a drainage hole in the bottom. Vermicomposting was conducted under laboratory conditions, in darkness, at an average temperature of 25 ^{o}C (±5), a temperature appropriate for maintaining *E. fetida* (Greiner *et al*., 2011).

A total of 1000 g of dry composting mixture (vermibeds) was used in each bin, which consisted of different proportions of the four substrate types. Ten types of vermibeds were prepared (3 replicates each): (M) 1000g cow manure, (S) 1000g sheep manure, (P) 1000g poultry manure, (L) 1000g dry leaves, (MS) 500g cow manure +500g sheep manure, (MP) 500g cow manure +500g poultry manure, (ML) 500g cow manure +500g dry leaves, (MSP) 500g cow manure + 250g sheep manure +250 g poultry manure, (MSL) 500g cow manure + 250g sheep manure +250g dry leaves, (MPL) 500g cow manure + 250g poultry manure +250g dry leaves.

Fifty adult E. *fetida* were introduced into each plastic bin. Water was added to the bedding daily to maintain a moisture level of 50–60%. At 2-weeks interval during the course of the four-month-long experiment, bedding material was sampled for chemical content: organic carbon (C), pH, electrical conductivity (EC), total nitrogen (N), available phosphorus (P), and exchangeable potassium (K), calcium (Ca), iron (Fe), manganese (Mn), and magnesium (Mg). Earthworm abundance was determined every 30 days.

2.4. Chemical analysis:

The chemical parameters of initial bedding material and vermicompost produced during experiment were analyzed by using standard methods. Vermicompost samples were drawn at 2-week intervals. The initial refers to the time of initial mixing of vermibeds before preliminary decomposition. The determination of pH was done by a digital pH meter (EYELA PHM-2000), and electrical conductivity by a conductivity meter (JENWAY 4010). Total organic C and total Kjeldahl N were estimated by Walkley and Black rapid titration method (Walkley and Black, 1934) and Kjeldahl method, respectively (Singh and Pradhan, 1981). Total P and total potassium K were determined from the wet-digest [tri-acid (HNO_3–H_2SO_4–$HClO_4$) mixture used for digestion of vermicompost (Jackson, 1975).

2.6. Statistical analysis:

All the reported data are the means of three replicates. One-way analysis of variance was used to test for differences in chemical parameters among the 10 substrate treatments. The analyses were conducted using the GLM procedure in SAS. Duncan's multiple range tests was used for making pair-wise comparisons. Statistical significance was set at p=0.05.

RESULTS AND DISCUSSION

3.1. Organic carbon and C/N:

During vermicomposting process, the organic carbon content of all substrates rapidly declined until about week 14, after which time the decrease slowed (Fig. 1), suggesting humification and stabilization of organic matter in VC (Veeken *et al*., 2000). This finding is similar to those of others (e.g., Loh *et al*. (2005)) who reported a decline in organic carbon content and accelerating the waste stabilization process during vermicomposting. Maximum organic carbon decline was observed in M (146%) followed by MSL (105%), MP (100%) and the lowest decrease were recorded in S (46%) after 16 weeks of vermicomposting (Fig. 1). Results showed that addition of sheep manure and/or dry leaves to cow manure could result in more stable organic matter than their pure substrates.

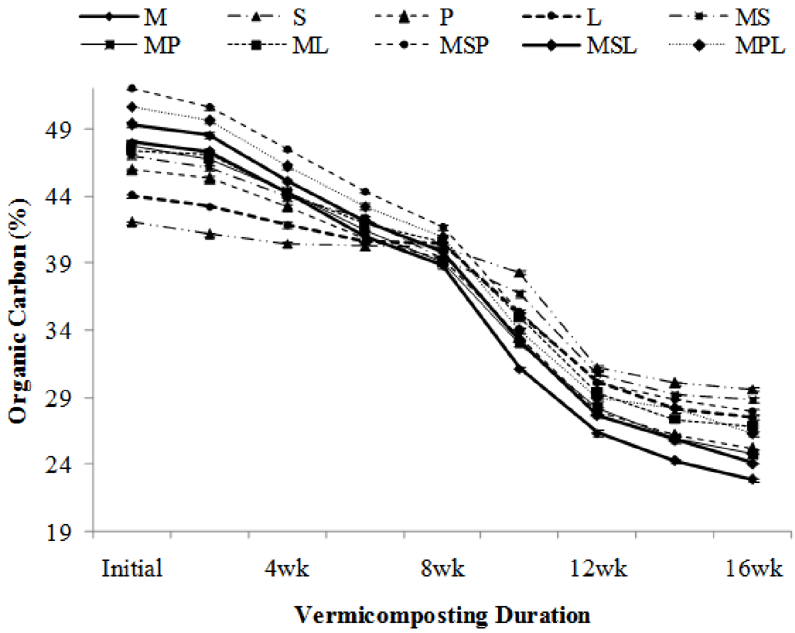

Fig. 1: Organic-carbon content of vermicompost generated from different bedding materials during the 5-month long experiment.

VC obtained from different vermibeds in this study had lower C/N ratio relative to initial substrates. The greatest decrease in C/N ratio was observed in M (6.8 fold), followed by MSL (4.4 fold), MP (3.7 fold) and phosphorous (3.2 fold), while the minimum increase was observed in S (1.6 fold) (Fig. 2). The C/N ratio reflects the spectra of changing carbon and nitrogen content of the substrate material during vermicomposting process (Suthar, 2007). The loss of carbon as carbon dioxide in the process of respiration, stabilization of organic matter (Veeken *et al*., 2000) and production of mucus and nitrogenous excreta lowers the C/N ratio. Previous studies have revealed that during the vermicomposting process the C/N ratio, as one of the most widely used indices for VC maturation, can decrease sharply (Loh *et al*., 2005). During vermicomposting process, rapid mineralization of organic matter as well as its decomposition lowers the C/N ratio (Grag *et al*., 2005)

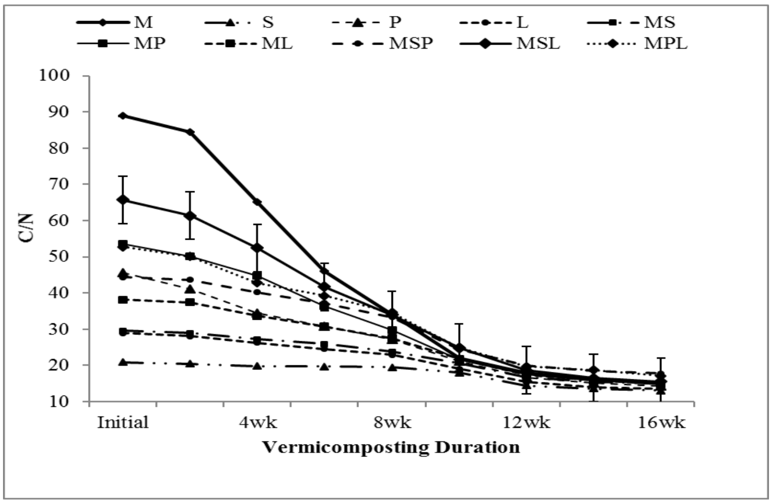

Fig. 2: C/N ratio in vermicompost generated from different bedding materials through time.

3.2. pH, EC, nitrogen and phosphorous:

During the vermicomposting period, pH significantly decreased in all vermibeds, rapidly during the first 14 weeks, then slowing. M had the greatest reduction (1.03 units) and the lowest reduction in pH was associated to MS (0.19 units, Table 1). Decrease in pH could be attributed to production of organic acids and CO_2, and increases in humic acid content as a result of microbial metabolism (Busato *et al*., 2012). These changes in pH may have, in turn, increased phosphorous availability. Electrical conductivity (EC) increased in all the substrates with increasing vermicomposting time. The EC increase in M was greater than for other treatments (Table 2). This may be attributed due to freely available ions and different mineral salts in available forms such as phosphate, ammonia and potassium that are produced during vermicomposting and also loss of organic matter (Garg *et al*., 2006).

Table 1: pH, EC, N and P content of vermicompost generated from the different substrate treatments at the start and end of the 4-month long experiment.

Treatment [a]	pH		EC (dSm^{-1})		N (%)		P (%)	
	Start	End	Start	End	Start	End	Start	End
M	$8.2^{a} \pm 0.00$	$7.17^{a} \pm 0.02$	$1.80^{a} \pm 0.00$	$3.20^{a} \pm 0.01$	$0.54^{i} \pm 0.00$	$1.51^{f} \pm 0.02$	$0.33^{d} \pm 0.00$	$2.43^{a} \pm 0.01$
S	$7.16^{f} \pm 0.02$	$6.75^{e} \pm 0.01$	$1.04^{e} \pm 0.01$	$1.10^{g} \pm 0.01$	$2.01^{a} \pm 0.01$	$2.29^{a} \pm 0.01$	$0.51^{a} \pm 0.01$	$0.69^{f} \pm 0.01$
P	$7.84^{b} \pm 0.02$	$7.03^{b} \pm 0.01$	$1.54^{b} \pm 0.00$	$2.50^{b} \pm 0.02$	$1.01^{f} \pm 0.01$	$1.76^{cd} \pm 0.01$	$0.39^{c} \pm 0.00$	$1.99^{b} \pm 0.01$
L	$7.49^{d} \pm 0.01$	$6.89^{c} \pm 0.02$	$1.30^{c} \pm 0.01$	$1.80^{d} \pm 0.02$	$1.52^{c} \pm 0.02$	$2.02^{b} \pm 0.03$	$0.45^{b} \pm 0.01$	$1.3^{e} \pm 0.01$
MS	$6.95^{g} \pm 0.03$	$6.76^{de} \pm 0.01$	$0.96^{f} \pm 0.01$	$1.00^{h} \pm 0.01$	$1.59^{b} \pm 0.01$	$1.93^{b} \pm 0.01$	$0.32^{d} \pm 0.01$	$0.6^{fg} \pm 0.01$
MP	$7.84^{b} \pm 0.01$	$7.03^{b} \pm 0.02$	$1.51^{b} \pm 0.02$	$2.47^{bc} \pm 0.02$	$0.89^{g} \pm 0.02$	$1.66^{de} \pm 0.02$	$0.33^{d} \pm 0.01$	$1.89^{bc} \pm 0.01$
ML	$7.35^{e} \pm 0.00$	$6.83^{cd} \pm 0.02$	$1.22^{d} \pm 0.00$	$1.73^{e} \pm 0.02$	$1.24^{d} \pm 0.01$	$1.80^{c} \pm 0.01$	$0.32^{d} \pm 0.00$	$1.21^{d} \pm 0.02$
MSP	$6.7^{h} \pm 0.00$	$6.47^{f} \pm 0.00$	$0.86^{g} \pm 0.01$	$0.89^{i} \pm 0.01$	$1.17^{e} \pm 0.01$	$1.61^{ef} \pm 0.03$	$0.12^{g} \pm 0.01$	$0.5^{g} \pm 0.00$
MSL	$7.7^{c} \pm 0.02$	$6.98^{b} \pm 0.01$	$1.48^{b} \pm 0.00$	$2.43^{c} \pm 0.01$	$0.75^{h} \pm 0.00$	$1.55^{f} \pm 0.03$	$0.25^{e} \pm 0.01$	$1.85^{c} \pm 0.02$
MPL	$7.2^{f} \pm 0.03$	$6.74^{e} \pm 0.02$	$1.18^{d} \pm 0.01$	$1.66^{f} \pm 0.01$	$0.96^{f} \pm 0.00$	$1.54^{f} \pm 0.02$	$0.19^{f} \pm 0.00$	$1.18^{d} \pm 0.01$

Mean value followed by different letters is statistically different (ANOVA; Duncan multiple-ranged test, $P < 0.05$).
[a] for bedding composition see text.

The nitrogen content of VC increased in all treatments through time, probably due to mineralization of organic matter (Garg *et al*., 2006). Viel *et al*. (1987) stated that loss in organic carbon might be caused by nitrogen enhancement during vermicomposting. M had the greatest and S had the least nitrogen content; M increased by 180% and S by about 14% compared to initial nitrogen content. Results revealed that nitrogen content in treatments increased rapidly until 14 weeks, and slowing afterward. In other treatments, considering the different percent of components, intermediate nitrogen content was observed compared to pure treatments. Suthar (2007) suggested that earthworms increased nitrogen levels of VC substrate by adding body fluids, excretory products, mucus and enzymes. Earthworms also affect nitrogen transformations in VC by nitrogen mineralization; however, final nitrogen content of VC is dependent on the initial nitrogen content in the substrate, and the extent of decomposition (Guar and singh, 1995).

Results showed that available phosphorous in VC increased through time. The greatest amounts of phosphorous were observed in M and lowest amount of available phosphorous were recorded in MSP. As summarized in Table 1, at the end of the experiment the maximum increase in available phosphorous (as a percentage of initial phosphorous content) was recorded in M (636%) and minimum increase in available phosphorous content was observed in S (35%). Results also revealed that available phosphorous content in most treatments increased rapidly until 16 weeks, and slowed thereafter. Results are consistent with Mansell *et al*. (1981) who reported that plant litter contained more available phosphorous after vermicomposting, which may be due to the physical breakdown of the plant material by earthworm mineralization of feed during vermicomposting process.

3.3. Calcium, Potassium and micronutrients:

At the end of the experiment nutrient content increased over initial values in all treatments (Table 3). Maximum increases in calcium, iron and potassium were observed in M (299%, 116% and 150%, respectively), and minimum increases for these nutrients were observed in S (43%, 42% and 14%, respectively). Increases in Mn and zinc content were greatest in S and MSL (147% and 127%, respectively). Compared to other treatments ML had intermediate values and had relatively elevated nutrient content compared to initial values (Table 2). Acid produced during vermicomposting is the major mechanism for solubilizing insoluble Potassium and other nutrients (Sharma *et al*., 2005). Increase in nutrients content could be attributed to mineralization of feed by earthworms and for calcium, secretion from earthworm calciferous glands could be the main cause of calcium increasing compared to initial amounts (Ishtiyaq and Khan, 2010). Barois and Lavelle (1986) stated in order to increase degradation of ingested organic matter secreted water and mucus and earthworms release the assailable

Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 1008-1013

metabolites. Through these and perhaps other mechanisms, earthworms enriched the bedding material with nutrients in our study.

Table 2: Ca, K, Fe, Zn and Mn content of vermicompost generated from the different substrate treatments at the start and end of the 4-month long experiment.

Treatment [a]	Ca (%)		K (%)		Fe ($g.Kg^{-1}$)		Zn ($g.Kg^{-1}$)		Mn ($g.Kg^{-1}$)	
	Start	End	Start	End	Start	End	Start	End	Start	End
M	2.2^{a} ± 0.00	8.77^{a} ± 0.16	0.48^{g} ± 0.00	1.20^{e} ± 0.01	3.7^{a} ± 0.01	8.0^{a} ± 0.005	0.6^{bc} ± 0.005	1.4^{a} ± 0.005	0.9^{a} ± 0.005	1.8^{d} ± 0.005
S	0.9^{g} ± 0.01	1.29^{f} ± 0.00	1.30^{a} ± 0.00	1.48^{a} ± 0.02	3.6^{ab} ± 0.00	5.1^{d} ± 0.005	0.9^{a} ± 0.00	1.2^{ab} ± 0.005	0.3^{a} ± 0.00	0.7^{f} ± 0.006
P	1.83^{c} ± 0.01	6.28^{c} ± 0.01	0.75^{e} ± 0.00	1.29^{cd} ± 0.01	3.7^{a} ± 0.01	7.0^{b} ± 0.00	0.7^{abc} ± 0.00	1.3^{ab} ± 0.005	0.7^{a} ± 0.00	1.4^{e} ± 0.005
L	1.36^{f} ± 0.01	3.78^{e} ± 0.14	1.03^{b} ± 0.00	1.39^{b} ± 0.01	3.6^{ab} ± 0.00	6.1^{c} ± 0.005	0.8^{a} ± 0.006	1.3^{ab} ± 0.005	0.5^{a} ± 0.005	1.1^{e} ± 0.005
MS	1.58^{e} ± 0.00	4.95^{d} ± 0.02	0.90^{c} ± 0.01	1.35^{bc} ± 0.00	3.5^{abc} ± 0.01	5.1^{d} ± 0.005	0.7^{ab} ± 0.00	1.1^{c} ± 0.006	0.7^{a} ± 0.21	1.8^{d} ± 0.00
MP	1.99^{b} ± 0.00	7.5^{b} ± 0.17	0.65^{f} ± 0.01	1.25^{de} ± 0.03	3.6^{ab} ± 0.00	7.0^{b} ± 0.017	0.6^{bc} ± 0.005	1.3^{ab} ± 0.005	0.8^{a} ± 0.005	1.8^{d} ± 0.005
ML	1.76^{d} ± 0.01	6.22^{c} ± 0.00	0.78^{d} ± 0.01	1.38^{b} ± 0.01	3.5^{abc} ± 0.00	6.1^{c} ± 0.005	0.6^{bc} ± 0.005	1.2^{ab} ± 0.005	0.7^{a} ± 0.005	1.8^{d} ± 0.006
MSP	2.17^{a} ± 0.00	8.6^{a} ± 0.19	0.50^{g} ± 0.01	1.22^{de} ± 0.02	3.3^{c} ± 0.01	5.1^{d} ± 0.012	0.5^{c} ± 0.00	1.1^{b} ± 0.005	1.0^{a} ± 0.00	2.9^{a} ± 0.005
MSL	2.19^{a} ± 0.00	8.71^{a} ± 0.02	0.49^{g} ± 0.01	1.21^{e} ± 0.00	3.6^{ab} ± 0.01	7.0^{b} ± 0.005	0.6^{bc} ± 0.006	1.3^{ab} ± 0.005	0.9^{a} ± 0.005	2.2^{c} ± 0.005
MPL	2.18^{a} ± 0.00	8.66^{a} ± 0.16	0.50^{g} ± 0.00	1.21^{e} ± 0.00	3.4^{bc} ± 0.01	6.1^{c} ± 0.017	0.5^{c} ± 0.00	1.2^{ab} ± 0.005	1.0^{a} ± 0.006	2.6^{b} ± 0.005

Mean value followed by different letters is statistically different (ANOVA; Duncan multiple-ranged test, $P < 0.05$).
[a] for bedding composition see text.

3.4. Earthworm population:

Results showed that as vermicomposting duration significantly increased total number of earthworms in all treatments. M has greatest and S has the least total number of earthworms. Earthworm abundance in cow manure increased by 3-fold during the experiment, indicating that is an appropriate bedding material for earthworm growth and reproduction (Fig 3). During the initial weeks of the experiment, earthworm numbers in S treatments decreased relative to other treatments, which could be due to degradation of proteins and heat production along with acidification in the medium (Munroe *et al*., 2007). Later, however, E. *fetida* numbers increased, perhaps due to conditions becoming more favorable in the bedding. The greatest increases in earthworm abundance occurred until 16 weeks, afterward which time the increase slowed, perhaps due to nutrient and organic-matter deficiency.

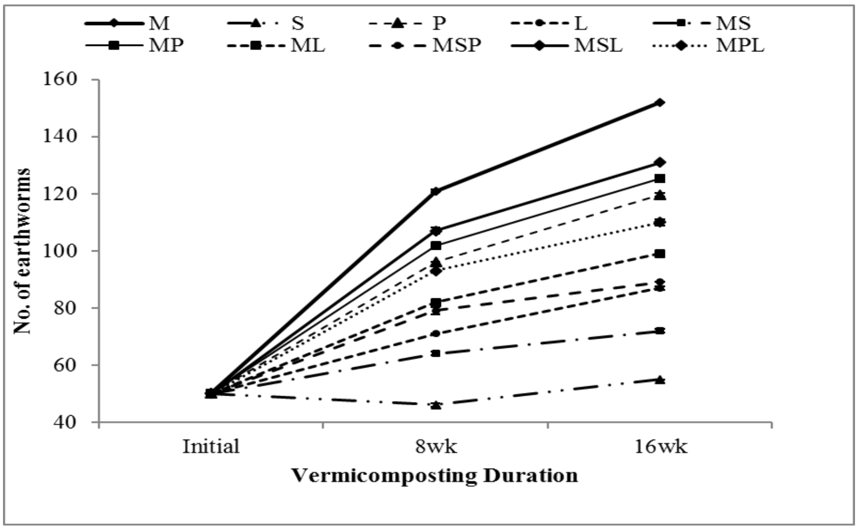

Fig. 3: Abundance of *E. fetida* from different substrates through time.

Conclusions:

Here we provided information on the amount of time required to yield stable vermicompost when using cow, sheep and poultry manure, and dry leaves as substrate. The results indicate that each of these substrates, when composted in the presence of the earthworm *Eisenia fetida*, can yield high-quality compost suitable for

Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 1008-1013

agricultural use. Additionally, given that the initial characteristics of the substrates were related to the final initial quality, combining these substrates in particular combinations will yield compost of a desired quality. However, overall results showed that purely cow manure could result in best quality of produced vermicompost and this treatment was selected as best bedding for enrichment treatments.

REFERENCES

Atiyeh, R.M., N.Q. Arancon, C.A. Edwards, J.D. Metzger, 2000. Influence of earthworm-processed pig manure on the growth and yield of greenhouse tomatoes. Bioresour. Technol., 75: 175-180.

Barois, I., P. Lavelle, 1986. Changes in respiration rate and some physiochemical properties of a tropical soil during transit through Pontoscolex corethrurus (*Glossoscolecidae, Oligochaeta*). Soil Biol. Biochem, 18: 539-591.

Busato, J.G., L.S. Lima, N.O. Aguiar, L.P. Canellas, F.L. Olivares, 2012. Changes in labile phosphorus forms during maturation of vermicompost enriched with phosphorus-solubilizing and diazotrophic bacteria. Bioresour. Technol. In press.

Campitelli, P., S. Ceppi, 2008. Effects of composting technologies on the chemical and physicochemical properties of humic acids. Geoderma., 144: 325-333.

Garg, P., A. Gupta, S. Satya, 2006. Vermicomposting of different types of waste using *Eisenia foetida*: A comparative study. Bioresour. Technol., 97: 391-395.

Gaur, A.C., G. Singh, 1995. Recycling of rural and urban wastes through conventional and vermicomposting. In: Tandon, H.L.S. (Ed.), Recycling of crop, animal, human and industrial wastes in agriculture. Fertilizer development and consultation organization, New Delhi, pp: 31-49.

Golchin, A., M. Nadi, V. Mozaffari, 2006. The effects of vermicomposts produced from various organic solid wastes on growth of pistachio seedlings. Acta Hort., 726: 301-306.

Grag, V.K., S. Chand, A. Chillar Yadav, 2005. Growth and reproduction of *Eisenia foetida* in various animal wastes during vermicomposting. Appl. Ecol. Environ. Res., 3: 51-59.

Grag, V.K., P. Kaushik, 2005. Vermistabilization of textile mill sludge spiked with poultry droppings by an epigeic earthworm *Eisenia foetida*. Bioresour. Technol., 96: 1063-1071.

Greiner, H.G., A.M.T. Stonehouse and S.D. Tiegs, 2011. Tolerance of commonly used composting earthworms to near-freezing temperatures to evaluate invasion potential. Am. Mid. Nat., 166: 349-357.

Ishtiyaq, A.N., A. Khan, 2010. Vermicomposting of invasive species Azolla pinnata with *Eisenia fetida*. The Bioscan., 5: 239-241.

Jackson, M.L., 1975. Soil Chemical Analysis. Pranctice Hall of India, New Delhi.

Joshi, P.C., A. Chauhan, 2006. Composting of some organic materials using *Eisenia fetida* and Conventional microbial methods: A comparative study. Uttar Pardesh J. Zool., 26: 123-125.

Kiehl, J.C., 2001. Production de composto orgaˆnico e vermicomposto. Informe Agropecua´rio, Belo Horizonte., 22: 40-52.

Loh, T.C., Y.C. Lee, J.B. Liang, D. Tan, 2005. Vermicomposting of cattle and goat manures by *Eisenia foetida* and their growth and reproduction preference. Bioresour. Technol., 96: 111-114.

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

Munroe, G., 2007. Manual of on-farm vermicomposting and vermiculture. [Online]Available:http://www.organicagcentre.ca/DOCs/Vermiculture_FarmersManual_gm.pdf.

Pramanik, P., G.K. Ghosh, P.K. Ghosal, P. Banik, 2007. Changes in organic – C, N, P and K and enzyme activities in vermicompost of biodegradable organic wastes under liming and microbial inoculants. Bioresour. Technol., 98: 2485-2494.

Sharma, S., K. Pradhan, S. Satan, P. Vasudevan, 2005. Potentiality of earthworms for waste management and in their uses – a review. J. Am. Sci., pp: 1.

Singh, R., K. Pradhan, 1981. Determination of nitrogen and protein by Khjeldahl method. In: Forage Evaluation Science. Pvt. Publishers Ltd., New Delhi, p: 23.

Suthar, S., 2007. Vermicomposting potential of *Perionyx sansibaricus* (Perrier) in different waste materials. Bioresour. Technol., 98: 1231-1237.

Veeken, A., K. Nierop, V.D. Wilde, 2000. Hamelers, B., Characterisation of NaOH-extracted humic acids during composting of a biowaste. Bioresour. Technol., 72: 33-41.

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

Walkley, A., I.A. Black, 1934. Chromic acid titration for determination of soil organic matter. Soil Sci., 63: 251.