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Trend of physico-chemical properties change in recycling spent mushroom compost through vermicomposting by epigeic earthworms *Eisenia foetida* and *E.andrei*

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This study performed to evaluate the potential of epigeic earthworms *Eisenia foetida* and *Eisenia andrei* to transform spent mushroom compost (SMC) into a more useful product in 12 weeks i.e., vermicompost. Vermicomposting caused significant reduction in pH (8%), electrical conductivity (41%), total organic carbon (35%), C:N ratio (56%), K (68%), Na (10%) and increased in available macro and micronutrients such as P by 3-fold,N 1.37-fold, B 1.29-fold, S 1.59-fold,Fe 2.1-fold, Cu 1.89-fold, Zn 1.68-fold, Mn 1.2-fold, Ca 1.92-fold and Mg 1.72-fold compared to those of the initial substrate. It is demonstrated that vermicomposting could be considered as an alternate technology for recycling and environmentally safe management of (SMC) which generate in abundance as residues using epigeic earthworms *E. foetida* and *E. andrei*.

Key words: Recycling spent mushroom compost, Physicochemical changes, Vermicomposting.

Introduction

Population increase that results in an ever increasing demand for food especially agricultural products. Mushrooms are among the most available

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healthy food ingredients which are low in calories, high in vegetable proteins, chitin, iron, zinc, fiber, essential amino acids, vitamins and minerals. Mushroom production is exponentially increasing over the world and during the year 2006 only in China the mushroom production has been 14,000,000. metric tones, (Chang, 2006b). Mushroom production requires a ready made substrate on which to grow named compost. Mushroom compost is prepared from chopped straw, poultry manure, gypsum and water.

At the end of cropping significant quantities of spent mushroom compost (SMC) should be disposed of away from the farm, and can be used in organic farming. SMC contains a lot of salts and unstable organic materials, so it should be aged for about two years before applying. SMC is a bulky waste by-product of mushroom industry and produced abundantly. About five kilograms of fresh compost are needed to produce one kilogram of mushrooms (Sample *et al*., 2001), so about 70,000,000 metric tons of SMC has been generated during the year 2007 in the world. Therefore, the huge amount of SMC is added to the burden of the municipal refuses, especially around the mushroom cultivation complexes. In the past decades, potential of earthworms for breaking down organic waste has been explored in depth and many large scale vermicomposting have been developed all over the world with varying success (Garg *et al.,* 2005).

Vermicomposting is the process by which worms are used to convert organic materials into a humus-like material known as vermicompost, and the goal is to process the material as quickly and efficiently as possible. The vermicompost has more available nutrients per kg weight than the organic substrate from which it is produced. The biological activity of earthworms provides nutrient rich vermicompost for plant growth thus facilitating the transfer of nutrients to plants. The earthworm species most commonly utilized for the breakdown of organic wastes are *Eisenia foetida* and its related species *Eisenia andrei*. Their biological requirements have been studied extensively (Hartenstein *et al*., 1989; Dominguez and Edwards 1997).

These two species are prolifilic, wide temperature tolerance, and can grow and produce well in many kinds of organic wastes with a wide range of moisture content. Most of the research on utilization of earthworms in waste management has focused on the final product, i.e. the vermicompost. There are only few literature references that have looked into the process, or examined the biochemical transformations that are brought about by the action of earthworms as they fragment the organic matter, resulting in the formation of a vermicompost with physic-chemical and biological properties which seem to be superior for plant growth to those of the original materials. The main objectives of this experiment were; a) to reduce the high volume of SMC by recycling through vermicomposting, b) to determine the physic-chemical changes effected in the SMC by *E. foetida* and *E. andrei* during a period of 12 weeks, and c) nutritional quality of produced vermicompost in comparison with the initial substrate.

Materials and methods

Collection of earthworms

The earthworms (*Eisenia foetida* and *Eisenia andrei*) were collected from the earthworm culture reservoir In the Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran.

Collection of spent mushroom compost

The SMC taken from the Pedam Mushroom Cultivation Complex in Mohammad Shahr, near Karaj, Iran.

Experimental setup

Due to the high salt content of SMC (EC around 14 dS/m) and to adapt worms with the substrate's environment, we performed the adaptation process first. Two separate beds 2 x 1 x 0.5 m (L, W, D) were prepared. Cow dung and SMC were soaked and placed in the bed separately. Matured worms *E. foetida* and *E. andrei* and cocoons picked up from the worm culture reservoir and introduced only to the cow dung part of the beds. About two weeks later worms came to the SMC part and distributed all over the beds.

Mixing the substrates and keeping the moisture content around 70–80%. After about four months all of the worms as well as the newly born ones were matured and adapted to the proposed environment. The trial conducted in 20 plastic containers of size 31 x 31 x 27 cm (L, W, H). Each container provided 961 cm^2 of exposed top surface with some holes at the bottom. Considering optimum feeding rate of 0.75 kg feed/kg worm/day, and to satisfy the condition of stocking density of 1.6 kg worms/m^2 (Ndegwa *et al.*, 2000), for a duration of 90 days, 2,700 g (on dry weight basis) of pre soaked SMC weighed for each bin. 40 matured worms which had been picked up from the adaptation beds, inoculated to each one of the bins.

The moisture content of the feed kept around 60-70% throughout the study period by sprinkling adequate quantities of distilled water. All containers were kept in a room and covered with a piece of gunny bag to keep them moistened. During the study period temperature fluctuated from 18 – 34 °C. pH was measured every week by a portable pH-meter. Containers divided in five sets of four-bins for the study period divisions of Week 0, 3, 6, 9 and 12. Week 0 refers to the initial substrate as a control (without worms).

By the end of each time interval i.e. week 0, week 3, week 6, week 9, and week 12, the worms were removed by hand sorting and the vermicompost well stirred and then samples from each set of bins were taken and refrigerated before delivering to the lab for measuring the proposed parameters. Each experiment replicated thrice and results were averaged.

Chemical analysis

Homogenized samples of the initial substrate and the final products were taken at 0, 3, 6, 9 and 12 weeks intervals from each container to monitor the changes in the proposed physicochemical properties. All the samples were analyzed in triplicate and results were averaged. The samples were used on dry weight basis for chemical analysis. The pH was determined using a double-distilled water suspension of each vermicompost in the ratio of 1:10 (w/v).
Total organic carbon (TOC) was measured using the method of Nelson and Sommers (1982). Total N by Kajeldahl method (Theroux *et al*., 2001), total P, S, B, and NO3 determined by means of spectrophotometer. Total Ca, Mg, Fe, Cu, Zn, Mn, K, and Na were determined by means of atomic absorption spectrophotometer.

Statistical analysis

The data in this study were analyzed using the SPSS package, and all the values are presented as the mean ±SE. One way ANOVA was used to analyze the significant difference between the initial and final product for the proposed parameters. The probability levels used for statistical significance were $p \leq 0.05$ for the tests.

Results and discussion

Initial physico-chemical characteristics of the used SMC (week 0), and changes in the physic-chemical properties of vermicomposts obtained from the SMC (week 3, 6, 9, and 12) are resented in Table 2A – C. The comparisons between the initial substrate and final product (vermicompost) based on Duncan Multiple Range Test are given in Table 1 A, B and C. Fig1a-1c show the increases and decreases of the physico-chemical properties graphically. The vermicomposting process appreciably modified the physical and physico-chemical properties of the spent mushroom compost. During the study period pH reduced from 7.23 ± 0.09 to 6.69 ± 0.01.

Other researchers have reported similar results (Gunadi and Edwards, 2003; Garg *et al*., 2006). This shift of pH from the initial near neutral towards acidic conditions could be attributed to the bioconversion of the organic material into other various intermediate species of the organic acids (Ndegwa e*t al*., 1999). It has been also reported that the lower pH in the final product s might have been due to the production of CO2 and organic acids by microbial metabolism during decomposition of the substrate (Chan and Griffiths, 1988; Elvira *et al.,* 1988).

The electrical conductivity (EC) of the vermicompost reduced about 40% by the end of 12th week in comparison to the initial value of week 0. The obtained results are in agreement with Warma and AngLopez (2002), which have reported an eventual decrease in EC, and supporting the earlier findings of Elvira *et al*. (1998). Total organic carbon (TOC) decreased by 36% ($p \leq 0.05$) by the end of the study period. Organic carbon decreased more significantly in week 3 as compared to the initial value (week 0). Our findings were supported by other researches' findings (Kaviraj and Sharma, 2003; Elvira *et al*., 1998) who have reported 20-45% loss of carbon as CO2 during vermicomposting of municipal or industrial wastes. C:N ratio decreased significantly ($P \leq 0.05$) with time from 15.43 in week 0 to 6.67 in week 12 due to substrate decomposition. C: N ratio reduction by the end of the study period was about 56%.

Our results are in agreement with the findings of Garg *et al*. (2006). According to Senesi (1989), a decline in C:N ratio to less than 20 indicates an advanced degree of organic matter stabilization and reflects a satisfactory degree of maturity of organic wastes. Total Kajeldahl nitrogen (TKN) significantly ($p \leq 0.05$) increased by 37% during the study period, probably because of the mineralization of the organic matter. According to Viel *et al*. (1987) losses in organic carbon might be responsible for nitrogen addition. Elvira *et al*. (1998) have reported high increase in total nitrogen concentrations due to the mineralization of organic matter.

Similarly, Warma and AngLopez (2002) observed 42-85% increase in total nitrogen in vermicomposted wastes after 45 and 68 days. Total phosphorus content (TP) increased significantly ($p \leq 0.05$) almost by 3-folds comparing to the initial value (Table 2a, week 0). Our findings are in agreement with the results obtained by Satchell and Martin (1984) who have found an increase of 25% in total P of paper waste sludge after worm activity. They attributed this increase of TP to direct action of the worm gut enzymes

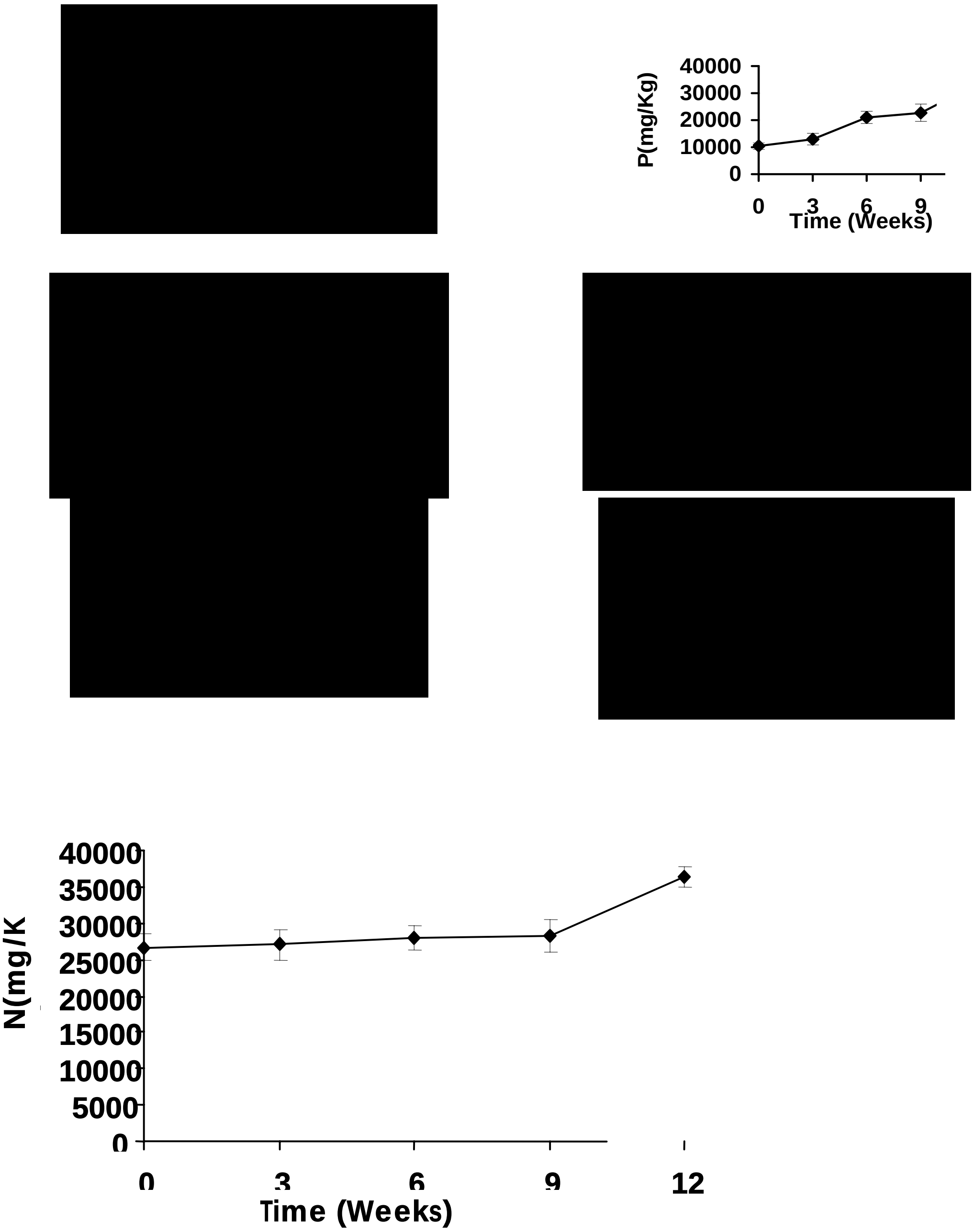

Fig.1-a) Trend of the physico- chemical changes.

Fig.1-b) Trend of the physico- chemical changes.

Fig.1-c) Trend of the physico- chemical changes.

and indirectly by stimulation of the micro flora. Increase in TP during vermicomposting is probably due to mineralization of phosphorus as a result of bacterial and fecal phosphate activity of earthworms (Edwards and Lofty, 1972).

Total Ca and Mg significantly ($P \leq 0.05$) increased during vermicomposting period. These results are supported by the findings of Orozco *et al.* (1996) and Gratelly *et al.* (1996) respectively. During vermicomposting period K and Na concentrations were observed to be lower than the initial substrate values. This probably reflects leaching of these soluble elements by the excess water that drained through the mass. Similar results were observed by other authors (Elvira *et al.* 1998).

Significant increase for some of the elemental substances presented in Table 2A, B and C occurred during vermicomposting period. Similar results have been reported by Gratelly *et al*. (1996) for the vermicomposting of dairy sludge. Such increases might have been probably attributed to the metal concentrations in the earthworms' tissues which are existed in vermicomposts.

Conclusion

Vermicomposting potentially converts SMC into value-added material which can be used in organic agriculture and avoiding environmental pollution**.** The information obtained could provide a sound basis for the management of SMC through the large commercial vermicomposting system. Vermicompost obtained in this study was rich in the micro and macronutrients which are essential elements for plant growth, had good physical properties, low conductivity, low C: N ratio, optimal stability and maturity. These characteristics make vermicompost useful and effective in sustainable agriculture**.**

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Table 1. A) ANOVA table of the physico-chemical characteristics of the initial substrate and final Product (vermicompost)

S.O.V	d.f	MS							
		N	P	K	B	S	Na	Fe	Cu
Treatment	4	**65315500.00****	**3.16E+08****	**1.4E+08****	**83.45****	**4.5E+07****	**70220.00***	**3.E+06****	**457.09****
Error	15	**1264500.00**	**42000.00**	**9666.67**	**7.67**	**21196.67**	**15260.00**	**1604.70**	**1.12**

** significant at 1% level

Table 1. B) ANOVA table of the physico-chemical characteristics of the initial substrate and final Product (vermicompost)

S.O.V	d.f	MS								
		Zn	Mn	Ca	Mg	NO_3	C/N	EC	pH	OC
Treatment	4	**16487.20****	**17045.36****	**1.5E+09 ****	**1.5E+07****	**8.E+06****	**39.28****	**23.53****	**0.18 ****	**97.71****
Error	15	**116.87**	**121.21**	**14666.67**	**11333.33**	**4488.12**	**0.59**	**0.44**	**0.00**	**0.52**

** significant at 1% level

Table 2. A) Table of comparison between the initial substrate and final product (vermicompost) Based on DMRT method (mean±SD, r= 4)

Treatment	N	P	K	B	S
SMC WK0	26600.00±816.50 b	10400.00±163.30 e	21700.00±81.65a	41.75±2.87 c	15000.00±81.65 e
SMC WK3	27000.00±816.50 b	12950.00±331.66 d	9500.00±163.30 b	45.00±4.08 bc	18197.50±159.24 d
SMC WK6	28000.00±1632.99 b	21000.00±81.65 c	8900.00±81.65 c	47.75±2.06 abc	19700.00±163.30 c
SMC WK9	28300.00±816.50 b	22700.00±244.95 b	8800.00±81.65 c	49.75±2.06 ab	21612.50±143.61 b
SMC WK12	36375.00±1286.79 a	32875.00±81.65 a	6950.00±40.82 d	53.75±2.22 a	23800.00±163.3 a

Mean value followed by different letters is statistically different (ANOVA, Duncan's test, p≤0.05)

Table 2. B) Table of comparison between the initial substrate and final product (vermicompost) Based on DMRT method (mean±SD, r= 4)

Treatment	Na	Fe	Cu	Zn	Mn
SMC WK0	3500.00±204.12 a	1935.50±4.12 e	31.70±0.57e	235.00±4.08 d	816.00±11.66 d
SMC WK3	3450.00±40.82 a	3523.50±20.49 d	38.20±0.65 d	320.00±16.33 c	830.00±16.33 cd
SMC WK6	3390.00±8.16 ab	3670.50±47.19 c	44.73±0.61 c	360.00±4.08 b	852.00±8.16 c
SMC WK9	3300.00±163.30 ab	3796.50±4.43 b	48.60±0.49 b	380.00±16.33 ab	875.00±8.16 b
SMC WK12	3165.00±78.95 b	4089.50±73.08 a	59.89±2.06 a	395.50±4.2 a	980.50±8.37 a

Mean value followed by different letters is statistically different (ANOVA, Duncan's test, p≤0.05)

Table 2. C) Table of comparison between the initial substrate and final product (vermicompost) Based on DMRT method (mean±SD, r= 4)

Treatment	Ca	Mg	NO_3	C/N	EC	pH	OC
SMC WK0	56100.00±81.65 e	7200.00±163.3 e	1601.25±1.26 e	15.43±0.91 a	14.65±0.9 a	7.23±0.09 a	37.68±0.78 a
SMC WK3	78000.00±163.3 d	8100.00±40.82 d	2257.00±81.65 d	10.74±0.81 b	10.29±0.82 b	6.94±0.03 b	29.00±0.82 b
SMC WK6	89000.00±122.47 c	8800.00±122.47 c	3312.00±83.29 c	10.19±0.82 b	9.37±0.83 bc	6.82±0.01 c	28.53±0.82 bc
SMC WK9	91200.00±81.65 b	9500.00±81.65 b	4465.50±82.47 b	9.58±0.86 b	9.35±0.08 bc	6.79±0.00 c	27.20±0.82 c
SMC WK12	107750.00±135.40 a	12350.00±81.65 a	4866.00±45.10 a	6.76±0.21 c	8.58±0.13 c	6.69±0.01 d	24.56±0.08 d

Mean value followed by different letters is statistically different (ANOVA, Duncan's test, p≤0.05)