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Vermicomposting of grass and newspaper waste mixed with cow dung using *Eisenia fetida*: physicochemical changes

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Abstract

This study was conducted to investigate the effect of different types of organic wastes (grass and newspaper wastes, cow dung and their combination) on physicochemical properties during vermicomposting using *Eisenia fetida*. Three set-ups were conducted in which three experiments were for composting (controls) indicated as C1 for newspaper waste, C2 for grass waste and C3 for cattle dung and the corresponding replicates for vermicomposting processes for grass and cattle dung were T1 to T7 and mixed of newspaper, grass and cattle dung were T8-T13. A significant difference was detected among weight and number of *Eisenia fetida* in treatments, which the highest weight and population growth of worms occurred in T7 (60% of newspaper, 30% of cattle dung and 10% of grass waste). Compared to control treatment (without earthworms), vermicomposting treatment resulted in a decrease of organic carbon and C/N ratio after 30 days. Vermicomposting caused significant reduction in organic carbon (3.9-32.8%) and C/N ratio (7.9–33.6%). The heavy metals degradation was evaluated after 90 days and at the end of the experiment the concentration of As, and Cd significantly decreased. This study clearly indicates that vermicomposting is a suitable technology for bioconversion of newspaper waste, grass clipping and cow dung to valuable material.

Keywords: Organic waste, cow dung, vermicomposting, *Eisenia fetida*, heavy metals.

1. Introduction

During the past decades, rapid population growth and high industrialization rate has increased the difficulty of effective disposal and management of organic solid wastes (Wani and Rao, 2013). Conventional solid waste management methods such as landfilling, open dumping, or open burning due to production of toxic materials and gases from the wastes are indefensible, that might have undesirable effects on the environment, health, and biodiversity (Lee *et al.*, 2012; Pérez-Godínez *et al.*, 2017). The transformation of waste into the value-added products is an important part of waste management. Scientific application of organic solid wastes can supply nutrients for plant growth and improve physical properties of soil (Scotti *et al.*, 2015). In recent years, vermicomposting as an eco-friendly and economically viable technology for decomposition of organic waste resources into odor-free humus-like materials has been verified in literatures (Suthar, 2009; Garg *et al.*, 2012; Cestonaro *et al.*, 2017; Sudkolai and Nourbakhsh, 2017). Vermicomposting process is a biological waste management method in which microorganisms and earthworms decompose and stabilize organic wastes under controlled environmental conditions to a level that can be handled, stored, and applied to agricultural fields without adverse effects on the environment (Aira *et al.*, 2002b). Among all earthworms, *Eisenia fetida* is most widely used for vermicomposting due to wide tolerance ranges for temperature, moisture content, pH, and heavy metals (Ravindran *et al.*, 2008). *Eisenia fetida* is more efficient in weather conditions of Iran (Jicong *et al.*, 2005). Different wastes which have been already used for vermicomposting are able to be converted to nutrient rich products as individual or mixed such as mushroom residue (Song *et al.*, 2014), tomato residue (Fernández-Gómez *et al.*, 2013), paper waste (Kaur *et al.*, 2010; Arumugam *et al.*, 2015), leaf litter (Suthar and Gairola, 2014), guar gum industrial waste (Suthar, 2006), tanning sludge (Malafaia *et al.*, 2015), beverage industry sludge (Singh *et al.*, 2010), jute mill (Das *et al.*, 2016), paddy straw (Das *et al.*, 2016), sugar industry wastes (Sen and Chandra, 2007), food and vegetable processing wastes (Sharma and Garg, 2017) and animal dung (Loh *et al.*, 2005). Paper waste that has increased globally, could be a proper substrate for earthworms owing to its non-toxic and biodegradable characteristics (Gupta and Garg, 2009). Waste paper also could be used as a bulking material in the vermicomposting of animal dung (Ravindran and Mnkeni, 2016). According to the previous studies, in developed countries approximately 80% of waste can be recycled and reused, and about 20% transfer to the sanitary landfill or incinerator facilities. While in Iran only about 8% of waste is recycled, and the rest is mainly landfilled in an unsanitary manner, which is not only uneconomical, but also inflicts massive damage on the environment (Jamshidi *et al.*, 2015). It has been reported that a large part of the waste in Iran is organic materials, so appropriate alternative for the safe, hygienic and cost-effective management of this type of waste is vermicomposting (Sharma, 2003). The main aim of this study was evaluating of the vermicomposting quality from three waste mixture including newspaper waste mixed with cow dung and grass at different percentage. Furthermore, the earthworm growth, productivity and changes in physicochemical composition of feed mixtures were investigated.

2. Material and methods

2.1. Organic wastes and preparation

The vermicomposting unit was located at the waste research center, faculty of health, Kermanshah university of medical sciences. The newspaper waste and grass were obtained from library and football land of faculty. Cow dung was prepared from a village nearby the university located in Dolatabad, Kermanshah city. The collected newspaper and grass wastes were crushed into fine particles (0.5 mm) so that it can become easier for worms to consume. For providing an appropriate inhabitation condition before introducing worms into treatments, all feed mixtures were pre-decomposed for 30 days to have thermal stabilization and remove unwanted gases.

2.2. Collection of earthworms

For vermicomposting treatments, the earthworms of the species *Eisenia f*etida has been collected from the vermicomposting unit of the environmental health engineering department, faculty of health, Kermanshah university of medical sciences, Kermanshah, Iran.

2.3. Experimental setup

Vermicomposting was conducted in sixteen perforated polyethylene containers of capacity 7.2 L (20 cm height and 18 cm width and 20 cm length) as compost treatments. Each treatment, was filled with the initial mixture of substrates (500 gdw). All bedding materials as control or treatment at different weight ratio according to Table 1 have been designed. To achieve accurate results and minimize of errors, all treatments were conducted in triplicate. After 30 days, 25 non-clitellated juvenile *Eisenia foetida* (weighing between 6.64-6.67 g) approximately at the same size and weight were inoculated into the each vermicomposting treatment. In order to provide an optimal environment conditions for worms, the moisture of all treatment keep at 60-70% by sprinkling water during the experiments at the optimum room temperature range of 23±2 °C. Samples collection have been carried out at the time interval of 40, 60 and 90 days. After vermicomposting for 90 days, the composting was terminated because the residuals of bedding materials in the treatments had been eaten up by *Eisenia foetida*. The collected dried and homogenized samples were grind into fine particles for further analysis.

Table 1. The composition of vermicomposting treatments

Sample no.	Newspaper waste	Grass waste	Cattle dung
C_1	100%	-	-
C_2	-	100%	-
C_3	-	-	100%
T1	-	20%	80%
T2	-	30%	70%
T3	-	40%	60%
T4	-	50%	50%
T5	-	60%	40%
T6	-	70%	30%
T7	-	80%	20%
T8	10	40	50
T9	20	10	70
T10	10	60	30
T11	10	20	70
T12	60	10	30
T13	40	10	50

2.4. Analytical methods

The physicochemical characteristics of initial and bioconverted substrates as vermicompost were analyzed in triplicate at the laboratories of health faculty. Samples were analyzed for total kjeldhal nitrogen (TKN), total phosphorous (P), total organic carbon (TOC), total sodium (Na), pH, electrical conductivity (EC). The organic matter and ash were measured by thermal method (weight reduction) using electric furnace, (Nabertherm, Germany). TKN was measured by Micro-Kjeldhal method of Bremner and Mulvaney (1982) after digesting the sample in digestion mixture (H_2SO_4+K_2SO_4:$CuSO_4$:SeO_2 in 10:4:1) (Bremner and Mulvaney, 1982). Total available phosphate was analyzed by using the spectrophotometric method with molybdenum in sulfuric acid. Total organic carbon was measured using the method provided by Nelson and Sommers (1996). Total sodium was determined by flame photometer (Jenway, England), after digesting the samples in diacid mixture. The pH (WTW, Germany) and electrical conductivity (EDT, England) were determined using a double distilled water suspension of each sample in the ratio of 1:10 (w/v). Total heavy metals (Cd, As and Pb) were determined using an IL Model 357 atomic absorption spectrophotometer, after digestion of the samples with HNO_3:$HClO_4$ (2:1).

2.5. Statistical analysis

SPSS software version 16 and Excel version 2013 have been applied to data analysis. In order to minimize analysis errors and validity of results, all reported data are the means of three replicates. One-way ANOVA using Kruskal-Wallis test was done to determine any difference between the numbers and weights of earthworms at 0.05% level of significance.

3. Results and discussion

3.1. Growth and reproduction of Eisenia foetida

The survival, growth and reproduction of earthworms are the best indicators to assess the vermicomposting process (Vig, Singh *et al.*, 2011). In the current study the number and weight of earthworms during the vermicomposting of different substrates are represented in Figures 1 and 2. As can be seen from the figures the earthworm biomass in all vermicomposting experiments increased during 60 days. The maximum number of worms (335) with weight of 100.5 g was in T7 feed mixture on 60th day of experiment. The relative change in earthworm weight and number was significantly affected by substrate mixture ratio (P < 0.05), as feed mixture with 60% of newspaper, 30% of cow dung and 10% of grass waste seems to be an appropriate growth medium for worms. Studies revealed that the kind, palatability and quality of food (in term of their chemistry) directly affected the survival, growth rate and reproduction potential of earthworms (Gajalakshmi, Ramasamy *et al.*, 2005; Lee, Hosaka *et al.*, 2012). In all feed mixtures except T7 the earthworm numbers and weight decreased at the 90th day of experiment. The decrease in the number can be attributed to the exhaustion and un-palatability of feed.

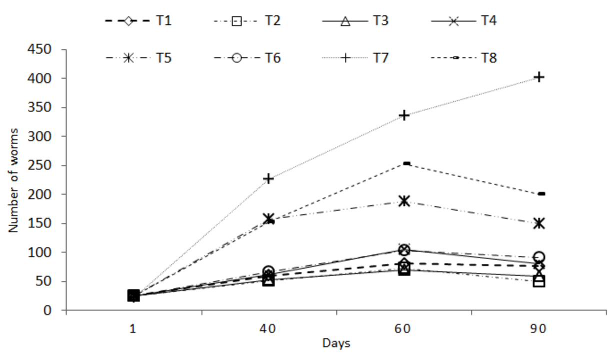

Figure 1. Number of earthworms in different feed mixtures

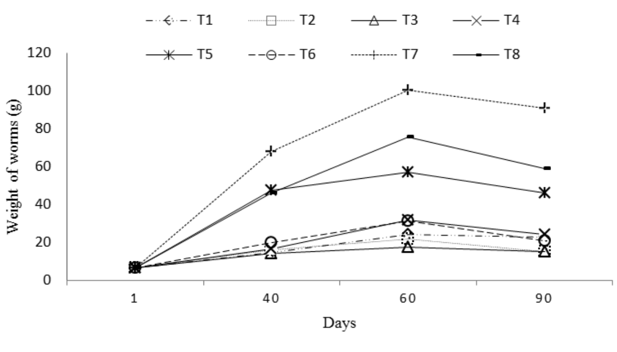

Figure 2. Weight of earthworms in various feed mixtures

3.2. Physicochemical changes in vermicompost

The physicochemical characteristics of different feedstock have been present in Table 2. As can be observed from the Table 2 the highest C/N ratio (125.38) was related to the newspaper waste followed by (26.78) in grass waste and (11.13) in cow dung.

Table 2. Initial Physicochemical characteristics of wastes

Parameter	Newspaper	Grass	Cow dung
pH	6.56	6.19	7.48
EC (ds/m)	0.43	4.2	3.6
TP (g/kg)	5.26	5.26	6.85
Na (%)	6.82	6.11	7.52
TOC (%)	48.9	39.1	14.8
TKN (%)	0.39	1.46	1.33
C/N	125.38	26.78	11.13
Cd (mg/kg)	0.008	0	0.03
Pb (mg/kg)	0	0	0
As (mg/kg)	22.76	9.87	17.98

All data represent average of triplicates.

3.2.1. pH

Table 3 represented the results of physicochemical parameters of initial feed mixtures and final vermicompost after 60 days of vermicomposting process. The pH of final products have showed small changes compared to initial values. The pH of all treatments was lower than initial waste mixtures (Table 3). Maximum (4.3%) and minimum (1.1%) decline in pH were observed in T3 and T5, respectlively. Previous research works reported similar results during vermicomposting of different wastes (Elvira *et al.*, 1998; Garg and Gupta, 2011). Decrease in pH may be owing to the mineralization of nitrogen and phosphorus into nitrites/nitrates and orthophosphates and transformation of organic waste into organic acids (Ndegwa *et al.*, 2000).

3.2.2. Electrical conductivity

Results of measuring samples characteristics showed that in all treatments, the EC increased gradually in the range of 4.4–56%, which maximum increase in EC (56%) was observed in T7. Based on statistical analysis through ANOVA the EC alteration was significant ($p < 0.05$) at the different composting interval time. According to the results of previous studies decomposition of organic material and release of minerals in the form of cations during vermicomposting may have increase EC (Tognetti *et al.*, 2005; Garg *et al.*, 2006; Khwairakpam and Bhargava, 2009).

3.2.3. TOC

TOC content of all treatments decreased about 3.9% to 32.8% from initial levels, and the maximum decline in TOC (32.8%) was recorded in T7 after 60 days. The percentage decrease in TOC content was in the order of T7 > T8 > T5 > T6 > T3 > T4 > T1 > T2 (Table 3). Several studies have reported that earthworms modify the feed mixture conditions, which subsequently enhance the carbon losses from the feed mixture through microbial respiration in the form of CO_2 (Elvira *et al.*, 1996; Aira *et al.*, 2007b; Hait and Tare, 2011). Wani *et al.* (2013) investigated vermicomposting of garden waste, kitchen waste and cow dung using earthworm *Eisenia fetida*. Their results confirmed the TOC reduction at the end of process. Also Sharma (2003) observed that a large fraction of TOC can be degraded to CO_2 during vermicomposting of municipal solid waste.

Table 3. Physicochemical properties of initial feed mixtures and final products

Physicochemical parameters		T1	T2	T3	T4	T5	T6	T7	T8
pH	Initial	7.22	7.09	6.96	6.87	7.16	7.13	6.79	6.98
	Final	7.08	6.93	6.69	6.73	7.08	6.92	6.7	6.75
EC	Initial	3.72	3.21	3.6	3.52	3.02	3.4	1.75	2.39
	Final	3.9	3.38	3.76	3.7	3.84	3.62	2.73	2.7
TP	Initial	6.53	6.37	6.21	6.06	6.34	6.34	5.73	6.06
	Final	8.83	8.59	8.39	8.32	8.38	8.62	8.46	8.53
Na	Initial	7.24	7.08	6.96	6.89	7.24	7.17	6.95	7.01
	Final	7.32	7.82	7.35	7.05	7.64	7.52	7.32	7.94
TOC	Initial	19.6	22.9	24.52	28.2	24.23	23.16	41.19	31.23
	Final	18	22	21	25.5	20	19.3	27.7	23.2
TKN	Initial	1.1	1.37	1.38	1.29	1.16	1.26	0.74	0.97
	Final	1.12	1.43	1.89	1.51	1.84	1.73	0.78	1.11
C/N	Initial	17.81	16.71	17.76	21.86	20.88	16.54	53.49	32.19
	Final	16.36	15.38	11.17	16.88	10.86	11.15	35.51	20.90
Cd	Initial	0.02	0.029	0.018	0.016	0.019	0.022	0.024	0.018
	Final	0	0.028	0.017	0.012	0.004	0	0	0
Pb	Initial	0	0	0	0	0	0	0	0
	Final	0	0	0	0	0	0	0	0
As	Initial	16.35	15.54	14.72	15.2	18.12	14.78	20	19.07
	Final	6.35	9.67	9.34	12.66	9.69	9.45	7.33	10.98

3.2.4. TKN

Table 2 shows the TKN content in treatments. A considerable increase in the TKN content was observed in all treatments units and the maximum increase for TKN (51%) was in T5 and minimum in T1 (1.8%). The percentage increase in TKN was in the order of T5 > T3 > T6 > T4 > T8 > T2 > T7 > T1. Manuel *et al.* (2010) demonstrated that during vermicomposting of tomato-fruit wastes the values of TKN significantly increased by 35%, after 150 day (Fernández-Gómez, Nogales *et al.*, 2010). The increase in nitrogen content may be due to mineralization of C-rich matters and the action of N- fixing bacteria that are presented in the feed mixtures (Plaza *et al.*, 2008). Suthar *et al.* (2006) reported that earthworms can add nitrogen in the form of mucus, growth stimulating hormones and enzymes during digestion of organic waste. Degradation of dead worms might be another reason for increasing of TKN, because significant portion of worm is protein (Atiyeh *et al.*, 2000). The results of study by Mousavi *et al.* (2017) showed that nitrogen content of compost using kitchen waste, rotting foliage and cow dung increased 2.16 fold in comparison to initial waste mixtures. Several studies have reported that vermicomposting causes a significant increase in the TN content after worm activity (Garg and Gupta, 2011; Soobhany *et al.*, 2015).

3.2.5. C/N ratio

The C/N ratio, which is one of the most traditional indicators of the compost maturation (Cardenas and Wang, 1980), represented the organic waste mineralization and stabilization during the vermicomposting process. The C/N ratio declined in all treatments because of the increase in TN and the decrease in TOC. The C/N ratios decreased from (16.54-53.49) to (11.15-35.51) (Figure 3). The ratio of C/N after 60 days was maximum in T7 (33.6%) and was minimum in T2 (7.9%). These alteration may be due to change in the relative concentration of organic C and total N as highlighted above. This was consistent with observations of Kaur *et al.* (2010) that according to their results, the C/N ratio decreased due to a higher loss of carbon accompanied by an increase in nitrogen during vermicomposting of waste paper (Kaur, Singh *et al.*, 2010). Studies also revealed that C:N ratio, which is one of the most widely used indicator of compost maturation, decreased sharply during vermicomposting process (Vig, Singh *et al.*, 2011; Malafaia, da Costa Estrela *et al.*, 2015). Results of different studies also demonstrated that the acceleration in humification promoted by earthworms during vermicomposting that cause a decrease in the C/N ratio (Suthar, 2006; Dores-Silva *et al.*, 2011; Vig *et al.*, 2011).

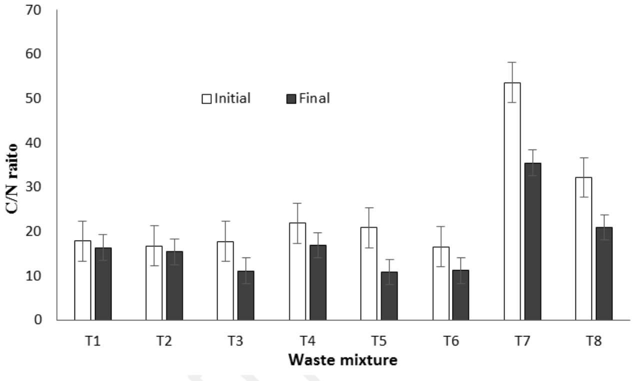

Figure 3. The C/N ratio of initial feed mixtures and final products

3.2.6. Total phosphorous (TP)

The total phosphorus content was significantly ($p < 0.05$) higher in the all vermicomposting units than the initial values based on different composting interval time. Total available phosphorus content increased from 32.1 to 47.6% in different vermicomposting units (Table 3). The maximum increase in TP was observed in T7 (47.6%). The percentage increase in TP was in the order of T7 > T8 > T6 > T4 > T1 > T2 > T3 > T5. According to previous studies, the reason for TP increasing associated to raw materials, processing time, quality of materials consumed by worms, the worms, and test conditions (Hartenstein and Hartenstein, 1981; Ndegwa *et al.*, 2000). Passing organic matter through the gut of earthworms can be a reason for adding some portion of P to worm excretion that consequently can increase the available phosphorous for plants (Lee, 1985), which may be the cause for the raise in the phosphorus concentration of the treatments in this study. Also, it has been reported that microorganisms during decomposition of organic matter produce acid, which solubilize insoluble phosphorus and subsequently cause increase in phosphorus content of vermicompost (Pramanik *et al.*, 2007). Vig *et al.* (2011) observed that after vermicomposting of tannery sludge mixed with cattle dung TP increased from initial in the range of 8.57%-44.8%, which is in accordance with the present study. Satchell and Martein (1984) also found an increase of 25% in phosphorus content of paper waste sludge, after worm activity (Satchell and Martin, 1984).

3.2.7. Macro-nutrient (Na)

The Na content of all treatments slightly increased from initial levels. The maximum increase in the Na concentration was 13.26% in T8, and the minimum was1.1% in T1. Variation in the Na content may be due to alteration in the initial concentration. Yadav and Garg (2011) reported the same observations during vermicomposting of mixed feed using cow dung, poultry droppings, and food industry sludge using *Eisenia fetida*. They revealed that initial Na content in the initial feed mixtures was in the range of 1.48–4.8 g/kg. Whereas final Na content was in range of 2.99–5.45 g/kg. The increase in the Na content was 1.06–2.05 fold in the final vermicomposts as compared with Na content in respective waste combination (Yadav and Garg, 2011).

3.2.8. Heavy metals (As, Cd and Pb)

Heavy metals (As, Cd, Pb) were monitored at the initial, and final vermicomposting stages. The obtained data showed that Pb concentration in all feed mixtures and final vermicomposting duration was not detected. The concentration of As and Cd was significantly reduced in the final vermicomposting time (Table 3). Heavy metal reduction at the end of the vermicomposting process was probably due to the accumulation of heavy metals in earthworms that has been confirmed by Ravindran and Mnkeni (2016), Shahmansouri *et al.* (2005) and Lu *et al.* (2012). The maximum heavy metal reduction in this study was observed in T7, consistent with the high earthworm biomass levels observed in this treatments (Ravindran and Mnkeni, 2016).

4. Conclusion

This study provides scientific information on the vermicomposting of grass, newspaper and cow dung either alone or in combination. The physicochemical analysis of the vermicompost produced by aforementioned substrates at different percentage pointed to the feasibility of the process. The vermicompost from substrate with 60% newspaper waste, 30% of cow dung and 10% of grass waste showed the highest reproduction of worms (402) after 90 days. All treatments with 50% to 80% grass were not good bedding for reproduction of worms and leading to a significant decrease of the worms. Therefore, the rate of biodegradation of organic matter was inhibited. The results indicated that the single substrate and mixed substrates had different effect on the process because of different physicochemical properties. The mixed culture with low concentration of grass showed better performance in terms of worm numbers, C/N and TKN. Finally, it is conclude that vermicomposting can be used for educational wastes, lawn waste and cow dung management.

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