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Physico chemical evaluation of coffee husk, wastes of enset (*Enset ventricosum*), vegetable and khat (*Catha edulis*) through vermicomposting employing an epigeic earthworm *Dendrobaena veneta* (Rosa, 1886)

Gezahegn Degefe[1*], Seyoum Mengistou[2] and Said Mohammed[1]

[1]Biology Department, College of Natural and Computational Sciences, Debre Berhan University, Ethiopia.
[2]Department of Zoological Science, College of Life Science, Addis Ababa University, Ethiopia.

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The major objective of this 90 days vermicomposting work was to evaluate the performance of epigeic earthworms, *Dendrobaena veneta*, to alter and change four commonly dumped and littered solid wastes in Ethiopian cities and towns into a high quality vermicompost. The experiments were conducted in cylindrical plastic containers with 26 cm depth and 53 cm width under shade. All containers were perforated on the sides for aeration as well as bottom for leachate drainage purpose. The wastes were mixed with cow dung in 3:1 ratio and treated with *D. veneta* in the following waste and worm mass proportion: 9 kg of vegetable waste treated with 130 g of worms, 9 kg of enset waste treated with 130 g of worms, 5 kg of coffee husk treated with 70 g of worms, 8 kg of khat waste treated with 115 g of worms. Results from all beddings treated by this earthworm species show that total Kjeldhal nitrogen (TKN) increased by 68 to 95%, total potassium (TK) increased between 51 and 76%, total phosphorus (TP) increased between 76 and 100% while total organic carbon (TOC) decreased between 35.3 and 38.5%, the C: N ratio reduced between 62 and 65.5% and considerable reduction was also observed in pH value of the final product. The findings from this experiment indicate that vermicomposting could be one good option to improve solid waste management performance of Ethiopian cities and towns through the production of excellent bio-fertilizer for agronomic purpose.

Key words: *Dendrobaena veneta*, enset, Khat, vermicomposting.

INTRODUCTION

For many cities in developing nations, dealing with the environmental costs of solid waste is a current phenomenal challenge (Wang and Nie, 2001). The enormous production of solid wastes coupled with poor management system result in a significant environmental degradation, thus the safe and environmentally harmonious management of solid wastes becomes a major issue for these nations. Today in all corners of the

*Corresponding author. Email: gezahegndegefe.teferedegn@gmail.com.

world managing different organic wastes at low capital and operational cost as well as in eco-friendly and energy saving basis has attracted much attention and among these methods, vermicomposting is one of the techniques that have been applied in various parts of the world (Sangwan et al., 2002).

Vermicomposting which is alternatively called earthworm vermistabilisation, worm composting, or annelic consumption (Wang et al., 2006), is an earthworm based aerobic process which has a unique position in the domain of environmental engineering, as it is the only pollution control that uses a multicellular animal as the main bioagent (Abbasi et al., 2009). In this process, energy rich and complex organic substances have been bio-oxidized and transformed into stabilized products by combined action of earthworms and microorganisms; hence earthworms play a considerable role by fragmenting and altering all biological activity of the waste (Dominguez, 2004). Being a developing country, Ethiopian cities and towns also suffer with the environmental costs of solid waste management and like other developing countries, the solid waste produced in Ethiopia are also dominated by food, paper and wastes from animal and vegetable origin (Kendie, 2009). These materials are wholly biodegradable. The organic nature of these wastes offers various biological management options such as vermicomposting instead of disposal to landfill sites, open dumping or any other environmentally risky waste management alternatives.

Despite the fact that vermicomposting is commonly used as a means of managing municipal solid wastes in various parts of the world; it has not been started in Ethiopia yet. However, the current economic growth, industrialization and urbanization throughout the country have led to the generation of large quantities of organic wastes which need marketable, environmentally sound and cost effective management system. It is now time for Ethiopian cities to think about biological waste treatment system like vermitechnology with the intervention of appropriate biological organisms. The aim of the study was to explore the suitability and potential use of an epigeic earthworm species, *Dendrobaena veneta* in managing commonly dumped solid wastes in Ethiopia and to identify the pattern of chemical changes during the vermicomposting of these wastes. Due to its wide temperature, moisture and disturbance (handling) tolerant *D. veneta* is among the best vermicomposting species (Dominguez, 2004). For this study four frequently dumped and indiscriminately littered wastes in most cities and open markets of the country were used, for example, vegetable waste, coffee husk, khat waste and enset waste.

MATERIALS AND METHODS

Waste collections and processing

This experiment was conducted in Addis Ababa city at Yeka sub city, Woreda 11 from January 2013 to March 2013. The vegetable waste sample (which constitutes both fresh and putrefied) was collected from the main vegetable market of Addis Ababa city around Piazza. The waste comprised of different leftover vegetables and fruits such as cabbage, tomato, potato, onion, carrot and other leafy vegetables. The coffee husk and enset wastes were collected from coffee processing stations around Dilla town and the main market site in Dilla town, respectively. From all wastes, the non-biodegradable fractions such as plastic, rubber, polythene bags, wood, cardboard, glass and stones were separated and discarded manually by hand sorting. The sample wastes were collected and were brought to experimental site in Addis Ababa at Yeka sub city. The cow dung was procured from farmers around Addis Ababa. The earthworm species *D. veneta* was obtained from the breeding site of Vigo University, Spain. Regarding waste processing, the waste materials and the cow dung used for the experiment were air dried for 48 h and chopped into small pieces before lying into experimental containers. All wastes were mixed with sliced cow dung in 3:1 ratio in dry weight basis. The cow dung serve as supplement and it also increases the nutrient quality of the final product (Muthukumaravel et al., 2008). Each experimental waste in this experiment was designated as follow: T1 = vegetable waste + cow dung (3:1), T2 = enset waste + cow dung (3:1), T3 = coffee husk + cow dung (3:1), T4 = Khat waste + cow dung (3:1).

Experimental set up

The experiments were conducted in cylindrical plastic containers with 25 cm depth and 53 cm width. All the containers were perforated on the sides for aeration as well as bottom for leachate drainage purpose. The containers were filled to a 3 cm height with chips stone and above it gravel to facilitate proper drainage. Immediately above the gravel 3 cm thick old frozen vermicompost bedding was layered which served as bedding material for the earthworms at their early stage before they were acclimatized to the treatment given. Freshly clitilated *D. veneta* in their good health condition were introduced in each respective container with vermicompost bedding one day prior to addition of experimental wastes hence earthworms easily settled themselves in the new habitat. Above the vermicompost beddings plastic mesh which separated the experimental wastes from the vermicompost bedding was laid. The mesh has several holes which allow free movement of earthworms. Following optimum feeding rate explanation of Ndegwa et al. (2000), the waste and worms were set in the following waste/worm mass proportion in each test container. 9 kg of T1 (vegetable waste + cow dung) treated with 130 g of worm, 9 kg of T2 (enset waste + cow dung) treated with 130 g of worm, 5 kg of T3 (coffee husk + cow dung) treated with 70 g of worm and 8 kg of T4 (khat waste + cow dung) treated with 115 g of worm. No additional feed was added into the containers at any stage during the study period. After the second week of the experiment cocoons were discarded by hand sorting in order to avoid any hatching or increment in worm number.Both the experimental beddings (substrates with worms) and the control (experimental feed mixture without earthworms) were replicated three times for every tested waste; therefore, there were 24 containers in total. Throughout the study period, the moisture content and the temperature of all beddings were maintained 60 to 70% and 24 to 27°C respectively, by spraying adequate quantity of water. The moisture level of the samples was determined gravimetrically (drying at 105°C) with the difference between moist and dried samples. The temperature of substrate was measured with mercury thermometer.

Physico-chemical analysis

The samples from each experimental container and control were

Table 1. Initial and final pH value of wastes treated with *D. veneta* and the control.

Waste	Wastes treated by *D. veneta*		Control	
	Initial pH value	Final pH value	Initial pH value	Final pH value
T1	7.52 ± 0.05	6.91 ± 0.04	7.52 ± 0.05	7.43 ± 0.00
T2	7.42 ± 0.02	6.91 ± 0.04	7.41 ± 0.03	7.3 ± 0.00
T3	7.46 ± 0.03	6.93 ± 0.02	7.46 ± 0.01	7.32 ± 0.05
T4	7.45 ±0.04	6.88 ± 0.01	7.44 ± 0.003	7.39 ± 0.00

Mean value and SD of the three replicates

collected on 15 days interval and air dried to monitor the changes in physico-chemical characters. All the samples were analyzed in triplicate and results were averaged. The samples were analyzed for pH and total organic carbon (TOC) at the initial and final phase of the experiment while total Kjeldahl nitrogen (TKN), available potassium (K), available phosphorous(P) were analyzed in 15 days interval in order to determine their progressive change. The pH was determined by distilled water suspension of the air dried sample in the ratio of 1:10 (vermicompost/waste: distilled water ratio) using digital pH meter. The TOC of the samples was determined by the empirical method followed by Nelson and Sommer (1982). Total kjeldhal nitrogen was estimated by using the standard kjeldahl method as described by Na'jera et al. (2015). Available total phosphorus and potassium was determined following the procedure described by Liu et al. (2005).

Statistical analysis

Statistical analyses were carried out with SPSS 15.0 for windows. Data were analyzed using one-way analysis of variance (ANOVA).

RESULTS AND DISCUSSION

pH

In both test experiment and the control, reduction was observed in the pH of the end product but significant variation was seen only in beddings treated with worms ($p<0.05$). Similar results have been reported by other researchers in vermicomposting various biodegradable wastes (Ndegwa et al., 2000; Garg et al., 2006). The overall decrease of pH from the initial near alkaline towards slightly acidic conditions might be due to the decomposition of organic substrates by earthworm and microbial activity resulting in the production of CO_2 and other intermediate species of organic acids in vermicompost (Gómez-Brandón et al., 2011). The resulted pH range in this experiment is the characteristic of good quality compost to retain nitrogen as this element lost as volatile ammonia at high pH values (Atiyeh et al., 2012). Contrary to the present finding, increasing results were reported by Ankaram et al. (2014) in vermicomposting residues from olive oil production and, Komilis and Ham (2006) in vermicomposting paper, yard wastes and food waste mixtures. Dominguez (2004) also reported that no considerable pH difference was observed between the control and test beddings in vermicomposting pig slurry.

Total Kjeldhal nitrogen (TKN)

In all beddings successive rise was observed in TKN from initial day to 90th day as decomposition proceeded but statistically significant variation was recorded in earthworm treated wastes ($p≤0.05$). Compared to their initial levels, TKN showed 45 to 55% notable increment in worm treated beddings (Tables 1 to 4). This result is in line with previous works on various biodegradable wastes treated by different species of earthworms. Chauhan and Josi (2010) reported a considerable rise of total nitrogen in vermicomposting some nuisance weeds such as congress grass (*Parthenium hysterophorus*), water hyacinth (*Eichhornia crassipes*) and bhang (*Cannabis sativa*). Ananthakrishnasamy et al. (2009) observed progressive rise of total nitrogen in vermicomposting fly ash with earthworm *Lampito mauritii*, an indigenous Indian worm. Zularisam et al. (2008) observed considerable rise in total nitrogen from 19.6 to 35.7 mg/l within 21 days of vermicomposting municipal sewage sludge. In contrast to the current findings, Atiyeh et al. (2012) reported 1.8 fold reduction of nitrogen in vermicomposting sludge with earthworm *E. fetida.*

Though the total nitrogen content in vermicompost is primarily governed by the initial nitrogen content in the organic waste used as earthworm feed and the suitability of the waste material for the earthworm mediated decomposition (Tognetti, 2007), earthworms play a crucial role in enhancing and improving the nitrogen profile of the waste by addition of mucus, nitrogenous casts, from decaying tissue of dead worms and by facilitating microbial mediated nitrogen mineralization (Suthar, 2007; Zularisam et al., 2008).

Potassium

There was a consecutive increment in potassium in both experimental and control beddings as the decomposition proceeded (Tables 1 to 4). However, statistically significant difference was observed for earthworm treated beddings ($p<0.05$). In line with this finding, Kumar et al. (2010) in vermicomposting pig slurry, Kavirag and

Table 2. Progressive changes of TKN, K and P during the vermicomposting of vegetable waste.

Nutrient	Species	Initial	15th day	30th day	45th day	60th day	75th day	90th day	Change from 0 day (%)
TKN	*D. veneta*	2.45±0.006	2.47±0.003	3.00±0.03	3.4±0.06	3.81±0.05	4.1±0.04	4.45±0.03	81.6
	Control	2.45±0.005	2.47±0.005	2.48±0.003	2.49±0.00	2.5±0.003	2.57±.003	3±0.005	22.4
K	*D. veneta*	3.2±0.05	3.32±0.02	3.37±0.006	3.49±0.007	3.7±0.003	4.30±0.01	4.83±0.01	51
	Control	3.2±0.05	3.3±0.01	3.32±0.005	3.36±0.003	3.4±0.003	3.45±0.003	3.5±0.005	9.4
P	*D. veneta*	0.64±0.006	0.69±0.00	0.74±0.005	0.83±0.01	0.88±0.003	1.15±0005	1.26±0.02	97
	Control	0.64±.006	0.65±0.003	0.67±0.01	0.68±0.003	0.69±0.003	0.71±0.003	0.72±0.005	12.5

Mean value and SD of the three replicates.

Table 3. Progressive changes of TKN, TK and TP during the vermicomposting of enset waste.

Nutrient	Species	Initial	15th day	30th day	45th day	60th day	75th day	90th day	Change from 0 day (%)
TKN	*D. veneta*	1.63±0.05	1.66±0.006	1.82±0.006	2.21±0.01	2.59±0.015	2.8±0.07	3.0±0.02	84
	Control	1.6±0.003	1.65±0.005	1.67±0.005	1.68±0.003	1.84±0.003	1.91±0.06	1.99±0.003	24
K	*D. veneta*	2.5±.02	2.61±0.00	2.64±0.003	2.69±0.003	2.77±0.02	3.36±.006	3.9±0.03	56
	Control	2.5±.008	2.54±0.003	2.56±0.005	2.57±0.003	2.58±0.003	2.6±.008	2.65±0.003	6
P	*D. veneta*	0.44±.01	0.64±.01	0.73±0.005	0.70±0.005	0.75±0.01	0.83±.008	0.85±0.01	93
	Control	0.44±0.003	0.45±0.003	0.48±0.005	0.49±0.005	0.5±0.005	0.52±0.003	0.54±0.005	23

Mean value and SD of the three replicates.

Sharma (2003) in vermicomposting municipal solid wastes, Chauhan and Joshi (2010) in vermicomposting toxic weeds such as congress grass (*Parthenium hysterophorous*), water hyacinth (*Eichhornia crassipes*) and bhang (*Cannabis sativa*) have reported the general rise of potassium in the final product. Large number of symbiotic micro flora present in the gut and the cast of earthworms in collaboration with secreted mucus and water might increase the degradation of ingested organic matter and the release of assailable metabolites. These metabolites enhance the enrichment of the vermicompost with exchangeable potassium (Kaviraj and Sharma, 2003). In contrast to this finding, some researchers have reported lower content of potassium in vermicompost (Ananthakrishnasamy et al., 2009; Gómez-Brandón et al., 2011). This probably reflects leaching of this soluble element By the excess water that drained through the mass (Song et al., 2015). Sharma (2003) in vermicomposting municipal solid wastes, Chauhan and Joshi (2010) in vermicomposting toxic weeds such as congress grass (*Parthenium hysterophorous*), water hyacinth (*Eichhornia crassipes*) and bhang (*Cannabis sativa*) have reported the general rise of potassium in the final product. Large number of symbiotic micro flora present in the gut and the cast of earthworms in collaboration with secreted mucus and water

Table 4. Progressive change of TKN, TK and TP during the vermicomposting of coffee husk.

Nutrient	Species	Initial	15th day	30th day	45th day	60th day	75th day	90th day	Change from 0 day (%)
TKN	*D. veneta*	1.35±0.03	1.38±0.01	1.2±0.007	1.56±0.03	1.9±0.01	2.12±0.03	2.27±0.03	68
	Control	1.35±0.003	1.36±0.003	1.38±0.003	1.4±0.006	1.42±0.005	1.45±0.05	1.6±0.005	18.5
TK	*D. veneta*	1.9±0.007	1.95±0.001	2.22±0.03	2.62±0.01	2.83±0.06	3.1±0.01	3.34±0.05	76
	Control	1.9±0.003	1.93±0.003	1.95±0.003	1.98±0.006	1.99±0.003	2.17±0.03	2.21±0.005	16
TP	*D. veneta*	0.15±0.02	0.18±0.01	0.22±0.003	0.25±0.001	0.28±0.006	0.29±0.003	0.3±0.07	100
	Control	0.15±0.005	0.16±0.005	0.16±0.005	0.17±0.005	0.18±.0.005	0.19±0.005	0.2±0.005	33.3

Mean value and SD of the three replicates.

might increase the degradation of ingested organic matter and the release of assailable metabolites. These metabolites enhance the enrichment of the vermicompost with exchangeable potassium (Kaviraj and Sharma, 2003). In contrast to this finding, some researchers have reported lower content of potassium in vermicompost (Ananthakrishnasamy et al., 2009; Gómez-Brandón et al., 2011). This probably reflects leaching of this soluble element by the excess water that drained through the mass (Song et al., 2015).

Phosphorous

In this experiment, the level of phosphorous showed successive increment in both worm treated and control beddings throughout the study period but statistically significant rise was observed in beddings treated with worms ($p<0.05$) (Tables 1 to 4). In agreement with this finding, Muthukumaravel et al. (2008) in vermicomposted vegetable waste, Zularisam et al. (2008) in vermicomposted municipal sewage sludge, Ananthakrishnasamy et al. (2009) in vermicomposted fly ash, and Chauhan and Joshi (2010) in vermicomposted toxic weeds recorded significant rise in the level of phosphorous. The rise of phosphorous might be due to the action of earthworms' phosphatases and phosphorous solubilizing microorganisms in the worm cast (Blouin et al., 2013). In support of this suggestion, Jouquet et al. (2011) stated that as the organic residue passes along the earthworms gut, the unavailable form of phosphorous in the organic matter was converted to available forms for plants. There are some contradicting reports to the findings here (Song et al., 2015).

Total organic carbon (TOC)

Generally, the total organic carbon in all test treatments and the control showed a declining trend as the decomposition progressed but beddings treated with *D. veneta* showed statistically significant variation ($p<0.05$). The wastes treated by *D. veneta* showed reduction in the following order 38.5% loss in T1, 37.5% loss in T2, 36.5% loss in T4 and 35.3% loss in T3. Like the findings of this study, the level of total carbon showed negative correlation with vermicomposting duration in several previous findings. Lower level of organic carbon was observed in the vermicomposted partenium plant (Sivakumar et al., 2009) and in vermicomposted pulp-mill sludge (Gómez-Brandón et al., 2011). The reduction of carbon in vermicompost is the result of respiration and mineralization of the organic matter mainly by microorganisms and earthworms. Earthworms through their fragmenting action modify the substrate condition which consequently increase the surface area for microbial action (Dominguez, 2004) thus promote carbon loss through microbial respiration and in similar pattern the oxidation of organic matter within the vermicomposting unit is also enhanced by earthworm population.

C: N Ratio

In this study, C:N ratio of all wastes treated by *D. veneta* decreased significantly from their respective initial level and the control at the end of the study period ($p<0.05$). The level of reduction and the corresponding C/N value is presented in Table 5. In agreement with this result, Suthar (2009) reported 62.7% reduction of C/N ratio in15 weeks of vermicomposting experiment on

Table 5. Progressive change (in %) of TKN, TP and TK during the vermicomposting of khat waste.

Nutrient	Species	Initial	15th day	30th day	45th day	60th day	75th day	90th day	Change from 0 day (%)
TKN	*D. veneta*	1.7±0.01	2.0±0.01	2.47±0.03	2.71±0.003	3.0±0.02	3.21±0.03	3.32±0.01	95
	Control	1.7±0.003	1.72±0.01	1.76±0.003	1.76±0.005	1.78±0.003	1.85±0.005	2.11±0.003	24
TK	*D. veneta*	1.98±0.01	1.99±0.003	2.36±0.04	2.58±0.09	2.70±0.01	2.9±0.006	3.34±0.03	69
	Control	1.98±0.003	1.99±0.003	2.13±0.005	2.16±0.005	2.17±0.005	2.2±0.006	2.23±0.005	13
TP	*D. veneta*	0.51±0.009	0.74±0.003	0.77±0.003	0.80±0.005	0.84±0.003	0.88±0.003	0.9±0.003	76
	Control	0.5±.003	0.53±0.003	0.56±0.005	0.57±0.005	0.58±0.008	0.59±0.005	0.61±0.005	22

Mean value and SD of the three replicates.

domestic waste. In vermicomposting Parthenium plant and neem leaves, the amount of carbon to nitrogen ratio decreased significantly (Sivakumar et al., 2009). Suthar and Singh (2008) also reported a considerable reduction of C:N ratio in vermicompost produced from municipal sewage sludge. Since decrease in C:N ratio reflects changes in the forms and properties of organic matter during bioconversion, reduction in C: N ratio during the vermicomposting process becomes one of the most widely used indicators of vermicompost maturation (Ansari and Jaikishun, 2010). According to Morais and Queda (2003), a C:N ratio below 20 is an acceptable maturity level, while a ratio of 15 or lower is highly preferable for agronomic purpose, therefore, the present result obtained from all wastes treated by *D. veneta*, showed the C:N ratio within the acceptable limit (Table 5) for agricultural usage. C/N value of 7.7, 9, 13.8 and 11.8 were recorded from Treatment 1, 2, 3 and 4, respectively and the reduction rate in percent were 62, 68, 63.5 and 62 from treatment 1, 2, 3, and 4.

Conflict of Interests

The authors have not declared any conflict of interests.

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