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Vermicomposting as a Sustainable Practice to Manage Coffee Husk, Enset waste(*Enset ventricosum*), Khat waste (*Catha edulis)* and Vegetable waste amended with Cow Dung using an epigeic earthworm *Eisenia Andrei* (Bouch' 1972)

Gezahegn Degefe[1]*, Seyoum Mengistu[2] and Jorge Dominguez[3]

[1]Debre Birhan University, College of Natural Science, Department of Biology, P. O. Box 23885/1000 Addis Ababa, Ethiopia.

[2]Addis Ababa University, Faculty of Life Science, [3]Departamento de Ecoloxia e Bioloxia Animal, Universidade de Vigo, E-36200 Vigo, Spain.

***Corres.author: gezahegndegefe.teferedegn@gmail.com,**

Abstract: This 90 days vermicomposting work was conducted to evaluate the performance of epigeic earthworms *E.andrei* to alter and change four commonly dumped and littered solid wastes in Ethiopian cities and towns in to a high quality vermicompost. All wastes were mixed with cow dung in 3:1 ratio and treated with earthworm *E.andrei* in the following waste and worm mass proportion. 9kg of vegetable waste treated with 130gm of worms, 9kg of enset waste treated with 130gm of worms, 5kg of coffee husk treated with 70gm of worms, 8kg of khat waste treated with 115gm of worms. Results from all beddings treated by this species of earthworms showed that TKN increased b/n 50.3 - 56%, TK increased between 29.6 – 43.6 %, TP increased between 58.9% - 73.2%, Ca increased between 39.6 % - 61.5%, while TOC decreased between 35% - 38.4 % and the C:N ratio reduced between 60 - 68 %. The findings from this experiment generally indicated that vermicomposting could be one good option to improve solid waste management performance of Ethiopian cities and towns through the production of excellent biofertilizer for agronomic purpose.

Key words/phrases: *Eisenia andrei*, Vermicomposting, Enest, Coffee Husk. Khat.

Introduction and experimental

Rapid growth of urbanization, industrialization and population increase has led to generation of huge amount of wastes over the whole world. Managing these wastes is one of the most serious environmental problems confronting urban areas in developing countries. Recently, managing different organic wastes at low capital and operational cost as well as in eco-friendly basis has attracted much attention worldwide and among these methods, vermicomposting is one of the techniques that have been applied in various parts of the world[1]. Vermicomposting which is alternatively called earthworm vermistabilisation, worm composting, or annelic consumption[2] 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[3].

In this process energy rich and complex organic substances have been biooxidized 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[4]. Being a developing nation, Ethiopian cities and towns are also suffer with the environmental costs of rapid growth and urbanization particularly in the area of solid waste management. Like other developing nations, the municipal solid wastes produced in Ethiopia are also dominated by food, paper and wastes from animal and vegetable origin. Obviously these materials are wholly biodegradable therefore, 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 corners 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 present study is to explore the suitability and potential use of an epigeic earthworm species, *Eisenia andrei* in four commonly dumped solid wastes in Ethiopia and to identify the pattern of chemical changes during the vermicomposting of these wastes. Due to its global distribution, wide temperature, moisture and disturbance tolerance these *Eisenia andrei* is accepted as best vermicomposting species worldwide[4]. For this study four frequently dumped and indiscriminately littered wastes in most cities and open markets of the country were used i.e. Coffee husk, vegetable waste, enset waste and khat waste.

Coffee husk: Coffee husk is the most abundantly available agro industrial waste produced during the pulping action of the coffee cherries to obtain coffee beans in many coffee-producing areas of the tropics including Ethiopia. It is estimated that, for a single kilogram of coffee beans produced, about 1kg husks are generated[5], whereas in the dry process 0.18 kg coffee husk is generated for every kilogram of fresh coffee cherries[6]. In most coffee producing and processing areas of Ethiopia the husk does not have much commercial or other industrial advantage other than, becoming the major polluting agent of rivers and lakes. The huge presence of proteins, sugars and minerals in coffee husk and its high humidity favors the rapid growth of microorganisms which can pose due environmental pollution[7]. So municipalities where coffee processing industries are found should pioneer various initiatives for improving the environmental performance of the coffee industries.

Vegetable waste: In Ethiopian cities, huge amount of market vegetable wastes are dumped indiscriminately or littered on the streets causing environmental deterioration. Even the vegetable market waste collected and dumped into the municipal landfills, has cause a nuisance because of high biodegradability. The biological treatment of these wastes appears to be environmentally friendly and cost effective.

Enset waste: Enset is a perennial, banana-like crop, endemic to Ethiopia that produces psuedostem and a starchy belly corm pulped for food, feed and fibre. Enset is one of the major staple foods in Ethiopia for about 13 million people who constitute more than 20% of the population residing in the southern Ethiopian highlands[8]. The whole plant is used to produce food, fibre, packaging material and fodder, so only small amounts of removals are left over unused. It is estimated that about 1kg fresh weight of waste is produced from one enset plant[9]. However, the leaf of the plant is widely used as a packaging material in most open markets and khat selling shops and it is dumped indiscriminately after utilization thus causing serious environmental problem.

Khat(*Catha edulis*): Khat is a flowering evergreen plant belonging to Celastrus family. Khat stands among the most important cash crops in Ethiopia, with strong markets domestically. In many parts of Ethiopia khat is mainly considered as a recreational drug. It may also be used by farmers and laborers for reducing physical fatigue or hunger, and by drivers and students for improving attention. Only the leaf and soft stem parts are used so large amount of removals are leftover unused. In most major cities of Ethiopia including Addis Ababa, almost in all roadsides and open spaces, there is a huge amount of khat leftovers throughout of the year, hence immediate and innovative solution should be needed.

Waste Collections and Processing

The vegetable waste sample (which constitutes both fresh and putrefied) was collected from the main vegetable market of Addis Ababa city around Piazza. 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 in large-sized sac and were brought to experimental site in Addis Ababa at Yeka sub city, Kebele 19. The cow dung was procured from farmers around Addis Ababa. The earthworms *Eisenia andrei* 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 hours and chopped into small pieces before laying in to experimental containers. All the experimental wastes were mixed with powdered cow dung in 3:1 ratio (dry weight proportion in plastic containers). The cow dung serve as supplement and it also increases the nutrient quality of the final product[10]. 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 25cm depth and 53cm width. All the containers were perforated on the top and sides for aeration as well as bottom for leachate drainage purpose. The containers were filled to a 3cm height with chips stone and above it gravel to facilitate proper drainage. Immediately above the gravel 3cm 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 *Eisenia andrei* 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.

Following optimum feeding rate explanation of Ndegwa *et al.*[11] the waste and worms were set in the following waste/worm mass proportion in each test container. 9kg of T1 treated with 130gm of worm, 9kg of T2 treated with 130gm of worm, 5kg of T3 treated with 70gm of worm and 8kg of T4 treated with 115gm of worm. No additional feed was added into the containers at any stage during the study period. The experimental beddings with each type of worm and the control (wastes 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 60-70% and 24-27^{0}C respectively, by spraying adequate quantity of water. The moisture level of the samples was determined gravimetrically (drying at 105^{0}c) with the difference between moist and dried samples. The temperature of substrate was measured with mercury thermometer.

Physico-chemical Analysis

The homogenized samples from each experimental container and control were 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, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total potassium (TK) and calcium. 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 total organic carbon (TOC) of the samples was determined by the empirical method followed by Nelson and Sommer[12]. Total kjeldhal nitrogen was estimated by using the standard kjeldahl method as described by Bremner and Mulvaney[13]. Available total phosphorus was determined following Anderson and Ingram[14] explanation, and total potassium and calcium were determined following the procedure described by Simard[15] (1993).

Result and Discussion

pH

A decreasing trend was observed in the pH of the end product in all substrates treated by *Eisenia andrei* and the control as the decomposition process continue from 0 day to 90 days(table 1). The reduction in the control beddings was insignificant ($p>0.05$) while the pH value for all test beddings (with worms) varied significantly ($p < 0.05$). Similar results have been reported by other researchers in vermicomposting various biodegradable wastes[11, 16, 17]. The overall decrease of pH from the initial near alkaline towards slightly acidic conditions might be due to the decomposition of organic substrates by microbial activity resulting in the production of CO_2 and other intermediate species of organic acids in vermicompost[18]. Nath *et al.*[19] described the mineralization of nitrogen and phosphorous into nitrate/nitrite and ortho-phosphate shifts the pH value towards acidic condition. Generally, in this experiment the end product from all waste sources shifted from alkaline to slightly acidic pH which is the characteristic of good quality compost and such reduction is advantageous in retaining nitrogen as this element lost as volatile ammonia at high pH values[20]. Contrary to the present finding, an increasing trend was reported in vermicomposting residues from olive oil[21] and paper, yard and food waste mixtures[22].

Table 1: Initial and final pH value of wastes treated with Eisenia andrei and the control

wastes	Initial PH value	Final PH value
T1	7.5 ± 0.05	6.90 ± 0.02
Control	7.53 ± 0.05	7.43 ± 0.00
T2	7.45 ± 0.02	6.89 ± 0.06
Control	7.40 ± 0.003	7.30 ± 0.00
T3	7.45 ± 0.03	6.93 ± 0.02
Control	7.45 ± 0.01	7.33 ± 0.05
T4	7.45 ± 0.04	6.89 ± 0.01
Control	7.44 ± 0.003	7.39 ± 0.00

Total Kjeldhal Nitrogen

Successive rise was observed in TKN from initial day to final 90th day as decomposition proceeded in both the experimental and control beddings but statistically significant variation was recorded in earthworm treated wastes ($p\leq 0.05$). Compared to their initial levels, the total TKN in all vermibeds treated by *Eisenia andrei*, showed 45.7 to 54.7% notable increment (Table 1 to 4). This result was in line with previous works on various biodegradable wastes treated by different species of earthworms. Chauhan and Josi[23] 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* Linn.). Progressive rise of TKN was reported in vermicomposting fly ash[24]. Considerable rise in TKN was observed in vermicomposting municipal sewage sludge[25]. In contrast to the current findings Venkatesh and Eevera[26] reported a gradual decline of nitrogen after 45th day in vermicomposting fly ash. Hartenstein and Hartenstein[20] also reported 1.8 fold reduction of nitrogen in vermicomposting sludge.

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[27] earthworms play a crucial role in enhancing and improving the nitrogen profile of the waste by addition of mucus, nitrogenous casts and by facilitating microbial mediated nitrogen mineralization[25]. The decaying tissue of dead worms also contributes for the addition of nitrogen in the waste[28].

Total Potassium

There was a consecutive increment in total potassium in all wastes acted by *Eisenia andrei* as the vermicomposting process proceeded (**Table: 1to4).** Statistically significant difference was observed in worm processed beddings ($p<0.05$). The increment in the control is small as compared with the test beddings. This finding was similar with several previous works. Delgado *et al.*[29] in vermicomposting sewage sludge, Orozco *et al.*[30] in vermicomposting coffee pulp and textile mill sludge, Dominguez and Edwards[31] in vermmicomposting pig slurry, in vermicompossting municipal solid wastes have reported the general rise of total 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[32]. Contrast to this finding, some researchers has reported lower content of TK in vermicompost. Elvira *et al.*[18] and Ananthakrishnasamy *et al.*[24] have reported lower level of potassium in vermicompost than the initial substrate. This probably reflects leaching of this soluble element by the excess water that drained through the mass. Benitez *et al.*[33] pointed out that the leacheates collected during vermicomposting process had higher potassium concentrations.

Total Phosphorous

Progressive rise was observed in TP throughout the vermicomposting period in this experiment (Tables 1to 4). The vermicomposts obtained from all four wastes treated by *Eisenia andrei* was significantly higher in total phosphorous content than their respective initial waste substrates as well as the control ($p<0.05$). In agreement with this finding, Muthukumaravel *et al.*[10] reported that vermicomposted vegetable waste contain more phosphorous than untreated fresh vegetable waste. Zularisam *et al.*[25] maintain that vermicomposted municipal sewage sludge contains more TP than untreated sewage sludge. Ananthakrishnasamy *et al.*[24] reported higher amount of phosphorous in vermicomposted fly ash. Chauhan and Joshi[23] found higher amount of TP in test treatments than control in vermicomposting toxic weeds. The rise of TP might be due to the action of earthworms' phosphatases and phosphorous solubilizing microorganisms in the worm cast, In supporting this suggestion Lee[34] 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. Venkatesh, and Eevera[26] claimed that in vermicomposting a fly ash, gradual reduction was observed in the amount of total phosphorous after 45th day. Benetiz[33] also reported low level of available phosphorous after six weeks of vermicomposting, Ndegwa and Thompson[35] reported considerable reduction of TP in vermicompost produced from biosolids.

Total calcium

The calcium content of both the experimental beddings (treated with earthworm *Eisenia andrei*) and the control (without earthworms) showed progressive increase as decomposition process progressed from 0 day to 90th sampling day (Tables 1 to 4), while in the control, 20% maximum and 11.1 % minimum rise was identified in T4 and T2 beddings, respectively. All the increment observed in test experiments were significantly different to their initial value and respective control ($p<0.05$). This finding was supported by several previous vermicomposting research works on various organic wastes. Jadia and Fulekar[36] in vermicomposting vegetable waste, Anasri[37] in vermicomposting various mixtures of urban solid wastes, Pattnaik and Reddy[38] in vermicomposting urban green wastes observed a considerable increment, but on the other hand, Elvera *et al*[18] in vermicomposting sludges from paper mill and diary industries, Chaudhuri *et al*[39] in vermicomposting kitchen wastes, observed lower amount of calcium than the initial substrate value. The decline might be the result of leaching of this soluble element by the excess water that is drained through[18].

Table 2: Pattern of chemical changes (in %) of TKN,T P, TK and Ca during the vermicomposting of vegetable waste with cow dung by eisenia andrei.

Nutrients	species	Initial	15th day	30th day	45th day	60th day	75th day	90th day	% of change from 0 day
TKN	*E. andrei*	2.45 ± 0.006	2.5 ± 0.003	3.1 ± 0.03	4 ± 0.03	*4.5 ± 0.01*	4.75 ± 0.05	4.93 ± 0.09	50.3
	Control	2.45 ± 0.005	2.47 ± 0.005	2.48 ± 0.003	2.49 ± 0.00	2.5 ± 0.003	2.57 ± 0.003	3 ± 0.005	18.3
TK	*E. andrei*	3.2 ± 0.05	3.3 ± 0.02	3.36 ± 0.006	3.49 ± 0.007	3.95 ± 0.003	4.28 ± 0.01	4.55 ± 0.01	29.6
	Control	3.2 ± 0.05	3.3 ± 0.01	3.32 ± 0.005	3.38 ± 0.003	3.4 ± 0.003	3.5 ± 0.003	3.55 ± 0.005	9.8
TP	*E. andrei*	0.64 ± 0.006	0.76 ± 0.006	0.77 ± 0.003	0.92 ± 0.003	0.97± 0.006	1.14 ± 0.005	1.56 ± 0.07	58.9
	Control	0.64 ± 0.006	0.65 ± 0.003	0.67 ± 0.01	0.68 ± 0.003	0.69 ± 0.003	0.71 ± 0.003	0.74 ± 0.005	13.5
Ca	*E. andrei*	0.29 ± 0.006	0.30 ± 0.003	0.32 ± 0.003	0.35 ± 0.003	0.39 ± 0.007	0.44 ± 0.009	0.48 ± 0.007	39.6
	Control	0.3 ± 0.005	0.3 ± 0.003	0.31 ± 0.003	0.32 ± 0.005	0.33 ± 0.003	0.34 ± 0.003	0.34 ± 0.008	11.7

Table 3: Pattern of chemical changes (in %) of TKN, TP, TK and Ca during the vermicomposting of enset waste with cow dung by eisenia andrei.

Nutrients	species	Initial	15th day	30th day	45th day	60th day	75th day	90th day	% of change from 0 day
TKN	*E. andrei*	1.61 ± 0.02	1.70 ± 0.01	2.00± 0.03	2.35± 0.03	2.8 ± 0.01	3.1 ± 0.06	3.55± 0.03	54.6
	Control	1.6 ± 0.003	1.66 ± 0.005	1.68 ± 0.005	1.69 ± 0.003	1.83 ± 0.003	1.9 ± 0.06	1.98 ± 0.003	18.6
TK	*E. andrei*	2.5 ± 0.02	2.6 ± 0.00	2.66± 0.003	2.76 ± 0.003	2.86 ± 0.02	3.15 ± 0.006	3.97 ± 0.03	37
	Control	2.5 ± 0.008	2.53 ± 0.003	2.56 ± 0.005	2.57 ± 0.003	2.58 ± 0.003	2.6 ± 0.008	2.65 ± 0.003	6.3
TP	*E. andrei*	0.42 ± 0.02	0.63 ± 0.003	0.72 ± 0.005	0.76 ± 0.003	0.8 ± 0.003	1.13± 0.003	1.57 ± 0.005	73.2
	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	18.5
Ca	*E. andrei*	0.22 ± 0.02	0.24 ± 0.01	0.26 ± 0.009	0.26 ± 0.003	0.29 ± 0.003	0.32 ± 0.006	0.38 ± 0.01	42.1
	Control	0.24 ± 0.003	0.22 ± 0.008	0.24 ± 0.005	0.25 ± 0.005	0.26 ± 0.005	0.27 ± 0.003	0.27 ± 0.003	11.1

Table 4: Pattern of chemical changes (in %) of TKN, TP, TK and Ca during the vermicomposting of coffee husk with cow dung by eisenia andrei.

Nutrients	species	Initial	15th day	30th day	45th day	60th day	75th day	90th day	% of change from 0 day
TKN	*E. andrei*	1.35 ± 0.03	1.4 ± 0.01	1.51 ± 0.01	1.75 ± 0.03	2 ± 0.01	2.1± 0.03	2.49 ± 0.04	45.7
	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	15.6
TK	*E. andrei*	1.9 ± 0.007	1.97 ± 0.001	25 ± 0.03	2.82 ± 0.01	2.93± 0.06	3.3 ± 0.01	3.37 ± 0.05	43.6
	Control	1.9 ± 0.003	1.92± 0.003	1.94 ± 0.003	1.97 ± 0.006	1.99 ± 0.003	2.16 ± 0.03	2.2 ± 0.005	13.6
TP	*E. andrei*	0.15 ± 0.02	0.21 ± 0.01	0.27 ± 0.003	0.29 ± 0.001	0.35± 0.006	0.39 ± 0.003	0.43 ± 0.07	65
	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	25
Ca	*E. andrei*	0.1 ± 0.007	0.12 ± 0.00	0.15 ± 0.00	0.18 ± 0.003	0.2 ± 0.03	0.23 ± 0.03	0.26 ± 0.06	61.5
	Control	0.1 ± 0.003	0.11 ± 0.005	0.11 ± 0.003	0.12 ± 0.005	0.12 ± 0.003	0.12± 0.003	0.13 ± 0.005	15.3

Table 5: Pattern of chemical changes (in %) of TKN, TP, TK and Ca during the vermicomposting of khat waste with cow dung by eisenia andrei.

Nutrients	species	Initial	15th day	30th day	45th day	60th day	75th day	90th day	% of Change from 0day
TKN	*E. andrei*	1.7± 0.01	1.9 ± 0.01	2.47 ± 0.003	2.92 ± 0.003	3.34 ± 0.02	3.54 ± 0.03	3.76 ± 0.01	54.7
	Control	1.7 ± 0.003	1.72 ± 0.01	1.75 ± 0.003	1.76 ± 0.005	1.78 ± 0.003	1.85 ± 0.005	2.11 ± 0.003	19.4
TK	*E. andrei*	1.97± 0.007	1.98 ± 0.003	2.38 ± 0.005	2.58 ± 0.009	2.79 ± 0.01	3 ± 0.006	3.5 ± 0.01	43
	Control	1.98 ± 0.003	1.99 ± 0.003	2.13 ± 0.005	2.16 ± 0.005	2.18 ± 0.005	2.2 ± 0.006	2.23 ± 0.005	11.2
TP	*E. andrei*	0.5 ± 0.003	0.73 ± 0.06	0.77 ± 0.006	0.81 ± 0.003	0.93 ± 0.006	1.14 ± 0.003	1.55 ± 0.01	67.7
	Control	0.5 ± 0.003	0.52 ± 0.003	0.55 ± 0.005	0.57 ± 0.005	0.6 ± 0.008	0.63 ± 0.005	0.65 ± 0.005	23
Ca	*E. andrei*	0.2 ± 0.006	0.21 ± 0.006	0.25 ± 0.00	0.28± 0.003	0.28 ± 0.003	0.37 ± 0.003	0.39 ± 0.00	48.7
	Control	0.2 ± 0.003	0.22 ± 0.005	0.22 ± 0.005	0.23 ± 0.005	0.24 ± 0.003	0.25 ± 0.003	0.25 ± 0.008	20

Total Organic Carbon

Generally the total organic carbon in all test treatments and the control showed a declining trend as the decomposition progressed. Beddings treated with *Eisenia andrei* significantly varied from their corresponding initial substrate as well as the control ($p<0.05$) however, no significant variation was observed in control beddings. Wastes treated by this worm species 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 during the final day of vermicomposting. Like the findings of this study, the level of total carbon showed negative correlation with vermicomposting duration in several previous findings. Meglar[40] reported a significant reduction in total organic carbon content in a vermicompost produced from olive oil industrial waste. Lower level of organic carbon was observed in the vermicomposted Partenium plant than in non vermicomposted Partenium[41]. Elvira *et al.*[18] was identified that vermicomposting of pulp-mill sludge for 40 days decreased carbon content by 1.7-fold. Suthar[42] also described that mineralization of organic matter in sewage sludge by earthworms leads to a considerable decrease in total organic carbon (TOC) content.

The reduction of carbon in vermicompost is the result of respiration and mineralization of the organic matter mainly by microorganisms and earthworms. Since vermicomposting is a combined action of earthworm and microorganisms, earthworms through their fragmenting action modify the substrate condition which consequently increase the surface area for microbial action[4] thus promote carbon loss through respiration and in similar pattern the oxidation of organic matter within the vermicomposting unit is enhanced by earthworm population in the vermicomposting unit. Suthar[28]stated that excreta and body fluid of earthworms like mucus encourage microbial multiplication which in turn promotes rapid respiration that minimizes the carbon level of the waste.

C: N Ratio

In this study C: N ratio of all wastes treated by *Eisenia andrei* 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[42] reported 62.7% reduction of C/N ratio in vermicomposting domestic waste. Similarly, Nath *et al.*[19] described a sharp decline of C:N ratio in vermicomposting different combinations of animal waste, agro and kitchen waste. In vermicomposting Parthenium plant and neem leaves, the amount of carbon to nitrogen ratio decreased significantly[41]. Suthar and Singh[43] 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[44]. According to Morais and Queda[45] 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 both species of earthworms, showed the C:N ratio within the acceptable limit (Table 5)for agricultural usage.

Table 6: Final C: N ratio and reduction rate for wastes treated by *E. andrei*

C/N value	Reduction rate (%)
7.9	60
9	68
13.5	64.6
11.9	61

References

1. Sangwan P., Kaushik C.P. and Garg V.K., Vermicomposting of sugar industry waste (press mud) mixed with cow dung employing an epigeic earthworm *Eisenia fetida*, Wast Manag. Resear., 1997, 00, 1-5.
2. Wong J.M.C., Fang G.X. and Wong M.H., Feasibility of using ash residues composting materials for sewage sludge, Environ Technol, 1997, 18, 563-568.
3. Abbasi T., Gajalakshmi S. and Abbasi S.A., Towards modeling and design of vermicomposting systems: mechanisms of composting/vermicomposting and their implications, Ind. J. Biotechnol., 2009, 8,177–182.
4. Dominguez J., State-of-the-art and new perspectives on vermicomposting research, In: Edwards C.A.(ed.), Earthworm Ecology, CRC Press LLC, Boca Raton, FL, 2004, 424.
5. Fransa A.S. and Olivera L.S., Alternative uses for coffee husks-a solid waste from green coffee production, Proceedings of the international conference on CBEE,Singapore, 2009.
6. Adams M.R. and Dougan J., Biological management of coffee processing, Trop Sci, 1981, 123,178-196.
7. Roussos S, Perraud IG, Raimbault M, Aquahuatl MA, Hernandez MRT, Favela E, Gonzalez GV and Ramakrishna M, Biotechnological management of coffee pulp-isolation, screening, characterization, selection of caffeine-degrading fungi and natural micro flora present in coffee pulp and husk, Appl Microbiol Biotechnol, 1995, 42, 756-762
8. Amede T and Diro M, Optimizing Soil Fertility Gradients in the Enset (*Ensete ventricosum*) Systems of the Ethiopian Highlands: Trade-offs and Local Innovations, in Improving Human Welfare and Environmental Conservation by Empowering Farmers to Combat Soil Fertility Degradation, edited by A Bationo A.(ed), African Highlands Initiative (AHI) working papers 2005,1-15.
9. Bierwirth J., The farming system and the use of organic wastes in rural small scale farms in Composting experiments in the bio village project, Gurage Zone, Southern Ethiopia, ICIPE, Ethiopia, 2000,1- 3.
10. Muthukumaravel K., Amsath A., Sukumaran M., Vermicomposting vegetable waste using cow dung, E-j Chem, 2008, 5(4), 810-813.
11. Ndegwa P.M., Thompson S.A. and Das K.C., Effects of stocking density and feeding rate on vermicomposting of biosolids, Biores Technol, 2000,71, 5–12
12. Nelson D.W. and Sommers L.E., Total carbon and organic carbon and organic matter, in *Method of Soil Analysis*, Page A.L., Miller R.H., Keeney D.R.(ed.), American Society of Agronomy, Madison, 1982, 539-579.
13. Bremner J.M. and Mulvaney R.G., Nitrogen total in Method of Soil Analysis, Page A.L., Miller R.H. and Keeney D.R., American Society of Agronomy, Madison, 1982, 575-624.
14. Anderson J.M. and Ingram J.S.I., Tropical Soil Biology and Fertility: A Handbook of Methods CAB International, Wallingford, UK, 1996, 221.
15. Simard R.R., Ammonium acetate extractable elements in Soil Sampling and Methods of Analysis, Martin R., and Carter S.(eds), Lewis, Boca Raton, Florida, USA, 1993, 39–43.
16. Gunadi B and Edwards CA, The effect of multiple applications of different organic wastes on the

growth, fecundity and survival of *Eisenia fetida*. *Pedobiologia*, **47,** 321–330 (2003).

17. Atiyeh R.M., Dominguez J., Subler S. and Edwrads C.A., Changes in biochemical properties of cow manure during processing by earthworms (*Eisenia andrei*, Bouche) and the effects on seedling growth, Pedobiologia, 2000, 44, 709–724.
18. Elvira C., Sampedro L., Benitez E., and Nogales R., Vermicomposting of sludges from paper mill and dairy industries with *Eisenia andre.* A pilot scale study, Biores. Techn., 1998, 63, 205 – 211.
19. Nath G., Singh K. and Singh D.K., Effect of different combinations of animal dung and agro/kitchen wastes on growth and development of earthworm *Eisenia fetida*, Austr J. Basic appl. Sci., 2009, 4, 3553-3556.
20. Hartenstein R and Hartenstein F, Physicochemical changes affected in activated sludge by the earthworms *Eisenia fetida*, J. Environ. Qual., 1981, 10(3), 377-382.
21. Nogales R., Melgar R., Guerrero A., Lozada G., Beniteze E., Thompson R., Gomez M. and Garvin MH, Growth and reproduction of *Eisenia andrei* in dry olive cake mixed with other organic wastes, Pedobiologia, 1999, 43(6), 744–752.
22. Komilis D.P. and Ham R.K., Carbon dioxide and ammonia emissions during composting of mixed paper, yard and food waste, Wast Manag, 2006, 26**,** 62–70.
23. Chauhan A. and Joshi P.C., Composting of Some Dangerous and Toxic Weeds Using *Eisenia fetida*, J Amer Sci, 2010, 6(3), 1-6.
24. Ananthakrishnasamy S., Gunasekaran S. and Manimegala G., Fly ash-lignite waste management through vermicomposting by indigeneous earthworms *Lampito mauritii*, Amer. Eur. J. Agric. Environ. Sci., 2009, 5(6), 720-724.
25. Zularisam A.W., Zahirah Z.S., Zakaria I., Syukiri M.M., Anwar A. and Sakinah M., production of biofertilizer from vermicomposting process of manucipal sewage sludge, J. Appl Sci, 2010, 10(7), 580-584.
26. Venkatesh R.M. and Eevera T., "Mass reduction and recovery of nutrients through vermicomposting of fly ash", Appl. Ecol. Environ. Resear., 2008, 6, 77–84.
27. Pramanik P., Ghosh G.K., Ghosal P.K. and Banik, P., Changes in organic-N, P and K and enzyme activities in vermicompost of biodegradable organic wastes under liming and microbial inoculants, Biores Technol, 2007, 98, 2485–2494.
28. Suthar S., Vermicomposting potential of *Perionyx sansibaricus* (Perrier) in different waste materials, Bioresour Tech, 2007, 98, 1231-1237.
29. Delgado M., Bigeriego M., Walter I. and Calbo R., Use of California redworm in sewage sludge transformation, Turrialba, 1995, 45, 33-41.
30. Orozco F.H., Cegarra J., Trujillo L.M. and Roig A., Vermicomposting of coffee pulp using the earthworm *E. fetida*: Effects of C and N contents and the availability of nutrients, Biol. Fert. Soils, 1996, 22,162-166.
31. Dominguez J., Briones M.J.I. and Mato S., Effect of the diet on growth and reproduction of *Eisenia Andrei* (Oligochaeta, Lumbricidae), Pedobiologia, 1997, 41, 566-576.
32. Kaviraj S, Sharma S, Municipal solid wastes management through vermicomposting employing exotic and local species of earthworm, Biores. Technol., 2003,90, 169-173.
33. Benitez E., Nogales R., Elvira C., Masciandaro G., Ceccanti B., Enzyme activities as indicators of the stabilization of sewage sludges composting with *Eisenia fetida*, Biores.Tech., 1999, 67, 297-303.
34. Lee K.E., Some trends opportunities in earthworm research or: Darwin's children. The future of our discipline, Soil Biol. Biochem., 1992, 24, 1765-1771.
35. Ndegwa P.M., Thompson S.A. and Das K.C., Effects of stocking density and feeding rate on vermicomposting of biosolids, Biores. Technol., 2000, 71, 5–12.
36. Pattnaik S. and Reddy M.V., Nutrient status of vermicompost of urban green waste processed by three earthworm species- *Eisenia fetida*, *Eudrilus eugeniae*, and *Perionyx excavates,* Appl. Environ. soil scie., 2010, 10, 1-13.
37. Ansari A.A., Indigenous approach in organic solid waste management in Guyana (South America), 2009, Glob. J. Environ. Resear, 3(1), 26-28.
38. Jadia C.D. and Fulekar M.H., "Vermicomposting of vegetable waste: a bio-physicochemical process based on hydro operating bioreactor", Afr J Biotechn, 2008, 7, 3723–3730.
39. Chaudhuri P.S., Pal T.K., Bhattacharjee G. and Dey S.K., Chemical changes during

vermicomposting (*Perionyx excavatus*) of kitchen wastes, Trop. Ecol., 2000, 41, 107–110.

40. Melgar R., Benitez E. and Nogales R., Bioconversion of wastes from olive oil industries by vermicomposting process using the epigeic earthworm *Eisenia Andrei*, J. Environ. Sci. Health, 2009, 44(5), 488 – 495.
41. Sivakumar S., Kasthuri H., Prabha D., Senthilkumar P., Subbhuraam C.V. and Song V.C., Efficiency of composting parthenium plant and neem leaves in the presence and absence of an Oligochaete, *Eisenia fetida*, Iran J. Environ. Health Sci. Eng., 2009, 6(3), 201-208.
42. Suthar S, Vermicomposting of Vegetable Market Solid Waste Using *E. fetida*: Impact of Bulking Material on Earthworm Growth and decomposition rate, Ecol. Engin., 2009, 35(5), 914-920.
43. Singh S and Suthar S, Vermicomposting of domestic waste by using two epigeic earthworms *Perionyx excavatus* and *P. sansibaricus*, Int. J. Environ. Sci. Tech., 2008, 5(1), 99-106.
44. Ansari A.A. and Jaikishun S., An investigation in to the vermicomposting of sugar cane bagasse and rice straw and its subsequent utilization in cultivation of phaseoulus vulgaris L. In Guyana, American-Eurasian J. Agric. Environ. Sci, 2010, 8(6), 666-671.
45. Morais F.M.C. and Queda C.A.C., Study of storage influence on evolution of stability and maturity properties of MSW compost, In: Advances for a sustainable Society Part II: Proceedings of the fourth International Conference of ORBIT association on Biological Processing of Organics, Perth, Australia (2003).

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