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Vermidegradation of Municipal Solid Waste Management through Using Epigeic Earthworm *Eudrilus Eugeniae* (Kinberg)

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Abstract: *In our country over population exploration, migrate rural to urban, agro-industries development, agricultural expansion and market wastes have led to dumping of organic wastes caused a serious causes to the environment. India enormous quantities of disposable organic wastes materials like municipal solid waste (MSW) rich in nutrients were presented. Though major nutrients (Nitrogen (N), Phosphorus (P) and Potassium (K), and minor nutrients are available more in MSW, it is not properly decomposed (or) biodegradation (vermicomposting). MSW can't be eaten directly by earthworms due to its odour, heavy metals toxicity, pests; water leach ate to organic wastes etc. So the organic wastes such as dairy farm waste – cow dung (CD) and a agro-sugar industrial waste - pressmud (PM) with clay soil high nutritive content were mixed in equal proportion and used as bedding material (BM).*

The experimental media were prepared on dry weight basis by mixing the MSW + BM in the following percentage: T_1 – 20% BM + 80% MSW, T_2 – 40% BM + 60% MSW, T_3 – 60% BM + 40% MSW, T_4 – 80% BM + 20% MSW, C_1 Control (BM alone) were also maintained separately. To observe the changes in pH, electrical conductivity (EC dS/m), organic carbon (OC %) and macro nutrients (N%, P% and K%) and carbon: nitrogen (C:N) ratio in the initial day and vermicomposts of earthworm from the above mentioned media at the intervals of 0, 15, 30, 45 and 60^{th} day. The variation of pH near neutral was observed in the vermicomposts of T_3 it might be due to higher acid production by vermicomposts. Higher EC values were achieved in the vermicomposts of T_3 it could be due to the higher mineralization by salts. The chemical analysis of vermicompost showed significant increase in the level of major nutrients over worm unworked compost (initial) mixture. Among the different experimental proportions T_3 showed significant increase in the level of macro nutrients. Reduced content of organic carbon was observed in all the treatments but most reduction was found in T_3.The drastic reduction in C:N ratio were found in the vermicomposts. The higher quantities of degradable organic waste (MSW, Leaf litter, restaurant wastes and vegetable market wastes) available in municipalities and road sides can be vermicomposted along with any organic additives (CD and Pressmud) to convert into the valuable organic manure. In addition to this, it may be recommended that the vermicompost from MSW is utilized for organic agriculture.

Keywords: *Municipal solid waste, Cow dung, Pressmud, Eudrilus eugeniae*

1. Introduction

In India, the amount of waste generated per capita is estimated to increase at a rate of 1 - 33% annually [1]. In such conditions, the total waste quantity generated in 2047 would be approximately more than five times of present level. This enormous increase in solid waste will have significant impacts in terms of the land required for disposing this waste as well as on methane emission. Moreover, 40 - 60% solid wastes in India are of organic nature and open dumping of such garbage not only facilitates the breeding for disease vectors, e.g., flies, mosquitoes, cockroaches, rats, other pests and create odour, but at the same time also creates the issue of environmental pollution. Since, recyclable organic waste can be converted into some useful products for agriculture industries, if processed through cost – effective technique.

Earthworm farming (vermiculture) is another bio-technique for converting the solid organic waste into compost [2]. Earthworms feed on partially decomposed matter, consuming five times of their body weight of organic matter per day. The ingested food is further decomposed in the gut of the worms, resulting in particle size reduction. The worm cast is a fine, odour less and granular product. This product can serve as a bio-fertilizer in agriculture. The area required is larger, when compared to dry composting [3].

Ananthakrishnasamy and Gunasekaran [4] reported that the earthworm *L. mauritii* was found suitable for the vermicomposting of bedding materials(BM) (pressmud and cowdung) and municipal solid waste mixed with different proportions particularly (*i.e.*) 80% + 20% (BM + MSW) dry weight basis. In these treatment worm worked composts (vermicomposts) is highest amount of nutrients content (pH, EC, OC, N, P, K and C:N ratio) were presented.

Dumping of wastes on land not only reduces the availability of fertile land, but also pollutes air, water and soil [5]. Though India has a huge biomass of crop residues like sugarcane trash, straw, bagasse, coir pith waste, cotton waste, farm land waste, industrial wastes, MSW etc., the potentiality of the organic resources have not yet been fully tapped [6].

Very few studies have been made on the vermicomposting of MSW, they are – Kaviraj and Sharma [7] (using *Eisenia fetida* and *Lampito mauritii* with cow dung; Tognetti *et al*. [9] using *Eisenia fetida* with wood shavings; Kumar *et al*. [9] using *Eudrilus eugeniae* with heavy metals; John Paul *et al*. [10] using *P. ceylanensis* with cowdung; Sriramulu Ananthakrishnasamy and Govindarajan Gunasekaran [11] using reproduction of *Eudrilus eugeniae* with MSW and cowdng. Though the above studies MSW vermicomposts are available there is limited evidence regarding the comparison on the quality of vermicompost with *E. eugeniae.* Therefore much work is needed to evaluate the role of commonly available exotic *E. eugeniae* in vermicomposting of MSW.

The aim of the present study was to identify the efficiencies of *E. eugeniae* on vermicomposting of MSW with a different bedding material cowdung and pressmud (CD + PM). So it was planned to evaluate the quantity of N, P, K and observe the changes in pH and EC of the substrate (MSW) before (Initial) and after vermicomposting.

2. MATERIALS AND METHODS

2.1. Collection and Maintenance of *Eudrilus Eugeniae*

The breeding stock of *Eudrilus eugeniae* was obtained from the culture maintained Department of Zoology Wing- DDE, Annamalai University. *Eudrilus eugeniae* were maintained in a separate cement tank. Cow dung was used as substrate to maintain the adult worms; moisture content of 60 – 70% was continuously maintained by sprinkling water on the stock culture of the cement tank. This stock culture in the cement tank were covered with gunny bag and maintained at room temperature (27± 2°) inside the animal house.

2.2. Municipal Solid Waste (MSW)

MSW was collected from Sethiathope town Panchayat, Cuddalore District, Tamil Nadu. After removing the plastics, polythene, metal scraps and glass pieces MSW was dried and brought by using jute bags to the laboratory.

2.3. Cowdung (CD)

Cow dung is deemed as highly suitable natural feed for earthworms Lee, [12] (1985). Hence, cow dung (CD) is selected for the present study for the biodegradation of municipal solid waste (MSW). Urine and straw free cow dung was collected from dairy yard at the Faculty of Agriculture, Annamalai University. It was sun dried, powdered and stored in jute bags.

2.4. Pressmud (PM)

The pressmud was collected from M.R.K Co-operative Sugar Mill, Sethiathope. The collected pressmud was cured for a month to remove the odour. Then it was used for the preparation of Bedding Material (BM).

2.5. Preparation of Bedding Material (BM)

The cow dung and one month old cured pressmud was used for the preparation of bedding material and they were equally mixed on dry weight basis and kept as such for 15 days and used for the preparation of substrate for vermiculture.

2.6. Preparation of Different Experimental Media – with Bedding Material (BM) and Municipal Solid Waste (MSW)

Combinations of bedding material (BM) and municipal solid waste (MSW) in four proportions were prepared in the following order given below:

S. No.	Experimental Proportions of Bedding Material (BM) + Municipal Solid Waste (MSW)	Weight of Bedding Material (BM) + Municipal Solid Waste (MSW)
C_1	BM alone (Control)	500g CD + 500g PM + 200g soil
T_1	20% + 80% (BM + MSW)	200g BM + 800g MSW + 200g soil
T_2	40% + 60% (BM + MSW)	400g BM + 600g MSW + 200g soil
T_3	60% + 40% (BM + MSW)	600g BM +400g MSW+ 200g soil
T_4	80% + 20% (BM + MSW)	800g BM + 200g MSW+ 200g soil

C_1, T_1 – T_4 – Substrates used for Eudrilus eugeniae

After the preparation of substrates in the above different proportions, water was sprinkled and kept as such for thermophilic composting for 15 days.

2.7. Inoculation of Earthworms

After the completion of thermophilic composting fifteen grams of sexually mature, clitellate *Eudrilus eugeniae* (approx. 38 days old) were introduced in plastic troughs; containing 1 Kg substrate + 200 g of soil. Bedding material alone was used as control, separately for *E. eugeniae* as C_1 respectively. Six replications in each experimental treatment have been maintained for 60 days.

2.8. Collection of Vermicompost Samples for Analysis

Samples were collected from all initial substrates (0-day) and vermicomposts on 15, 30, 45 and 60^{th} days. Then the samples were air dried (shadow place), sieved and stored in polythene bags for analysis.

2.9. Physico – Chemical Analysis of Vermicomposts Samples

Analysis of physico – chemical parameters of pH and EC were determined by the method described by ISI Bulletin [13]. The organic carbon was determined by the empirical method followed by Walkely and Black [14]. The total nitrogen (N %), Total phosphorus (P %), Total Potassium (K %) content of the sample was estimated, by Kjeldahl method as per Tandon [15], Colorimetric method was used for phosphorus estimation and flame photometric method was used for potassium. C:N ratio was calculated by dividing the percentage of carbon estimated for the manure sample with the percentage of nitrogen estimated for the same manure sample.

2.10. Statistical Analysis

The data on various chemical characteristics of samples were computed and mean values with standard deviation (S.D). The statistical significance between treatments was analyzed by using two - way analysis of variance (ANOVA).

3. Results and Discussion

The pH, EC, OC, C:N ratio and macronutrients in different MSW + BM mixtures, worm unworked initial (0 - day) compost and worm worked vermicomposts of *E. eugeniae* at different time intervals (15, 30, 45 and 60^{th} days) are represented in the Tables - 1 to 7.

3.1. pH

The pH in the vermicomposts was reduced in all the mixtures (T_1 – T_4) and in controls (C_1) from initial day to 60^{th} day and they are presented in Table - 1. The pH values were reduced more in the vermicomposts of *E. eugeniae.* The maximum percentage reduction was observed in T_3 (- 6.51%). The percentage change in other treatments are in the following order $C_1 > T_4 > T_1$ and T_2.

Kaviraj and Sharma [7] have reported that pH decline in all the cases and was believed to occur because of the high mineralization of the nitrogen and phosphorus into nitrates/nitrites and orthophosphate. Padmavathiamma *et al*. [16] have reported that the pH of vermicompost ranged from neutral to alkaline, whereas it was acidic for conventional compost.

John Paul *et al.* [10] reported, decrease in pH in all the substrates (different ratios of MSW + CD) after vermicomposting. They observed highest reduction in pH in the substrate which had higher percentage of CD with MSW as observed in our study. In the present study though the reduction in the pH was observed in the vermicomposts of earthworm highest reduction towards neutrality was observed in the vermicomposts of *E. eugeniae*. The reason for the variation in the pH values of vermicomposting made by *E. eugeniae* could be due to species – specific difference in their mineralization efficiency as suggested by Suthar and Singh [17].

Table1. *Variations in the pH of vermicomposts from MSW made by E. eugeniae (p<0.05)*

Substrate Proportions	***E. eugeniae***				
	Vermicomposting Days				
	0 (Initial)	**15**	**30**	**45**	**60**
C_1	7.40±0.060	7.31±0.069	7.25±0.049	7.10±0.051	7.03±0.061 (–5.00)
T_1	7.89±0.052	7.80±0.070	7.69±0.051	7.60±0.054	7.55±0.067 (–4.31)
T_2	7.70±0.064	7.56±0.050	7.44±0.053	7.37±0.054	7.34±0.051 (–4.68)
T_3	7.53±0.063	7.44±0.054	7.31±0.061	7.11±0.041	7.04±0.051 (–6.51)
T_4	7.47±0.041	7.21±0.049	7.17±0.063	7.13±0.039	7.10±0.062 (–4.95)

Two–Way Anova

Analysis of variance	Sum of square	df	Mean of square	F-value	P-value
Rows	0.893216	4	0.223304	95.46986	5.93E-11
Columns	0.483896	4	0.120974	51.72039	5.94E-09
Error	0.037424	16	0.002339		

C_1– Control (BM alone), T_1– (20% BM + 80% MSW), T_2 – (40% BM + 60% MSW), T_3 – (60% BM + 40% MSW), T_4 – (80% BM + 20% MSW)

Initial (0) – Worm unworked substrates, Mean ± SD of six observations.

(+/–) – Percent change of increase or decrease over the initial.

3.2. Electrical Conductivity (EC)

The EC values were increased over initial in controls and in all treatments (vermicomposts of earthworm) and they are presented in Table- 2.The vermicomposts of *E. eugeniae* the minimum EC value was observed in T_1 (1.79 ± 0.097) and the maximum value in C_1 (1.98 ± 0.123) on initial day compost. The EC values were gradually increased in all treatments and control. The percentage change in EC value was most in T_3 (53.10%) and the minimum value was obtained in T_1 (36.87%) on 60th day.

Table2. *Electrical Conductivity (dS/m) of the vermicomposts from MSW made by E. eugeniae (p<0.05)*

Substrate Proportions	***E. eugeniae***				
	Vermicomposting Days				
	0 (Initial)	**15**	**30**	**45**	**60**
C_1	1.98±0.123	2.14±0.122	2.37±0.089	2.69±0.123	2.86±0.114 (44.44)
T_1	1.79±0.097	1.83±0.131	2.2±0.114	2.28±0.121	2.45±0.094 (36.87)
T_2	1.82±0.125	1.90±0.092	2.31±0.142	2.46±0.120	2.53±0.093 (39.01)
T_3	1.89±0.101	1.97±0.093	2.30±0.092	2.66±0.104	2.91±0.087 (53.10)
T_4	1.91±0.087	2.22±0.090	2.46±0.126	2.54±0.112	2.72±0.086 (42.41)

Two–Way Anova

Analysis of variance	Sum of square	df	Mean of square	F-value	P-value
Rows	0.316136	4	0.079034	10.404	0.00024
Columns	2.336776	4	0.584194	76.90305	3.07E-10
Error	0.121544	16	0.007597		

C_1– Control (BM alone), T_1 - (20% BM + 80% MSW), T_2– (40% BM + 60% MSW), T_3– (60% BM + 40% MSW), T_4– (80% BM + 20% MSW)

Initial (0) – Worm unworked substrates, Mean ± SD of six observations.

(+/–) – Percent change of increase or decrease over the initial.

Wong *et al*. [18] reported that a gradual increase in EC was observed with increase in decomposition time and it might due to the loss of weight of organic matter and release of different mineral salts in available forms (such as phosphate, ammonium and potassium).

Gradual increase in the EC was recorded in all the feed substrates of the present study of during vermicomposting were fall in line with the observations made by Garg *et al*.[19] where they suggested that it may be attributed due to freely available ions and minerals that are generated during ingestion and excretion by earthworm.

Jayakumar *et al*. [20] observed increased EC in the vermicompost than worm unworked compost and during vermicomposting process, the soluble salt level increases due to the mineralization activity of earthworms and microorganisms in the organic substance and as well in the gut of earthworms.

In the present observation, the EC level gradually increased from the initial substrate to worm worked vermicompost in all experimental ratios and control. Our work was supported by the studies of Karthikeyan *et al*. [21]; John Paul *et al*. [10]; Ananthakrishnasamy and Gunasekaran [22] who observed the increased EC in the vermicomposts of market waste and MSW respectively.

3.3. Organic Carbon (OC %)

The OC content of vermicomposts and control are presented in Table - 3. The vermicomposts of *E. eugeniae* show a higher reduction in OC content were observed. The T_3 showed maximum reduction (*i.e.* - 46.36%) and the T_1 (-31.85) showed minimum reduction. In the present study, vermicomposts obtained from MSW show reduction in OC percentage than initial substrates.

Table3. *Organic carbon (%) level in the vermicomposts from MSW made by E. eugeniae (p<0.05)*

Substrate Proportions	***E. eugeniae***				
	Vermicomposting Days				
	0 (Initial)	**15**	**30**	**45**	**60**
C_1	36.14±1.21	34.17±1.42	29.61±1.18	24.41±1.15	21.37±1.20 (–40.87)
T_1	38.37±1.16	36.82±1.55	32.87±1.27	29.67±1.17	26.15±1.24 (–31.85)
T_2	37.28±1.36	34.63±1.39	31.80±1.37	28.13±1.26	25.31±1.41 (–32.11)
T_3	36.22±1.44	32.69±1.42	27.77±1.29	22.89±1.31	19.43±1.21 (–46.36)
T_4	35.81±1.41	31.73±1.32	27.18±1.35	24.36±1.54	22.14±1.29 (–38.17)

Anova

Analysis of variance	Sum of square	df	Mean of square	F-value	P-value
Rows	91.69896	4	22.92474	22.10967	2.36E-06
Columns	646.6756	4	161.6689	155.9209	1.35E-12
Error	16.58984	16	1.036865		

C_1– Control (BM alone), T_1– (20% BM + 80% MSW), T_2– (40% BM + 60% MSW), T_3– (60% BM + 40% MSW), T_4– (80% BM + 20% MSW)

Initial (0) – Worm unworked substrates, Mean ± SD of six observations.

(+/–) – Percent change of increase or decrease over the initial.

Dominguez [23] suggested that vermicomposting is a combined operation of earthworm and microorganisms in which the earthworm fragments and homogenizes the ingested material through muscular action of their foregut and also add mucus and enzymes ingested material and there by increases the surface area for microbial action while, microorganisms perform the biochemical degradation of waste material providing some extra – cellular enzymes required for organic waste decomposition within the worm's gut. Moreover, this biological mutuality caused C loss in the form of CO_2 from the substrates during the decomposition of organic waste.

The significant reduction of organic carbon content in the samples collected on 15, 30, 45 and 60th days of the present study, supporting the findings of Ramalingam and Thilagar [24].

The present results are similar with previous findings of Kaviraj and Sharma [7] in MSW + CD, Karthikeyan *et al*. [21] in market waste + CD and John Paul *et al*. [10] in MSW + CD who observed the highest OC reduction in worm worked vermicompost over the initial substrates. In the present study, vermicomposts of the treatments vary in their OC content and this may be due to the differential feeding efficiency of the earthworms.

3.4. Macronutrients

The quantity of macronutrients increased in the compost of earthworm from 0 day to 60th day. The changes observed in NPK content out of various treatments are presented in Tables- 4 to 7.

Nitrogen (N %)

The content of total nitrogen on 0, 15, 30, 45 and 60th day vermicomposts of various mixtures are presented in Table-4. The vermicomposts of *E. eugeniae* the highest mineralization of N was observed in T_3 (3.38 ± 0.097) and it was followed by C_1 (3.28 ± 0.095), T_4 (3.20 ± 0.121), T_2 (2.93 ± 0.115) and T_1 (2.84 ± 0.097).

Table4. *Nitrogen (%) level in the vermicomposts from MSW made by E. eugeniae (p<0.05)*

Substrate Proportions	*E. eugeniae*				
	Vermicomposting Days				
	0 (Initial)	15	30	45	60
C_1	2.14±0.095	2.43±0.122	2.87±0.119	3.09±0.113	3.28±0.095 (53.27)
T_1	1.92±0.105	2.17±0.121	2.44±0.114	2.66±0.121	2.84±0.097 (47.92)
T_2	1.97±0.091	2.26±0.094	2.58±0.095	2.76±0.115	2.93±0.115 (48.73)
T_3	1.99±0.112	2.28±0.096	2.64±0.096	3.06±0.121	3.38±0.097 (69.85)
T_4	2.11±0.114	2.42±0.127	2.86±0.113	3.11±0.125	3.20±0.121 (51.66)

Anova

Analysis of variance	Sum of square	df	Mean of square	F-value	P-value
Rows	0.485816	4	0.121454	15.24081	2.56E-05
Columns	4.034296	4	1.008574	126.5622	6.8E-12
Error	0.127504	16	0.007969		

C_1– Control (BM alone), T_1– (20% BM + 80% MSW), T_2– (40% BM + 60% MSW), T_3– (60% BM + 40% MSW), T_4– (80% BM + 20% MSW)

Initial (0) – Worm unworked substrates, Mean ± SD of six observations.

(+/–) – Percent change of increase or decrease over the initial.

Phosphorus (P %)

The quantity of P present in the vermicomposts made by *E. eugeniae* on 0, 15, 30, 45 and 60th day of earthworm are presented in Table – 5. The level of P content increased gradually in control and in all treatments. The level of P was increased in all treatments and control upto 60 days. From the percentage increased over initial it can be inferred that the mineralization of P may be ranked in the following order i.e. T_3 (36.36%) > C_1 (31.85%) > T_4 (29.32%) > T_2 (26.92%) and T_1 (24.80%) on 60th day.

Table5. *Phosphorous (%) level in the vermicomposts from MSW made by E. eugeniae (p<0.05)*

Substrate Proportions	*E. eugeniae*				
	Vermicomposting Days				
	0 (Initial)	15	30	45	60
C_1	1.35±0.051	1.45±0.047	1.57±0.055	1.68±0.042	1.78±0.031 (31.85)
T_1	1.29±0.052	1.37±0.052	1.47±0.050	1.55±0.043	1.61±0.039 (24.80)
T_2	1.30±0.049	1.39±0.053	1.49±0.053	1.57±0.051	1.65±0.041 (26.92)
T_3	1.32±0.047	1.40±0.049	1.54±0.041	1.67±0.034	1.80±0.049 (36.36)
T_4	1.33±0.053	1.44±0.047	1.53±0.037	1.61±0.030	1.72±0.047 (29.32)

Anova

Analysis of variance	Sum of square	df	Mean of square	F-value	P-value
Rows	0.040784	4	0.010196	12.8494	7.16E-05
Columns	0.494344	4	0.123586	155.748	1.36E-12
Error	0.012696	16	0.000794		

C_1– Control (BM alone), T_1– (20% BM + 80% MSW), T_2– (40% BM + 60% MSW), T_3– (60% BM + 40% MSW), T_4– (80% BM + 20% MSW)

Initial (0) – Worm unworked substrates, Mean ± SD of six observations.

(+/–) – Percent change of increase or decrease over the initial.

Potassium (K %)

The quantities of potassium present in the vermicomposts made by E. eugeniae are presented in Table- 6. The content of potassium increased in all observations from the initial value. In *E. eugeniae* vermicomposts, the maximum mineralization was found in T_3 on 60th day, it was followed by C_1, T_4, T_2 and T_1. But in the vermicomposts of *E. eugeniae* the K mineralization was more and the quantity of K were 1.12 ± 0.031, 1.28 ± 0.025, 1.25 ± 0.024, 1.24 ± 0.021and 1.20 ± 0.037 respectively in C_1, T_1, T_2, T_3 and T_4.

Table6. *Potassium (%) level in the vermicomposts from MSW made by E. eugeniae (p<0.05)*

Substrate Proportions	*E. eugeniae*				
	Vermicomposting Days				
	0 (Initial)	**15**	**30**	**45**	**60**
C_1	0.66±0.025	0.80±0.041	0.91±0.033	1.07±0.032	1.12±0.031 (69.60)
T_1	0.78±0.027	0.93±0.027	1.17±0.029	1.24±0.032	1.28±0.025 (64.10)
T_2	0.75±0.036	0.90±0.031	1.10±0.019	1.18±0.029	1.25±0.024 (66.67)
T_3	0.73±0.025	0.88±0.031	1.09±0.029	1.16±0.021	1.24±0.021 (69.90)
T_4	0.71±0.036	0.83±0.033	1.07±0.031	1.14±0.017	1.20±0.037 (69.00)

Anova

Analysis of variance	Sum of square	df	Mean of square	F-value	P-value
Rows	0.078256	4	0.019564	37.33588	6.32E-08
Columns	0.846616	4	0.211654	403.9198	7.63E-16
Error	0.008384	16	0.000524		

C_1– Control (BM alone), T_1– (20% BM + 80% MSW), T_2– (40% BM + 60% MSW), T_3– (60% BM + 40% MSW), T_4– (80% BM + 20% MSW)

Initial (0) – Worm unworked substrates, Mean ± SD of six observations.

(+/–) – Percent change of increase or decrease over the initial.

The gradually increased content of N, P and K was observed in the vermicomposts obtained from all the experiments and control. Particularly vermicomposts of T_3 by *E. eugeniae* have been shown to posses higher N, P and K over the initial substrates where the effective decomposition of MSW was carried out by the combined action of earthworms and microbes as suggested by Garg *et al*. [19]. Increased levels of N, P and K in the vermicomposts are in conformity the results of earlier workers (Review: Mariappan and Vijayalakshmi, [25]; Pandit *et al*., [26].

Jayakumar *et al*. [20] reported that the pressmud with *E. eugeniae*, *L. mauritii* and *P. ceylanensis* and showed very good results of N, P and K, microbial population and enzyme activity in the vermicomposts of *E. eugeniae* and was followed by *P. ceylanensis* and *L. mauritii*. Zularisam *et al*. [27] have reported that earthworms play a crucial role in enhancing and improving the nitrogen profile of the waste by the addition of mucus, nitrogenous casts and by facilitating microbial mediated nitrogen mineralization. Falling in line in the above mentioned studies in the present study also the *E. eugeniae* due to its higher feeding rate shows highest N, P and K content in their vermicasts.

The increased level of N, P and K in the vermicomposts was in conformity with the observations of earlier studies (Jayakumar *et al*., [20]; John Paul *et al*., [10]; Ananthakrishnasamy, [28].

C:N ratio

Vermicomposts obtained from all treatments show decline in the C:N ratio. The results are presented in Table – 7. Vermicomposts all the samples from 0 day to 60th day showed better reduction in C:N ratio. All the vermicomposts samples made by *E. eugeniae* show the reduction of C:N ratio. On 60th day, the percentage change over the initial was highest in T_3 (–68.41%), it was followed by of C_1 (–61.40%), T_4 (–59.22%), T_2 (–54.33%) and T_1 (–53.90%). From the beginning of the experiment there was a reduction in C:N ratio in the worm worked vermicomposts of all treatments and control. The highest reduction in the content of C:N ratio were observed in T_4 by *E. eugeniae* reflected the efficient worm activity, leading to accelerated rate of decomposition and mineralization, thereby resulting in high grade, nutrient rich, good quality compost.

Table7. *C:N ratio in the vermicomposts from MSW made by E. eugeniae (p<0.05)*

Substrate Proportions	*E. eugeniae*				
	Vermicomposting Days				
	0 (Initial)	**15**	**30**	**45**	**60**
C_1	16.89±0.95	14.06±0.91	10.32±1.26	7.7±0.96	6.52±0.99 (–61.40)
T_1	19.98±0.93	16.97±0.94	13.48±1.21	11.23±1.14	9.21±0.97 (–53.90)
T_2	18.92±1.12	15.32±1.12	12.33±1.17	10.19±1.12	8.64±0.67 (–54.33)
T_3	18.2±1.25	14.34±0.97	10.52±1.18	7.48±1.14	5.75±0.68 (–68.41)
T_4	16.97±1.10	13.11±0.99	9.50±1.14	7.83±1.13	6.92±0.98 (–59.22)

Anova

Analysis of variance	Sum of square	df	Mean of square	F-value	P-value
Rows	42.48742	4	10.62186	44.18575	1.88E-08
Columns	386.4475	4	96.61189	401.8948	7.94E-16
Error	3.846256	16	0.240391		

C_1– Control (BM alone), T_1– (20% BM + 80% MSW), T_2– (40% BM + 60% MSW), T_3– (60% BM + 40% MSW), T_4– (80% BM + 20% MSW)

Initial (0) – Worm unworked substrates, Mean ± SD of six observations.

(+/–) – Percent change of increase or decrease over the initial.

The loss of carbon as carbon dioxide through microbial respiration and simultaneous addition of nitrogen by worms in the form of mucus and nitrogenous excretory material lowered the C:N ratio of the substrate (Suthar, [29]. Reduced C:N ratio was shown in the vermicomposts than worm–unworked compost (Rajasekar and Karmegam, [30]. Pattnaik and Vikram Reddy [31] suggested 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. In the present investigation the *E. eugeniae* performed well in terms of available N, P, K and highly acceptable C:N ratio in the vermicomposts.

4. Conclusion

It can be concluded that the earthworm *Eudrilus eugeniae* was found suitable for the vermicomposting of bedding materials (pressmud and cow dung) and municipal solid waste mixed with different proportions particularly (*i.e.*) T_3 - 60% + 40% (BM + MSW) 600g BM + 400g MSW mixed dry weight basis. In these treatment T_3 ratio worm worked composts (vermicomposts) is highest amount of major nutrients content (pH, EC, OC, N, P, K and C:N ratio) were presented. The unutilized much quantity available municipal solid waste (MSW) can be vermicomposted along with any organic additives convert into the valuable organic manure. In addition to this, it may be recommended that the vermicomposts from MSW can be utilized for organic farm.

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