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VERMICOMPOSTING OF MUNICIPAL SOLID WASTE USING DIFFERENT TYPES OF EARTHWORM SPECIES – A COMPARATIVE STUDY

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ABSTRACT

Earthworms eat many types of organic waste materials and convert them into vermin-compost which is highly valued as a fertilizer because it contains plant-available yet stable nutrients. The optimum environmental conditions such as temperature, moisture, pH, EC etc required for vermin-composting of municipal solid waste with different earthworm species and with different substrates are studied. The study indicates that the addition of soil or cow dung appears to be essential in order to provide favorable medium for the growth of earthworms and microorganisms present in them. The loss in the weight of vermin-compost of municipal solid waste with *Eisenia foetida* is 62.8% after 60 days of vermin-composting where as the loss in the weight of vermin-compost in the case of *Perionyx excavatus* is only 51% for municipal solid waste. Out of the four substrates used, MSW with the addition of cow-dung appears to be best substrate for *E.foetida* whereas MSW with cow-dung and soil are best substrates for *P. excavatus.* Out of the two earthworm species used *P. excavatus* is a suitable earthworm to convert the MSW mixed with soil and cow dung into nutrient rich vermin-compost.

KEYWORDS: **Municipal solid waste, vermin-compost, *Eisenia foetida, Periyanx excavates*, organic waste.**

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INTRODUCTION

Vermin-composting of municipal solid waste can be seen as a form of livestock (earthworms) production. Many different materials in municipal solid wastes (organic solid waste) can be used as a feedstock for earthworms and the waste can be converted into organic fertilizer. Thus, vermin-composting can be applied to stabilize organic wastes like urban solid waste at the same time minimizing the environmental problems arising from their disposal without needing in many processes to complete the process of decomposing.[1] Earthworms process organic waste and excrete material rich in organic material which has stable, plant-available nutrients that looks like fine textured soil. Nutrients in vermin-compost are often much higher than traditional garden compost.[2, 3] Though the system is extremely simple, it is essential to maintain process control for the consistent productivity through matching feed rates to population and adjusting environmental parameters to optimal level. Therefore, in vermin-composting enterprises it is critical to maintain optimal conditions because of variety of substances in the waste.[4] Environmental factors such as moisture, temperature and aerobic conditions in growing medium must be maintained to ensure healthy growing worm populations. Profitable production depends on both growth and reproduction rates of worms as well as on the choice of suitable species for feed stuff available.[5] Vermin-composting of organic waste could be carried out with the use of different types of earthworms. At present vermin-composting of municipal solid waste or organic solid waste is accomplished by the use of the earthworm *Eisenia foetida*. This earthworm converts the organic matter into compost efficiently but they live in the top of the soil and they never go deep into the soil by making burrows when they are present in soil or agricultural fields. On the other hand, the earthworms naturally present in the soil (like *P.excavatus*) make burrows and bring the soil nutrients present in the deeper layers of the soil to the top layer thus making soil more fertile.[6] Further, it is thought that the efficiency of *E. foetida* would be reduced if the organic waste contains significant amount of soil where as the efficiency of indigenous variety of earthworms will not be reduced in the presence of soil (organic waste available in its natural state in municipalities).[5,6] In this context, effort is made in this study to compare the ability of earthworm species in terms of growth and reproductive characters, environmental suitability, vermin-composting efficiency and quality of vermin-compost.

MATERIALS AND METHODS

Vegetable waste materials collected from the municipal vegetable market are used as the main substrate. Normal soil (garden soil), cow dung or farm yard manure are added in different proportions to municipal solid waste as supplements to the green waste. The problem in treating the waste with earthworms is its lower pH value. When the organic waste is piled at a place the acidity of waste increases due to microbial action and the resulting higher acidity or lower pH values affects the growth of earthworms used for vermin-composting. Therefore, it may be necessary to mix some substances such as soil, cow dung etc in order to increase the pH of the waste for proper vermin-composting process. Further, this process reflects the state of organic waste (solid waste) available along with soil, trash etc in its natural state.

Experimental design

Five sets of plastic pots for each earthworm species are taken for this comparative study. Each set of pots is filled with five kg of the substrate - municipal solid waste, cow dung and soil separately in the ratio given below.

Set I Municipal solid waste (MSW)
Set II MSW and soil (3:1 ratio)
Set III MSW and Cow dung (3:1 ratio)
Set IV MSW: Soil: Cow dung (2:1:1)
Control Organic waste without earthworms

Four sets are used for vermi- composting with each set using one species of earthworm and one set is used as control (without earthworms). Two species of earthworms, 16-20 week old individuals of each species, *Eisenia foetida* and *Perionyx excavates* (having individual live weight ranging from 250 to 300 mg) were collected from the stock culture. Both the earthworm cultures are collected from the vermin-composting yard of SEEDS (an NGO) organization working in Duttalur village, Nellore district. These earthworms, each of fifty adult individuals, are introduced on the top of the pre-composted substrate in each of the four sets of pots keeping aside another set for composting without earthworms. All the pots were covered on the top by jute cloth cover and wire mesh to protect the earthworms from the predators (centipedes, moles, shrews etc). The process of vermin-composting is carried out for a period of 60 days and the samples are collected from each set of the substrate /substrate mixture at 0 day, 15, 30, 45 and 60th day and analyzed for various parameters such as temperature, moisture, weight, pH, EC etc using standard protocols. The organic carbon (OC) of the samples was measured by Datta et al 1962, the nitrogen (N) was estimated by the spectrophotometer.[7,8] and the phosphorus (P) and potassium (K) contents of the samples were analyzed by calorimetric method and flame photometric method respectively.[9] These methods are given in the manual by Murugasan and Rajakumari, 2005.[7] The C: N ratio was calculated from the measured values of Carbon and Nitrogen.

RESULTS

Chemical characters of substrates used for vermin-composting

The substrates used in the present study are municipal solid waste, cow dung (manure) and garden soil and the characteristics of these substrates are studied and results are presented in Table-1. The pH of the soil and manure is neutral (7.0-7.2), whereas the pH of municipal solid waste is 6.3 suggesting that pH of the municipal solid waste is slightly acidic. The electrical conductivity of soil is 3.3, manure is 2.4 and municipal solid waste is 1.6(mho/cm). Thus, the pH value and electrical conductivity value are less for municipal solid waste

compared to soil and manure.[10] The organic carbon% of the waste is very high, that is 35.4%, whereas the organic carbon of soil is 12.8% and manure is 33%. The nitrogen content of the soil is very low compared to manure and municipal solid waste. The phosphorous and potassium contents of the waste (municipal solid waste) are lower than soil and manure.[11,12].

Table 1
Chemical characters of raw materials/ waste used for vermin-composting

S.No	Character	Soil	Manure	Waste	Pre-compost
1	pH	7.0	7.2	6.3	6.9
2	EC(electrical conductivity) mho/cm	3.3	2.4	1.6	2.8
3	OC %(organic carbon)	12.8	33	35.4	19.1
4	N% (Nitrogen)	0.21	0.62	0.56	0.52
5	P% (phosphorus)	0.34	0.36	0.24	0.27
6	K% (potash)	0.62	0.28	0.19	0.32

Growth of earthworms in different substrates

The kind and amount of food available influences not only the size of earthworm population but also the species present and their rate of growth and fecundity.[13,14] The growth of earthworms is measured in terms of individual length, individual weight and total biomass. The average length of *E. foetida* is 5.1cm in the initial stage and it is 10.5 cm at the final stage (after 60 days) registering about 100% increase in the length in municipal solid waste media for *E. foetida*.(Fig-1). The corresponding growth for *P. excavates* is from 3.3cm to 7.2 cm (Fig-2) registering 119% growth during 60 days of composting.[14] With regards to the effect of substrate composition on the growth of earthworms, it is observed that the presence of cow dung enhances the growth of earthworms considerably. Further, the enhancement in the growth is much higher (33% percentage points) for *P. excavates* compared to *E. foetida* (19 percentage points) (Figure 1&2).

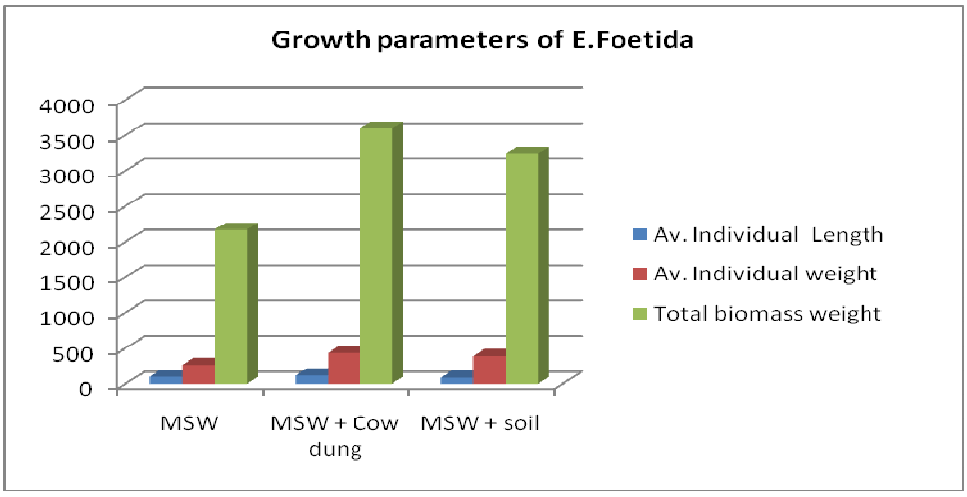

Figure 1
Growth parameters of E. Foetida during vermin-composting of municipal solid waste

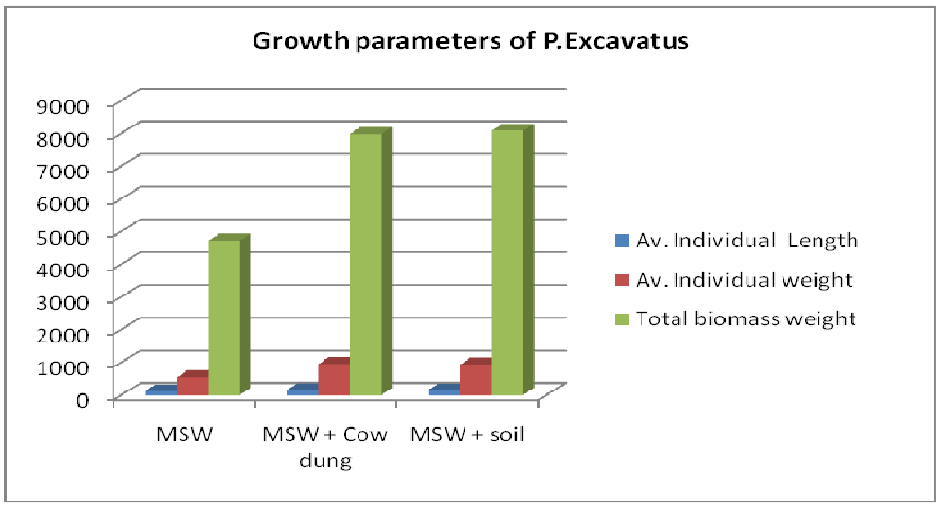

Figure 2
Growth parameters of P. excavatus during vermin-composting of municipal solid waste

On the other hand, the addition of soil to municipal solid waste has varied effect on the growth of both the earthworms. The growth in length of *E. foetida* in municipal solid waste is 100% and it is 86% in municipal solid waste & soil media registering a 14% decline in the growth of *E. foetida.* In the case of *P. excavates* the addition of soil improved its growth. Similar pattern of growth could be observed in the growth of earthworms in terms of weight and biomass production. The growth rates of *E. foetida* show that addition of soil is not favorable to its growth (Fig 1&2). Therefore, *P. excavates* appears to be favorable organism for treating the municipal solid waste compared to *E. foetida.*[15,16]

Environmental factors affecting vermin-composting of municipal solid waste

The study is aimed at determining the optimal environmental factors required for successful vermin-composting of the waste. The environmental factors studied include temperature, moisture, pH, EC and weight reduction. The moisture content of the compost without earthworms is higher compared to vermin-composts of both the species of earthworms used. The moisture content of vermin-compost (after 60 days) ranged from 50.3 to 57.8% in all the samples kept for vermin-composting with *E.foetida* and for *P.excavatus* the moisture content ranged from 52.5 to 53.6%. It indicates that the vermin-compost obtained using *P.excavatus* has lower level of moisture content compared to that of *E.foetida*. Lower level of moisture in the final product is desirable for longer storage and for its keeping quality.[17] However, the difference in the moisture content in vermin-composts obtained from both these earthworm species is narrow and insignificant.

The initial temperature of compost was 34.5^0c and the temperature of vermin-compost obtained after 60 days of vermin-composting was 27^0c. The similar trend of decline in the temperature during vermin-compost could be observed for all the samples and for all the earthworms. The difference in the temperature of various samples is narrow and insignificant. The pH of the substrate is an important factor which determines the growth of earthworms and microorganisms present in the gut of earthworms. For the better activity of microbes and earthworms, the pH of the substrate shall be neutral or around 7.0. The pH of the municipal solid waste is 6.3 and it is lower than the neutral pH. However, the pH of the municipal solid waste and other samples increased to 6.8-7.2 after vermin-composting especially with the addition of soil or cow dung or both (Table-2). The EC of the samples increased after vermin-composting particularly with the addition of cow dung or soil (Table-2). Therefore, the addition of soil or cow dung appears to be essential in order to provide favorable medium for the growth of earthworms and for successful reclamation of municipal solid waste.[18] The loss in the weight of vermin-compost of municipal solid waste with *E. foetida* is 62.8% after 60 days of vermin-composting whereas the loss in the weight of vermin-compost in the case of *P. excavates* is only 51% for municipal solid waste (Fig- 3). In the case of municipal solid waste and soil mixture (S2) the loss in the weight of vermin-compost after 60 days of composting is 59% in the case of *E. foetida* while it is only 45.6% in the case of *P.excavatus* (Fig-3). For the other two samples i.e., S3 and S4 also the loss in the weight of the compost is higher for *E. foetida* compared to *P. excavatus.*

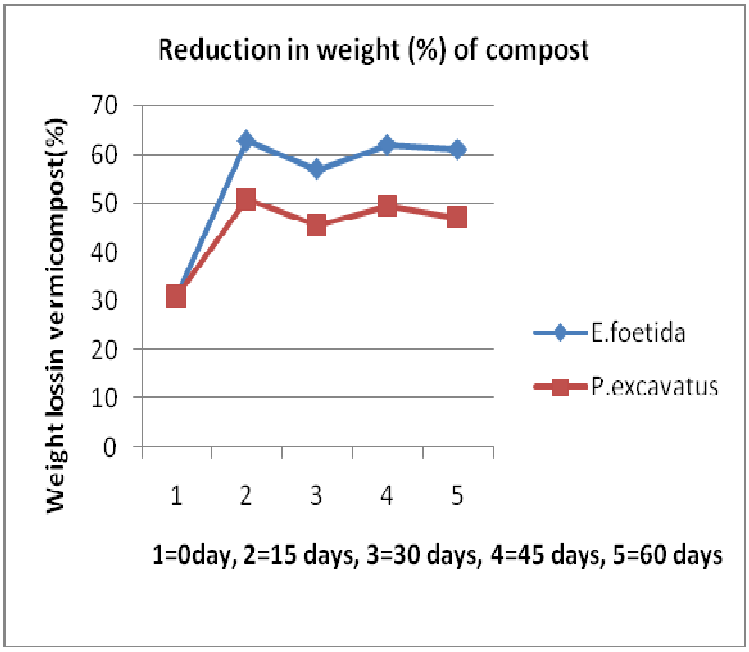

Figure 3
Changes in the weight of vermin-compost prepared using E. Foetida and P. excavatus.

Effect of substrate composition on the nutrients of vermin-compost prepared by different types of earthworms

Soil nutrients present in soil influence the fertility of the soil and plant growth. Soil nutrients such as nitrogen, phosphorus, potassium, sulfur etc (N,P,K,S) are the required salts to be present in soil. The vermin-compost having considerably higher proportion of these nutrients is considered as very good fertilizer.[19] The nitrogen% of msw is 0.56%, msw + soil is 0.45%, msw + cow dung is

0.64% and msw+ cow dung + soil is 0.55% (Table-2). The results indicate that the addition of soil reduce the nitrogen% where as the addition of cow dung increase the nitrogen percentage of substrate mixture. After 60 days of vermin-composting, the nitrogen% of all the samples increased gradually. After 60 days, the nitrogen% of msw + cow dung is higher compared to all the other samples in the case of both the earthworms. The nitrogen% of msw + cow dung sample is 0.92% for *E.foetida* and 1.05% for *P. excavates.*[20] Thus, it is observed that the addition of cow dung increase the nitrogen% of vermin-compost irrespective of earthworm species. On the other hand, the addition of cow dung as well as soil increased the nitrogen% of vermin-compost in the case of *P.excavatus*. Further, the nitrogen% of vermin-compost of *P.excavatus* is higher than that of *E.foetida* (Table-2). The similar pattern to that of nitrogen could be observed in the case of phosphorus and potassium contents of vermin-compost with regards to both substrate composition and earthworm type.[12] With regards to the effect of substrate on the organic carbon% (OC) of vermin-compost a different pattern that of nitrogen is observed. The organic carbon% of initial MSW is 20.4%, MSW + soil is 15.2%, msw + cow dung is 20.1% and msw+ cow dung + soil is 18.02%. The results show that the addition of soil reduces the OC% of the substrate mixture whereas the addition of cow dung has no effect on the OC% of the substrate. In all the vermin-composts of the present study the OC decreased significantly with the passage of time, i.e., from 0 to 15, 30, 45, and 60 days. The OC% of vermin-compost after 60 days is 12.14% for msw, 11.4% for msw + soil, 14.2% for msw + cow dung, and 13.5% for msw+ cow dung + soil mixture in the case of *E.foetida* (Table-2). Results show that the vermin-compost of msw + cow dung mixture has retained higher organic carbon percent in the case of *E.foetida*. In the case of *P.excavatus*, the vermin-compost of msw+ cow dung mixture and msw + soil + cow dung has higher OC%. Further, the organic carbon content is higher in all the samples of vermin-composts produced by *P.excavatus* compared to *E.foetida*.

Table 2
Changes in various parameters of MSW before and after vermi-composting using different earthworms and with the addition of various substrates.

	Compost at 0 day				Vermi-compost (after 60 days)			
				Eisenia foetida				
Parameter	**S1**	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**
Moisture%	78	78	78	78	55.4	57.8	50.3	54.5
Temperature	34.5^0c	34.5^0c	34.5^0c	34.5^0c	27.4^0c	27.7^0c	27.2^0c	27.5^0c
pH	6.3	6.7	6.8	6.7	6.8	7.1	7.2	7.1
EC	2.87	2.40	4.85	3.86	3.25	4.90	5.17	4.80
Total Nitrogen%	0.56	0.45	0.64	0.55	0.82	0.65	0.92	0.72
Phospharous%	0.24	0.20	0.44	0.41	0.80	0.68	0.85	0.72
Potassium%	0.19	0.22	0.35	0.32	0.60	0.52	0.56	0.52
Organic carbon%	20.4	15.2	20.1	18.0	12.14	11.4	14.2	13.5
C/N ratio	36.42	33.77	31.40	32.76	15.95	17.53	16.52	20.13
				Perionyx excavates				
Parameter	**S1**	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**
Moisture	78	78	78	78	53.2	53.6	52.5	52.6
Temperature	34.5^0c	34.5^0c	34.5^0c	34.5^0c	27.2^0c	27.3^0c	27.5^0c	27.4^0c
pH	6.3	6.7	6.8	6.7	6.8	7.2	7.2	7.2
EC	2.87	2.40	4.85	3.86	4.90	4.54	5.90	5.98
Total Nitrogen%	0.56	0.45	0.64	0.55	0.88	0.84	1.15	0.96
Phospharous%	0.24	0.20	0.44	0.41	1.02	0.70	1.09	1.01
Potassium%	0.19	0.22	0.35	0.32	0.64	0.68	0.78	0.75
Organic carbon%	20.4	15.2	20.1	18.0	12.5	12.10	14.50	13.8
C/N ratio	36.42	33.77	31.40	32.76	14.20	16.21	13.80	13.02

Effect of substrate on the C/N ratio of vermin-compost is almost similar to that of organic carbon. The C/N ratio of vermin-compost of msw + cow dung, as well as msw + cow dung + soil is higher in the case of *E. foetida* compared to *P. excavates*. On the other hand, the C/N ratio of vermin-compost of msw + soil, as well as msw + cow dung + soil is lower in the case of *P.excavatus*, indicating its efficiency in producing good quality vermin-compost. The present study revealed that when the cow dung and soil are added to the organic waste, the resultant vermi-compost showed higher levels of plant nutrients like N, P, K, and lower C/N ratio.[12] Further, the vermin-compost prepared by the two earthworm species showed a substantial difference in total N content, which could be attributed directly to the species-specific feeding preference of individual earthworm species.

Quality of Vermin-compost made out of municipal solid waste in relation to WHO standards

Vermin-compost is a useful organic fertilizer and thus it could be sold in the market as fertilizer. To convert the waste material into vermin-compost any type of method i.e., small scale or large scale method can be adopted, and all types of organic wastes can be used for the conversion into vermin-compost. However, when it comes to marketing, the vermin-compost should have the minimum quality as prescribed by the government. Thus, an attempt is made in this study to compare the quality of the vermin-compost with the quality parameters specified by WHO. The quality parameters tested are total carbon, moisture, nitrogen, phosphorus, potassium contents, C/N ratio, pH etc. A comparison is made with the quality parameters of the samples with that of WHO standards and against period of vermin-composting i.e., 30 days and 60 days for different earth-worms used.[21] Out of eight parameters mentioned in the

standards, six parameters are taken into consideration and they are compared with the samples. These six parameters are total carbon, total nitrogen, total phosphorus, moisture contents, pH and C/N Ratio (Fig-4). Of these six parameters the total carbon, total phosphorus, moisture and pH of the samples are in accordance with the WHO standards. Nitrogen content of all the samples is much lower than the nitrogen content of the standards. On the other hand, C/N ratio varies with the period of vermin-composting and materials used for vermicomposting.[14] Based on the quality parameters mentioned by WHO standards, vermin-compost prepared out of only municipal solid waste is observed to be of poor quality. Out of the six quality parameters considered, total carbon, nitrogen and C/N ratio are most important quality parameters. The C/N ratio and nitrogen contents of vermin-compost made out of only municipal solid waste are lower than the WHO standards. However, the organic carbon and C/N ratios of vermin-composts made with the addition of cattle dung or soil or both to municipal solid waste in limited proportion are comparable to WHO standards for the both the earthworm species. The moisture content of the vermin-compost ranged from 47 to 51% as against 30-50% as per WHO standards. The phosphorous content of the samples ranged from 0.60% to 1.10% and this is much higher than the WHO standard of 0.02 - 0.03%. Further, the quality parameters with regards to nitrogen, moisture, pH, organic carbon and C/N ratios are higher for *P.excavatus* compared to *E.foetida*.[6,22] But the results are statically insignificant indicating that the vermin-composts produced by both earthworm species have equally good quality parameters.

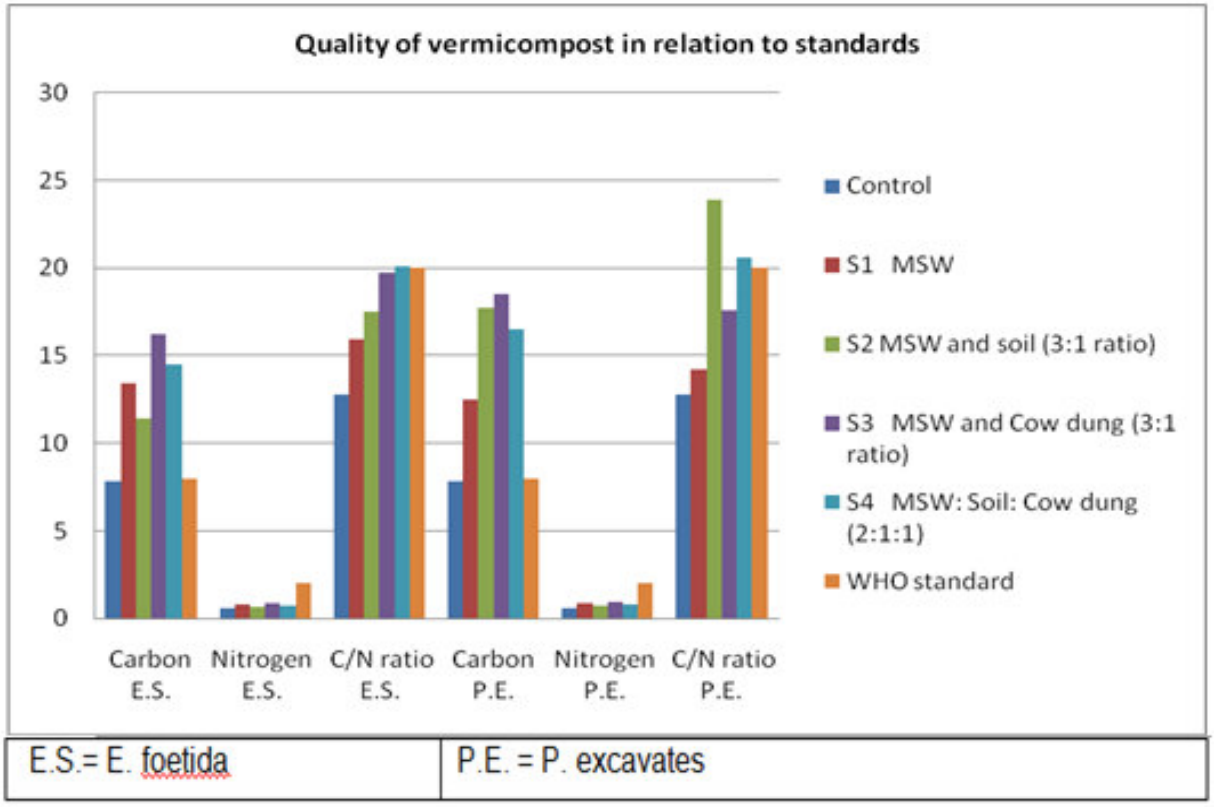

Figure 4
Quality of vermin-compost prepared using E. foetida and P. excavates

DISCUSSION

Different types of materials in municipal solid wastes (organic solid waste) can be used as a feedstock for earthworms and the waste can be converted into organic fertilizer. The type of nutrients available in the substrate or sample has definite bearing on the efficiency of different species of the earthworms.[13,14] Different types of substrates such as MSW, soil and cow dung in different proportions are used in the present study and kept for vermin-composting with two types of earthworms viz., *E.foetida* and *P. excavates* for a period of 60 days. Analysis of the chemical characteristics of raw materials used in the study indicates that no single substrate posses all the nutrients at required level for the growth of earthworms. Therefore, there is need for mixing of different raw materials for proper growth of earthworms and also to obtain a good quality fertilizer in the form of vermi-compost[11,12]. With regards to the effect of substrate composition on the growth of earthworms, it is observed that the presence of cow dung enhances the growth of earthworms considerably. Further, the enhancement in the growth is much higher (33% percentage points) for *P. excavates* compared to *E. foetida* (19 percentage points). On the other hand, the addition of soil to municipal solid waste has varied effect on the growth of both the earthworms while the addition of cow dung enhanced the growth rate of both the earthworm species. In an another study it was reported that the production of cocoons, juveniles and adults of all three species (*P.excavatus, E. foetida E. eguine)* of earthworms used was higher in farm waste having cow dung than that of MSW. Further they reported that the growth of earthworms was higher for *P.excavatus*

compared to other species of earthworms.[14] Therefore, *P. excavates* appears to be favorable organism for treating the municipal solid waste compared to *E. foetida.*[15] In the present study only organic waste is taken as municipal solid waste. But in natural conditions this solid waste in municipality obviously contains organic waste, soil and other trash. To treat this waste the suitable earthworms should have the character of utilizing the soil along with organic waste. The results of this study clearly states that *P. excavates* grows at a higher rate compared to *E. foetida* in the presence of soil. This is due to the difference in their ecological characters. The *E. foetida* is epigeic in nature (litter dweller and lives on the surface of the soil), while the nature of *P. excavates* is anecic (deep burrowing, litter and soil feeder).[5,15,16] The environmental factors, such as temperature, moisture, pH, EC and weight reduction required for successful vermin-composting of the waste are analyzed. The initial temperature of compost was 34.5^0c and the temperature of vermin-compost obtained after 60 days of vermin-composting was 27^0c. The decline in the temperature may due to the aeration through the furrows caused by earthworms. There is not much variation in the temperature of samples kept for vermin-composting with *P.excavatus* as well as *E.foetida*. In a similar study, it was observed that the temperature of substrates and compost at 0 day was higher than the ambient temperature.[23] This is because of exothermic decomposition process of organic matter. Among the other environmental factors, the moisture content of the compost without earthworms is higher compared to vermin-composts of both the species of earthworms used. It indicates that the vermin-compost obtained using *P.excavatus* has lower level of moisture content compared to that of *E.foetida*. Lower level of moisture in the final product is desirable for longer storage and for its longer keeping quality.[17] The moisture content of the present study ranged from 48.5- 51.4% for *E.foetida* and 47.6 – 49.2% for *P.excavates*. The study of Pattnaik and Reddy indicates that the moisture content of vermin-composts ranged from 50-70 percent.[14] According to Liang et al the moisture content of 60-70% is proved to be optimal having maximum microbial activity while 50% moisture content was the minimal requirement for rapid rise in microbial activity.[29] Moisture content of vermin-composts around 50% in the present study reduces the rate of mineralization and decomposition of organic matter resulting in longer keeping quality of vermin-compost.For the better activity of microbes and earthworms, the pH of the substrate shall be neutral or around 7.0. The pH of the municipal solid waste is 6.3 and it is lower than the neutral pH. During vermin-composting with the addition of soil or cow dung or both to MSW, the lower pH at the initial stage rose up to 7.2 by the end of 60 days period. The increased trend of pH in the vermin-compost and compost samples is in consistence with the findings of Tripati and Bharadwaj[25], Loh et al[4] and Pattnaik and Reddy.[14] The study by Smars et al states that the initial phase of vermin-composting is characterized by a low pH and it was attributed to the composting of organic wastes and perhaps especially of easily degraded energy-rich materials like household waste.[24] The pH in household waste often low when it arrives at the composting plant. Further, it was found that a considerable gain in time and vermin-composting process results in the decline in the temperature and rise in pH values as a result of a mesophillic control of the microorganisms present in the waste.[24] The EC of all the samples increased after vermin-composting particularly with the addition of cow dung or soil. The increased EC values during vermin-composting process are in consistence with that of Kaviraj and Sharma,[26] and Jadea and Fulekar.[27] The increase in EC was probably due to the degradation of organic matter resulting in the release of minerals such as exchangeable calcium, magnesium, sodium and phosphorous in the available form.[28] As the cow dung and soil have higher EC values, the addition of soil or cow dung appears to be essential in order to provide favorable medium for the growth of earthworms and for successful reclamation of municipal solid waste.[18] The loss in the weight of vermin-compost of municipal solid waste with *E. foetida* is higher after 60 days of vermin-composting compared to the vermin-compost by *P. excavates.* In the case of municipal solid waste and soil mixture (S2) the loss in the weight of vermin-compost after 60 days of composting is 59% in the case of *E. foetida* while it is only 45.6% in the case of *P. excavates* (Fig- 3). For the other two samples i.e., S3 and S4 also the loss in the weight of the compost is higher for *E. foetida* compared to *P. excavates.* Therefore, it can be inferred that the yield of vermin-compost would be higher if we use *P. excavates* compared to *E. foetida.* However, it is necessary to examine the composition of vermin-compost in terms of soil nutrients (N,P,K etc) before one can say that *P. excavates* is efficient organism compared to *E. foetida.* The effect of substrate composition on the nutrients of vermin-compost prepared by different types of earthworms emphasizes that *P.excavatus* produces good quality vermin-compost compared to *E,foetida*. Soil nutrients such as nitrogen, phosphorus, potassium, sulfur etc, are the required salts to be present in vermin-compost as these nutrients influence the fertility of the soil and plant growth. The vermin-compost having considerably higher proportion of these nutrients is considered as very good fertilizer.[19] The results of the study indicate that the addition of soil reduce the nitrogen% where as the addition of cow dung increase the nitrogen percentage of substrate mixture. After 60 days of vermin-composting, the nitrogen% of all the samples increased gradually. After 60 days, the nitrogen% of msw + cow dung is higher compared to all the other samples in the case of both the earthworms.[20.] Further, the nitrogen% of vermin-compost of *P.excavatus* is higher than that of *E.foetida.*[12] Similar type of results as in the case of nitrogen, could be observed in the case of phosphorous and potassium and the all the results are comparable to the study made by Parisaheb et al.[21] With regards to the effect of substrate on the organic carbon% (OC) of vermin-compost a different pattern that of nitrogen could be recorded. The results show that the addition of soil reduces the OC% of the substrate mixture whereas the addition of cow dung has no effect on the OC% of the substrate. Further, the organic carbon of the vermin-composts decreased significantly with the passage of time. The decline in the OC of the substrate is due to the utilization of material by microorganisms and earthworms present in the compost. In an earlier study

on vermin-composting of organic solid waste, it is observed that the percentage of organic carbon decreased and that of nitrogen, P, Ca, Mg and K increased while C/N ratio and C/P ratios declined in all the samples of vermicompost.[14] Further, the results show that the vermin-compost of msw + cow dung mixture has retained higher organic carbon percent in the case of *E.foetida*. In the case of *P.excavatus*, the vermin-compost of msw+ cow dung mixture and msw + soil + cow dung has higher OC% compared to *E.foetida* and thus it indicates the efficiency of *P.excavatus*. The vermin-compost prepared by the two earthworm species showed a substantial difference in total nitrogen and organic carbon contents, which could be attributed directly to the species-specific feeding preference of individual earthworm species and indirectly to mutual relationship between ingested microorganisms and intestinal mucus. The increase in the total nitrogen content could be a result of loss of dry mass (organic carbon) in terms of CO_2 as well as water loss by evaporation during mineralization of organic matter.[12]To analyze the quality of vermin-compost prepared out of municipal solid waste, an attempt is made in this study to compare the quality of the vermin-compost vis-à-vis quality parameters specified by WHO. A comparison is made with the quality parameters of the samples with that of WHO standards and against period of vermin-composting i.e., 30 days and 60 days for different earth-worms used.[21] Out of eight parameters mentioned in the standards, six parameters are taken into consideration and they are compared with the samples. Of these six parameters the total carbon, total phosphorus, moisture and pH of the samples are in accordance with the WHO standards. Nitrogen content of all the samples is much lower than the nitrogen content of the standards. Perisaheb et al also observed a lower level of total nitrogen in the vermin-compost compared to WHO standards.[21] On the other hand, C/N ratio varies with the period of vermin-composting and materials used for vermicomposting.[14] The C/N ratio and nitrogen contents of vermin-compost made out of only municipal solid waste are lower than the WHO standards. Therefore, it could be concluded that the vermin-composting of municipal solid waste alone (organic waste) will not yield good quality vermin-compost. However, higher C/N ratios of the vermin-composts of the present study indicate that the addition of cattle dung or soil or both to municipal solid waste in limited proportion will yield good quality vermin-compost. The nitrogen content and C/N ratios of vermin-composts are near optimal in the vermin-composts obtained after 60 days of vermin-composting compared to that of the samples obtained after 30 days. Thus, it indicates that 60 days period of vermin-composting is necessary in order to obtain good quality vermin-compost. To reduce the nitrogen loss and composting time, carbon-rich materials were added in another study by Zibilske.[30] When this was not done, stabilization of nitrogen rich substrates led to increase of C\N ratio as ammonium loss becomes more conspicuous. In the present analysis, C/N ratio was found less than optimum range upon which nitrogen content was dependent. Time is also an important parameter to be considered in case of successful vermin-composting. If it takes more than two months in the process, the qualitative value of vermin-compost will deteriorate. Mainly hormone and enzyme part of the manure will be lost if it is stored for more days after production.[30] Vermin-compost is rich in several enzymes and growth regulators such as auxins, gibberellins, etc which are necessary for plant growth.Within the two types of earthworms used the quality of vermin-compost using *P.excavatus* is better than the vermin-compost produced using *E.* foetida.[6,22] But the results are statically insignificant indicating that the vermin-compost produced by both the earthworm species have equally good quality parameters. Therefore, the study indicates that both the earthworm species, *E. foetida*, *P.excavatus*, are equally efficient in converting municipal solid waste into good quality vermin-compost. However, in another study the authors found that, on the basis of chemical analysis *E. foetida* is superior in performance over *L. mauritii* or *P.excavatus* in terms of loss of total organic carbon, reduction in carbon to nitrogen ratio, increase in electrical conductivity (EC) and total potassium.[31] Although this epigeic species of earthworm, i.e. *E. foetida*, is capable of working hard to convert all the organic waste into manure, they have no significant value in modifying the structure of soil. The anaecic earthworms like *P. excavates, L. mauritii,* however, are capable of both organic waste consumption as well as modifying the soil structure.[26,31] Therefore, it could be concluded that *P. excavates* is more efficient organism for the production of vermin-compost useful for the improvement of soil fertility.

CONCLUSION

Vermin-composting of municipal solid waste is becoming a commercial enterprise and it is critical to maintain optimal conditions because of variety of substances in the waste. An attempt is made in this study to use the substrate which has almost similar composition of original municipal solid waste. Out of the four substrates used, MSW with the addition of cow-dung appears to be the best substrate for *Eisenia foetida* whereas MSW with cow-dung and soil are best substrates for *Perionyx excavates.* Out of the two earthworm species used, the study indicates, that *P. excavates* is a suitable earthworm to convert the MSW mixed with soil and cow dung into nutrient rich vermin-compost. Further, among the different substrates used MSW mixed with soil and MSW mixed with cow- dung showed almost similar results in enhancing the soil nutrients. Since soil is easily available and less costly substance than cow-dung, it is advisable to use organic waste or MSW and soil in 3:1 ratio for efficient conversion of waste into valuable vermin-compost with *P.excavatus*. Therefore, it can be concluded that the vermin-composting of municipal solid waste alone (organic waste) will not yield good quality vermin-compost. The addition of cattle dung or soil or both to municipal solid waste in limited proportion will yield good quality vermin-compost. Further, the study indicates that both the earthworm species, *E. foetida,* and *P. excavates*, are equally efficient in converting municipal solid waste into good quality vermin-compost.

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