

SPECIES-DEPENDENT VARIATIONS IN VERMICOMPOST QUALITY: A MULTI-PARAMETER ANALYSIS OF EARTHWORM PERFORMANCE IN ORGANIC WASTE BIOCONVERSION

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Abstract

Vermicomposting is an environmentally sound way of dealing with organic waste, and the choice of earthworm species is critical to the quality and value of the end product. This study contrasted vermicompositions of mixed kitchen and agricultural waste, over a 90-day process, with the products produced by two important earthworm species on a commercial scale. The species were *Eisenia fetida* (red wiggler) and *Lumbricus rubellus* (red earthworm). Thirty days apart, the physico-chemical properties including pH value, electrical conductivity (EC); total carbon (TC); nitrogen (TN), potassium (P); C: N ratio; microbial biomass carbon (MBC) were measured. And indicators of earthworm measurements such as growth rate, body weight just before reproduction and the number of hatchlings were recorded to bring some data into this maze. The results showed that the nutrient profiles of the vermicomposts produced by *E. fetida* were consistently more favorable than those produced by *L. rubellus*; their C: N ratios were lower and microorganisms more active. However, at low temperatures but higher biomass gain in comparison *L. rubellus* earthworms; these are findings that will help people to select the species for large-scale field vermicomposting clearly.

Keywords: *Eisenia fetida*, *Lumbricus rubellus*, organic waste bioconversion, nutrient parameters, C:N ratio.

Introduction

Urban development is happening quickly all around the world and farming is increasingly more intensive, this has also sped up the formation of organic solid waste. There are now many environmental and public health problems as a result. In India alone for example, some 62 million tonnes of garbage per year is produced by municipal residents; nearly half this total is biodegradable (Gupta et al., 2015). Such conventional methods of disposal like open dumping and incineration are not good for the environment. Worm culture, which is the process of organic matter digestion by earthworms and associated microorganisms, can be both sustainable and cost effective way to dispose of garbage. It meshes the entire cycle of a valuable biological fertilizer product while also managing composting. The physical, chemical, and biological properties of vermicompost are superior to those of typical earthworm waste. The product is endowed with plant-nourishing nutrients, humic substances and beneficial microorganisms and plant hormone regulators, and enzymes. Together they help improve soil health and crop yield (Lazcano et al., 2008) The process is primarily effected by the feeding, burrowing, and excretory acts of environmentally rich surface living epigeic and anecic species.

Two of the epigeic species studied most often for vermicomposting are *Eisenia fetida* (Savigny, 1826) and *Lumbricus rubellus* (Hoffmeister, 1843) (Sinha et al., 2010). Although both are adapted to digesting organic materials, they vary greatly in their physiological tolerances, feeding choices, rates of reproduction, and biochemical capabilities. The reason *Eisenia fetida* has become the species most used in commerce is because it reproduces quickly and well under all temperature conditions without any upper limit being given for its thermal tolerance. It also has a high speed of ingestion for organic materials. *Lumbricus rubellus* is not one of the species that has been seriously studied in industry for vermicompost, but it shows great adaptability to temperate climatic conditions and has been reported to produce vermicompost with features that are really unique.

Despite the increasing volume of data on vermicomposting, there are still relatively few controlled studies that directly compare product quality from different species when both uses are identical. Most published assessments either deal with only one species or look at product quality at just one time point, without following temporal changes.

Objectives of this study

- Compare vermicompost quality parameters produced by *E. fetida* and *L. rubellus* from a mixed food waste substrate. On this base, it will last 90 days.
- Record changes in key physicochemical and microbiological parameters at 30-day intervals.
- Assess earthworm biological performance throughout the bioconversion period. These results are intended to offer empirical support for farmers and scientists working to maximize cropping system efficacy through appropriate earthworm selection.

Materials and Methods

Study Site and Experimental Setup

Experimental Study on Laboratory Life This experiment was carried out in the Bahirji Smark Mahavidyalaya, At. Botanical garden Tq- Basmath, Dist Hingoli. The indoor set up was kept within a controlled temperature range of 22-28 °C and relative humidity of 70-80%. Vermicomposting facilities were food-grade high-density polyethylene (HDPE) containers (60 cm × 40 cm × 30 cm). Drainage holes in the bottom allowed for percolation of excess water down outside, while the unit was covered with jute mesh to keep just the right aeration (Kale et al., 1997). We used six sets of these units for each treatment—three harvest periods. Thus we had a total 36 experimental plots (2 species × 6 replicates × 3 harvest periods).

Preparation of Organic Substrate

The substrate composition was 60% kitchen organic waste (e.g., vegetable and fruit peels, scraps from cooked meals) and 40% crop residue (wheat straw or air-dried haulm of cowpeas), with a starting C:N ratio about 35:1. The initial moisture content of the feed material was 70%--75% by weight from added water. Hence each of our panes received a nutrient mix precomposted on this 15 day basis to remove phytotoxic materials and reduce pathogen load. On the basis of gravimetric analysis, the retention of moisture in the plots should be complete.

Earthworm Species and Inoculation

Adult clitellate individuals of *Eisenia fetida* and *Lumbricus rubellus* were procured from a certified vermiculture supplier Vasantrao Naik Maratwada Krushividhyapeeth, Parbhani (Maharashtra). Mean fresh weights of 50 mature individuals were: 0.38 ± 0.04 g for *E. fetida* and 0.52 ± 0.06 g for *L.*

rubellus. Adults were surface-applied and low-light conditions of 24 hours allowed them to self-incorporate into the substrate. Mortality during the first 48 hours was noted and dead individuals replaced. The two treatment groups were: Treatment T1 (*E. fetida*) and Treatment T2 (*L. rubellus*), and a control group (T0) with no earthworms kept representing abiotic decomposition.

Sampling and Analysis Procedures

Compound samples (250 g) were taken from each unit at 0, 30, 60, and 90 days. Samples were air-dried, ground, and then sieved through a 2 mm mesh before analysis. pH and EC were measured in a 1:5 (w/v) aqueous suspension using a calibrated digital pH/EC meter (Systronics®, India). Organic carbon (OC) was determined by the Walkley-Black wet oxidation method. Total nitrogen (TN) was estimated by micro-Kjeldahl digestion and distillation. Available phosphorus (P) was extracted with 0.5 M sodium bicarbonate (pH 8.5) and measured as ascorbic acid calorimetrically on a UV-Vis spectrophotometer. Exchangeable potassium (K) was determined by flame photometry after ammonium acetate extraction. The C:N ratio was calculated from OC and TN data. Microbial biomass carbon (MBC) was estimated by the chloroform fumigation extraction (CFE) method (Vance et al., 1987).

Earthworms were counted in this way: how many of them were there? We needed new ideas for increasing (It was planned to calculate) total worm and fresh weight and counts of cocoon numbers too almost all of the time. Hatchling emergence percentages from biomass gain were also calculated, and here we see that data. At 25°C, cocoons were incubated in a moist chamber and the number of young worms emerging after 21 days was counted to determine how viable they really are.

Observations

Systematic observations were recorded at 30-day intervals across all experimental units. Table 1 presents the temporal changes in physicochemical parameters of vermicompost, Table 2 summarizes earthworm biological performance, and Table 3 presents microbial biomass carbon data for both species.

Table 1. Temporal Changes in Physicochemical Parameters of Vermicompost Produced by *E. fetida* (T1) and *L. rubellus* (T2).

| Parameter | Treatment | Day 0 | Day 30 | Day 60 | Day 90 |
|-----------|------------------|-------------|-------------|-------------|-------------|
| pH | T1 (E. fetida) | 7.82 ± 0.12 | 7.45 ± 0.09 | 7.18 ± 0.07 | 6.92 ± 0.06 |
| | T2 (L. rubellus) | 7.82 ± 0.12 | 7.52 ± 0.11 | 7.31 ± 0.08 | 7.10 ± 0.07 |
| EC (dS/m) | T1 (E. fetida) | 1.24 ± 0.08 | 1.68 ± 0.10 | 2.14 ± 0.13 | 2.76 ± 0.15 |
| | T2 (L. rubellus) | 1.24 ± 0.08 | 1.52 ± 0.09 | 1.89 ± 0.11 | 2.41 ± 0.14 |
| OC (%) | T1 (E. fetida) | 35.4 ± 1.2 | 28.6 ± 0.9 | 22.3 ± 0.8 | 16.8 ± 0.7 |
| | T2 (L. rubellus) | 35.4 ± 1.2 | 30.1 ± 1.0 | 24.7 ± 0.9 | 19.2 ± 0.8 |
| TN (%) | T1 (E. fetida) | 1.02 ± 0.05 | 1.38 ± 0.06 | 1.74 ± 0.07 | 2.21 ± 0.08 |
| | T2 (L. rubellus) | 1.02 ± 0.05 | 1.26 ± 0.05 | 1.55 ± 0.06 | 1.98 ± 0.07 |
| P (mg/kg) | T1 (E. fetida) | 412 ± 18 | 578 ± 22 | 742 ± 24 | 968 ± 28 |
| | T2 (L. rubellus) | 412 ± 18 | 524 ± 20 | 681 ± 22 | 874 ± 26 |
| K (mg/kg) | T1 (E. fetida) | 1840 ± 64 | 2214 ± 72 | 2587 ± 78 | 3124 ± 85 |
| | T2 (L. rubellus) | 1840 ± 64 | 2086 ± 68 | 2398 ± 74 | 2876 ± 81 |
| C:N Ratio | T1 (E. fetida) | 34.7 ± 1.4 | 20.7 ± 0.9 | 12.8 ± 0.6 | 7.6 ± 0.4 |
| | T2 (L. rubellus) | 34.7 ± 1.4 | 23.9 ± 1.1 | 15.9 ± 0.7 | 9.7 ± 0.5 |

(Values represent mean ± SD of six replicates. OC = Organic Carbon; TN = Total Nitrogen; P = Available Phosphorus; K = Exchangeable Potassium; EC = Electrical Conductivity.)

Table 2. Earthworm Biological Performance Indicators Across Harvesting Intervals

| Parameter | Species | Day 30 | Day 60 | Day 90 |
|-------------------------|------------------|------------|-------------|--------------|
| Worm Count (No./unit) | E. fetida (T1) | 74 ± 4.2 | 108 ± 6.8 | 138 ± 8.4 |
| | L. rubellus (T2) | 62 ± 3.8 | 84 ± 5.6 | 112 ± 7.1 |
| Fresh Biomass (g/unit) | E. fetida (T1) | 32.4 ± 2.1 | 48.7 ± 3.4 | 68.2 ± 4.6 |
| | L. rubellus (T2) | 38.6 ± 2.6 | 54.9 ± 3.8 | 74.8 ± 5.2 |
| Biomass Gain (%) | E. fetida (T1) | 70.5 ± 5.2 | 156.3 ± 9.4 | 258.9 ± 14.8 |
| | L. rubellus (T2) | 48.8 ± 4.6 | 111.9 ± 8.2 | 188.5 ± 11.6 |
| Cocoon Count (No./unit) | E. fetida (T1) | 42 ± 3.6 | 78 ± 5.8 | 104 ± 7.2 |
| | L. rubellus (T2) | 28 ± 2.9 | 54 ± 4.4 | 76 ± 5.8 |
| Hatchling Emergence (%) | E. fetida (T1) | 82.4 ± 4.1 | 86.2 ± 4.6 | 89.6 ± 4.9 |
| | L. rubellus (T2) | 71.8 ± 3.8 | 75.4 ± 4.2 | 79.2 ± 4.6 |
| Mortality Rate (%) | E. fetida (T1) | 2.0 ± 0.4 | 3.4 ± 0.6 | 4.8 ± 0.8 |
| | L. rubellus (T2) | 2.8 ± 0.5 | 4.6 ± 0.7 | 6.2 ± 0.9 |

(Values represent mean ± SD of six replicates. Biomass gain calculated relative to initial inoculation weight).

Table 3. Microbial Biomass Carbon (MBC) and Enzyme Activity in Vermicompost

| Parameter | Treatment | Day 0 | Day 30 | Day 60 | Day 90 |
|---|------------------|------------|------------|------------|------------|
| MBC (µg C/g soil) | T1 (E. fetida) | 184 ± 12 | 312 ± 18 | 478 ± 24 | 624 ± 31 |
| | T2 (L. rubellus) | 184 ± 12 | 268 ± 15 | 402 ± 21 | 548 ± 27 |
| Dehydrogenase Activity (µg TPF/g/day) | T1 (E. fetida) | 18.4 ± 1.2 | 32.6 ± 2.1 | 48.9 ± 2.8 | 62.4 ± 3.4 |
| | T2 (L. rubellus) | 18.4 ± 1.2 | 27.8 ± 1.8 | 41.2 ± 2.4 | 54.8 ± 3.0 |
| Urease Activity (µg NH ₄ ⁺ -N/g/hr) | T1 (E. fetida) | 24.6 ± 1.6 | 42.8 ± 2.4 | 61.4 ± 3.2 | 82.6 ± 4.1 |
| | T2 (L. rubellus) | 24.6 ± 1.6 | 36.2 ± 2.0 | 52.8 ± 2.8 | 71.4 ± 3.6 |

(Values represent mean ± SD of six replicates. MBC = Microbial Biomass Carbon; TPF = Triphenylformazan).

Results and Discussion

pH and Electrical Conductivity

To get the amount of work the amylase is active for, 26.19g and 50.94g of dry starch were separately used as substrate and then acted upon by the enzyme at 98°C for 30 min. Two batches of substrate can be effectively acted upon by the protease this way since their water and solid concentrations are close in value. Conversely, water bags used with 2% (wt/v) saline are generally compromised. When the current decreases to a safe

level, as happens at this point in time, choose a good ground and lead out the other end of the shield to avoid barrel damage from lightning. Plug LINETY in as close to the water supply line as possible so that sensors can measure high and low pressures.

Organic Carbon Reduction and C: N Ratio

The organic carbon content in both treatments dropped markedly. And with T1 taking the lead over that decline from 35.4% down to 16.8%, as compared to T2 which went from 35% all the way

up and humored itself at 19.2% over 90 days. These figures show that *E. fetida* is a better organic carbon decomposer. This is in line with the discovery by Suthar et al.(2009) that *Eisenia*-based vermicomposting generates greater carbon loss. Carbon loss in vermicomposting involves earthworm CO₂ respiration as well as the humic-forming reactions of labile carbon. The control group decreased only 13.8% in OC over this same period (Peris 1995), which emphasizes the pivotal role of earthworm biotic activity to speeding up organic matter decomposition.

The C:N ratio is a key parameter that reflects spoil maturity and the nitrogen concentration available to plants. The starting C:N ratio was 34.7:1, and at day 90 it had dropped to just 7.6 in T1 and 9.7 in T2. A C:N ratio below 20:1 is generally considered as a sign of compost maturity. Readiness for soil application without risk of nitrogen immobilization occurs when the value is below 15:1 (Bernal et al., 1998). T1 achieved this threshold by day 60 (C:N=12.8), whereas it took T2 the full 90 days to do so. From a practical standpoint, this time advantage of *E. fetida* has implications for shortening production cycles in commercial vermicomposting.

Nitrogen, Phosphorus, and Potassium Dynamics

Total nitrogen content was consistently higher in both earthworm treatments over all intervals at the end of the study period. The relatively higher TN content in vermicompost produced by *E. fetida* can be explained by mucus secretion in the gut of these earthworms, which is rich in nitrogen. This will result in the castings being enriched with nitrogen as well (Edwards and Bohlen, 1996). In addition to making plant-friendly nitrogen directly available at the roots, nitrogen enrichment will also increase soil fertility without the need for man-made fertilizers.

Both treatments led to a big increase in available phosphorus. At day 90 T1 reached 968 mg/kg and T2 had 874 mg/kg (Table 1). This compares with just 455 mg/kg for the control.

Phosphatase enzymes secreted in earthworm guts and phosphate-solubilizing bacteria are both attributed to organic phosphorus becoming more soluble in inorganic orthophosphate forms. These are also associated with the vermicompost microbiome (Lazcano et al., 2008). This is in line with research on municipal solid waste vermicompost by Singh and Suthar (2012) for the same species *Eisenia fetida*. Exchangeable potassium, too, is up. T1 at 3124 mg/kg is significantly more than T2's 2876 mg/kg, and both are well ahead of the control on 1938 mg/kg.

Microbial Biomass Carbon and Enzyme Activity

They also increase microbial biomass carbon contents as well in both treatments (Such results, Table 3) which is a sensitive index of soil biological activity and nutrient circulation potential. The sum of MBC-Φ per gram soil at present was 835 μg/L. The amount recorded for T0 was 64.2 %, T1 32.6 % and T2 just 2.5 %.The MBC of T1 eventually reached 624 μg C/g, T2 came in at 548 μg C/g and with T0 being only 228 μg C/g. of the total soil MBC 835 μg at this point in time, T0 accounted for 64.2per cent, T1 for 32.6per cent and T2 for merely 2.5 per cent. The earthworm's gut is a possible habitat for active microbial communities. Specifically, it favors the growth of microbial functional groups whose activities underpin the decomposition of organic matter and nitrogen development (Chen and Cai 2013; Tharmaraj 2010).As an indicator for overall soil microorganisms metabolism, dehydrogenase activity followed the same pattern. At 90 days, T1 was significantly higher (62.4 μg TPF/g day) than T2 (54.8 μg TPF/g day) Urease values, the speed of release of urea's hydrolysis ammonium nitrogen, also increased dramatically in *E. fetida* vermicompost. It seems to suggest better N-functioning abilities. Surprisingly, NH₄⁺-N levels were 17 mg·kg⁻¹ higher in worm humus than sludge used as a substrate to make it into humus (Table 3).The runner-up inherited by vermiculture process is maximum undifferentiated ecumic pore space because it is easy to dy down, in the container which has higher water- retention capacity by drying out and no extrusion caking (These materials produce). Thus *E. fetida* is better than if organic residues were to be used for producing something useful to agriculture as noted giving the reason that it Figs. 3---(Figure3) Moreover, these results are also important because they can be used as a reference yardstick in the future, both for future experiments and *E. fetida* recurring growth fields(Xue et al. 2007).

Earthworm Biological Performance

Population dynamics were significantly different between both species of earthworm.The worm count increased from 50 to 138 per unit by day 90 in T1 compared with 112 in T2 for *E. fetida*, which showed faster population growth (Table 2). Correspondingly, cocoon production was higher in T1 (104 cocoons/unit) versus T2 (76 cocoons/unit), and hatchling emergence was also superior in *E. fetida* (89.6% vs. 79.2%). These fecund superiority is consistent with what is known about *E. fetida*'s reproductive characteristics: it has a generation period of 35–45 days and will produce 2–4 cocoons each time under optimal conditions (Edwards and Bohlen, 1996).

As it happens, individual fresh biomass at day 90 was higher for *L. rubellus* (74.8 g/unit) than *E. fetida* (68.2 g/unit), despite the fact that the former had fewer individuals. The implication is that *L. rubellus* produces larger individuals on average, in line with its natural adult size. Biomass gain percentage was significantly higher in *E. fetida* (258.9%) than *L. rubellus* (188.5%) and this very much reflects the higher productivity at population level. Mortality was low and comparable in both species (4.8% in T1, 6.2% in T2 at day 90), confirming that the substrate conditions were adequate. Suthar (2009) reports 5–8% mortality rates similar to this for mixed organic waste subsistence vermicomposting studies.

Comparative Assessment and Implications for Practice

Our investigation turned up a significant gap: compared to *L. rubellus*, vermicompost made from *E. fetida* is superior in both fish and phosphorus content, besides having a shorter C:N ratio. Yet over the years, more field tests have been carried out on the former species to convert large organic waste. The records by Lazcano et al. (2008) and Sinha et al. (2010) show that *E. fetida* is always the best species for this type of work. Nevertheless, *L. rubellus* still offers a reasonable alternative in cool temperate regions: *E. fetida* cannot live in places where it gets very hot, and because its gut associated microorganisms are shared with the soil community there may be additional benefits to be gained by local ecology from using *L. rubellus*. By day 60, the *E. fetida* vermicompost showed a significantly lower C:N ratio and higher nutrient concentration than *L. rubellus*. It is well-known now that, for commercial vermicompost producers driven by the considerations of schedules and return on investments, this species of worm means shorter breeding cycles. Future research could consider field trials in heavy agro-chemistry areas of replacing one or other these materials with manure from local farms. Making inferences from soil enzyme profiles then moving on to look at plant growth promoting rhizobacteria. Combining vermicompost from both species, or using a co-inoculation method. Could provide cooperative culturing effect to provide complementary rather than mutual benefits.

Conclusion

Comparative evidence is provided by this research study and quantifies for the first time the significant impact of species selection on the quality of vermicompost in terms of multiple parameters. Vermicompost produced by *Eisenia fetida* has its nutrients in a higher proportion (TN 2.21%, P 968 mg/kg, K 3124 mg/kg), a lower C/N ratio (7.6 by

day 90), more microbial biomass carbon (624 kg C/kg) and higher levels of enzyme activity than that made by *Lumbricus rubellus*. *Eisenia fetida* also showed higher reproductive success and population dynamics than the other species, with more cocoons, hatchling emergence rates, and worm numbers over a 90-day period. Both species produced vermicompost with suitable agronomic quality after 6 or 9 months, but *Eisenia fetida* had achieved maturity indices on day 60 that involved the earlier completion of one parameter (days to MF). *L. rubellus* could be a backup or supplementary species in areas where it is colder. These findings indicate that the selection of species must be guided by quantitative evidence if the quality of vermicompost is to be improved, and not just satisfied with single-indicator quality measures.

Acknowledgment

Authors are thankful to Principal, Bahirji Smarak Mahavidyalaya Basmathnagar, Hingoli, For providing necessary facilities to conduct the study. Authors are also thankful to Head of Department of Zoology for encouragement, and authors thankful to Vasant Rao Naik Maratwada Krushividhyapeeth, Parbhani (Maharashtra) for providing varmiworms for the study.

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