Chapter 14
Potential of Earthworms in Bioconversion of Organic Solid Waste

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Abstract The generation of waste materials is increasing proportionately with the growth of human population and increasing pace of industrialisation. Millions of tonne of solid waste generated from the modern society are ending up in the landfills every day, creating extraordinary economic and environmental problems for the local government to manage and monitor them for environmental safety. The methodology of solid waste management has shifted from conventional disposal strategies such as incineration, landfill etc. to conversion of waste into value added products during recent years. The usage of solid waste by recycling can supply nutrients to vegetative plants and also improve soil physical conditions and its fertility. Earthworm with their marvellous capability of ingestion, digestion and excretion are nature's most useful converters of wastes. Earthworm participation enhances natural biodegradation and decomposition of solid waste from 60 to 80 % thus significantly reducing the composting time by several weeks. To reduce the cost of disposal of solid waste and best utilization, it was planned to convert the solid waste into a valuable vermicompost. Consumption of organic waste earthworm culture is an ecologically safe and economically viable process to get beneficial products. While they devour our organic waste, thus decreasing our disposal problems, they are also and concurrently manufacturing two new products-earthworm biomass and vermicompost.

A laboratory experiment was carried out for proper management of solid waste through the action of indigenous earthworm, *Metaphire posthuma* of mixtures containing solid waste and cow dung. The action of worms accelerated the decomposition of wastes. Analysis of soil bed and waste from experimental container after 15 days interval for physical and bio chemical activities revealed that worm is capable of recycling of solid waste into useful nutrients. During this process organic matter, pH and C:N ratio revealed negative trend, however total nitrogen, phosphorous and potassium content expressed positive trend of increment with

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vermicomposting up to 60 days, clearly indicate the potential of earthworm biotechnology in recycling of waste, nutrient enrichment in the form of vermicompost.

Keywords Bioconversion • Biotechnology • Metaphire posthuma • Recycling

14.1 Introduction

With progress in industrialization and consequent urbanization, not only the quantity of solid waste increased, but its quality has also changed. The misuse and abuse of environment increased accumulation of wastes, impairing health and well being of human beings. In India, about 3,000 million tons of waste is produced annually. Piles of garbage and wastes of all kinds littered everywhere have become common sight in our urban life. All these waste materials are assimilated pollution and degradation. Tackling this huge quantity of wastes with currently used methods of treatment and disposal has met with little success and seems to be unsustainable. Around our dwelling, the effective and fruitful disposal of garbage is one of the prime problems which need to be taken up at priority. A number of solid waste disposal strategies have been adopted around the world. Most common practices of waste processing are uncontrolled open dumping, hog feeding, land filling, land spreading and incineration. Each solution has its own benefits and limitations.

An ecosystem cannot absorb them at natural cost and the pilling of such waste pose extra ordinary economic and environmental problems. The increasing waste generation rate, high collection cost and dwindling financial resources are the major problems faced by most of the developing countries for efficient solid waste management. Hence, there is an urgent need for a technique to save the future generation from adverse effects of solid waste. Solid waste management includes all activities that benefit public health in particular, environmental quality in general and minimizes the aesthetic impacts of solid waste directly and substantially. Unless organic solid waste is managed appropriately, its adverse impact continues contaminate the soil and environment. The fully decomposition and stabilization of these wastes through the biological treatment appears to be most cost effective and carry a less negative environmental impact.

Among the various possible ways to improve the nutrient status of organic solid waste, vermicomposting appears to be boon to the economy. Vermicomposting is ecotechnology rooted in principles of ecology, economics and equity. The basic aim of vermicomposting is to bring about decomposition of organic solid wastes without loss of nutrients and the production of end product rich in plant nutrients, which are used for agricultural and horticultural uses. The nutrients contained in the organic wastes are partly converted to more bioavailable forms in vermicomposting. In the present study an attempt has been made to manage the agricultural waste by vermicomposting using an indigenous earthworm *Metaphire posthuma*. The experiments were carried out for a period of 60 days to assess the ability of '*Metaphire posthuma*' to decompose the agricultural waste. Hence, this waste management biotechnology thus resulted in utilization of waste material into useful product on one side environment clean up another side.

14.2 Materials and Method

14.2.1 Collection of Material

Solid waste material was selected for the experiment, then air dried and grinded into smaller pieces. This grinded waste material was mixed with cow dung and was subjected aerobic composting to initiate microbial activity for 12 days. The pre composting is very essential to avoid the mortality of worms (Garg et al. 2006). The mixture was hand manipulated at regular time intervals and remoistened for sufficient activity. Specimens of Metaphire *posthuma* was obtained from laboratory stock.

14.2.2 Physicochemical Analysis

Waste samples were collected from the container by randomly mixing the waste and bedding soil. The sample dried at 110 °C for 5 h were passed through 2.0 mm sieve. During the composting process the material was analysed for different physiochemical parameter such as pH, organic matter, phosphorus as per standard methods (APHA 2005), total nitrogen by Kjeldahl method (Jackson 1973), potassium by flame photometric method (Simard 1993). During the experiment the samples were examined at regular interval of 15 days up to 60 days vermicomposting.

14.2.3 Experimental Design for Composting

The decomposition experiments were carried out in plastic container covered with muslin cloth to facilitate aeration in order to get final composted material. Worm worked compost was placed in each container to act as microbial inoculums and as a suitable habitat for the earthworms.

14.2.4 Statistical Analysis

Standard Deviation: $\delta = \sqrt{\frac{\Sigma y^2 - (\Sigma y^2)^2/N}{(N-1)}}$ where δ is the standard deviation; N is the number of observations.

Standard Error: The standard error of the mean is a measure of the reliability.

$$\text{SEM} = \frac{S}{\sqrt{N}}$$ of the mean calculated from a set of observations.

14.2.5 Three Way Analysis of Variance

A three-way analysis of variance (ANOVA) test of significance was used to evaluate the level of significance of difference between the vermicomposts produced by three substrates (cow dung, kitchen waste and agriculture waste) and control samples with respects to nutrient parameters. The data were analysed on software package statistica, version 7.0 programmes.

14.3 Results and Discussion

The physical and chemical parameters were changed in final vermicomposts with respect to initial feed substrate which revealed the potentiality of *Metaphire posthuma* in bioconversion of organic solid waste into nutrient rich vermicompost.

During vermicomposting the pH, electrical conductivity, organic matter, C: N ratio decrease till the end of the experimental tenure except total nitrogen, phosphorus and potassium. Lowest value of total nitrogen (0.93 ± 0.220), phosphorus (652.30 ± 128.761) and potassium (20.47 ± 4.037) were found at initial level. During vermicomposting period these parameters increases and their maximum values total nitrogen (0.98 ± 2.405), phosphorus (989.80 ± 117.690), and potassium (36.78 ± 3.615) were obtained after 60 days vermicomposting period.

pH of the raw waste before composting lies in alkaline range tend towards neutrality which might have been due to reduction of organic matter to mineral acids and thereby decreasing the alkalinity. The decomposition of organic matter produces 'organic acids' that lower the pH of the vermicomposts. With the advancement of composting process the decrease in pH of the compost was observed which can be attributed to the production of carbon dioxide, simple organic acid and loss of nitrogen as volatile ammonia at high pH values (Hartenstein and Hartenstein 1981) or mineralization of nitrogen and phosphorous into nitrates/nitrites and orthophosphate respectively by microbial activity (Ndegwa et al. 2000).

The decrease in E.C. at the end of compost formation was observed by Venkatrajan et al. (2001). Decrease in E.C. due to increased rate of loss of organic matter consequently release different minerals salt of this combination (Kaviraj and Sharma 2003). The decrease in organic matter may be due to that the carbon substrates are utilized by the microorganisms for respiration and for their cell growth. Earthworms and microorganisms uses large portion of carbon as source of energy (Venkatesh and Eevera 2008).

Final nitrogen content of vermicompost is dependent on the initial nitrogen content present in the organic wastes and the extent of decomposition (Crawford 1983). Earthworms enhanced the nitrogen levels of the substrate during digestion in their gut adding their nitrogenous excretory products, mucus, body fluid and enzymes in vermicomposting process (Suthar 2007). Nitrogen content is increased even through the decaying dead tissues of worms as proteineous portion was converted into ammonia and nitrogeneous like substances (Tripathi and Bhardwaj 2004).

During vermicomposting, the population of nitrogen fixer bacteria increased (Kavian and Ghatnekar 1991) which fix the nitrogen in the substrates. Earthworms strongly influence soil nitrogen status and nitrogen cycling, transferring nitrogen from decaying plant material to form that can be easily recycled and taken up by plants (Syers et al. 1979).

The unavailable forms of phosphorous transformed into the easily available form for plants through the action of worms during vermicomposting (Ghosh et al. 1999). Release of available phosphorous content from feed material may be due to the earthworm gut enzyme phosphatases and P-solubilizing microorganism present in worm casts (Suthar and Singh 2008). In the present study, it has been observed that potassium concentration was decreased in final vermicompost. The loss of potassium may be due to its higher susceptibility to leaching (Swift et al. 1979). Edwards and Burrows (1988) found that exchangeable potassium decreased in the worm worked substrate which may be due to greater leaching of potassium in comparison with other cations (Tables 14.1 and 14.2, Fig. 14.1).

After vermicomposting a decreases in potassium content due to leaching was reported by Garg et al. (2006). A decrease in potassium can be attributed to the microbial activities in the composting material as potassium is very much essential for their metabolic activity. The C: N ratio is the critical factor that limits earthworm's population. When the C: N ratio of the feed substrates increases, it becomes difficult to extract enough nitrogen for tissue production. C: N ratio play an important role in the nutrient balance in vermicomposting, this ratio told the amount of carbon available with respect to nitrogen for the composting microorganisms.

The reduction in C: N ratio was due to the fast degradation of organic matter mainly the degradation of cellulose and other readily available carbon and consequent volatilization of organic matter as the compost heats up. Microorganisms use carbon for both energy and growth while nitrogen is essential for protein production and reproduction. The nitrogen content in the composting material remained more or less same only it was transformed to inorganic forms, which might be the reason behind the drop in C: N ratio. Earthworms help to lower the C: N ratio of fresh

Table 14.1 Changes during vermicomposting of organic waste using *Metaphire posthuma*

Treatments				
Observations	Sets	pH	E.C.	Organic matter (per 100 g)
No. of days	Initial	8.14	0.64 ± 0.026	76.72 ± 2.805
15 days	Cont.	8.09 − (0.61)	0.61 ± 0.086 − (4.68)	71.91 ± 2.801 − (6.26)
	Expt.	7.98 − (1.96)	0.45 ± 0.158 − (29.68)	64.79 ± 2.971 − (15.55)
30 days	Cont.	8.10 − (0.49)	0.62 ± 0.266 − (3.13)	65.05 ± 4.667 − (15.21)
	Expt.	7.69 − (5.52)	0.38 ± 0.177 − (40.63)	55.78 ± 3.534 − (27.29)
45 days	Cont.	7.97 − (2.09)	0.59 ± 0.152 − (7.81)	64.03 ± 2.616 − (16.54)
	Expt.	7.47 − (8.23)	0.30 ± 0.707 − (53.13)	44.93 ± 1.413 − (41.43)
60 days	Cont.	7.91 − (2.83)	0.43 ± 0.125 − (32.81)	57.287 ± 0.960 − (25.32)
	Expt.	7.30 − (10.31)	0.22 ± 0.076 − (65.63)	36.78 ± 3.615 − (52.05)

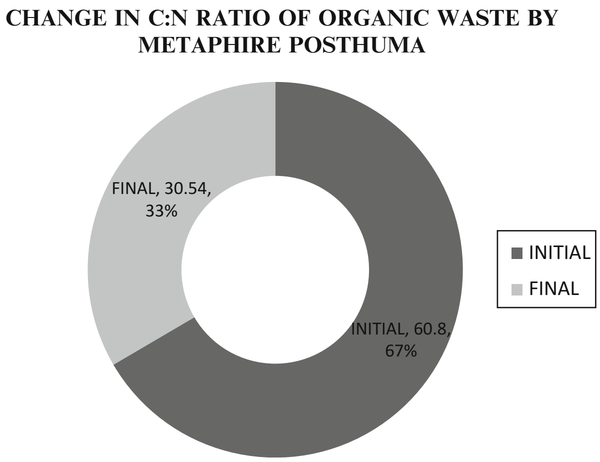
Values are mean ± S.D., n = 6, Values in parentheses are % alteration

Table 14.2 Changes during vermicomposting of organic waste using *Metaphire posthuma*

Treatments				
Observations	Sets	Nitrogen (%)	Phosphorous (per 100 g)	Potassium (per 100 g)
No. of days	Initial	0.93 ± 0.220	652.30 ± 128.761	20.47 ± 4.037
15 days	Cont.	0.91 ± 0.498 − (2.15)	642.02 ± 31.714 − (1.60)	19.28 ± 2.430 − (5.81)
	Expt.	0.89 ± 2.261 − (4.30)	817.14 ± 85.499 + (25.27)	17.68 ± 2.180 − (13.62)
30 days	Cont.	0.89 ± 0.743 − (4.30)	622.44 ± 73.992 − (4.58)	18.37 ± 2.586 − (10.25)
	Expt.	0.87 ± 1.372 − (6.45)	876.90 ± 71.992 + (34.43)	14.17 ± 2.270 − (30.77)
45 days	Cont.	0.86 ± 1.432 − (7.52)	659.22 ± 116.771 + (1.06)	17.56 ± 1.618 − (14.21)
	Expt.	0.91 ± 3.540 − (2.15)	882.84 ± 67.510 + (35.34)	10.08 ± 2.958 − (50.75)
60 days	Cont.	0.83 ± 1.577 − (10.75)	662.48 ± 34.682 + (1.56)	16.46 ± 2.712 − (19.58)
	Expt.	0.98 ± 2.405 + (5.37)	989.80 ± 117.690 + (51.73)	36.78 ± 3.615 − (52.05)

Values are mean ± S.D., n = 6, Values in parentheses are % alteration

Fig. 14.1 Change in C: N ratio of organic waste



organic matter by consuming the matter, breaking it down and using the carbon for energy during respiration (Ronald and Donald 1997).

The ratio of carbon to nitrogen is important for the proper growth of any plant. All studies on vermicomposting have reported a decrease in C: N ratio of organic wastes although decrease in C: N ratio is different for different organic wastes. The increase in earthworm population might also be attributed to the C: N ratio decreasing with time (Ndegwa et al. 2000). C: N ratio was significantly lower in the treatments involving vermicomposting which indicates that they underwent more intense decomposition.

14.4 Conclusion

From the present study, It can be concluded that vermicomposting mediated by earthworms is an ecofriendly waste management technology and resulting in the bioconversion from waste to wealth. Composting by earthworm is proving to be environmentally preferred process over the normal microbial composting and much more over the landfills, as it is rapid and nearly odourless process, can reduce composting time significantly and there is no emission of green house gas methane. All-in-all, the vermicompost is believed to be very good organic fertilizer and soil conditioner.

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