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ORIGINAL ARTICLE

AN ECO-BIOTECHNOLOGICAL APPROACH FOR RECYCLING OF DIFFERENT SOLID ORGANIC WASTES INTO USEFUL PRODUCTS-A COMPARATIVE STUDY.

[1]P.Karthikeyan, [*2]G.Sathiya and [2]D.Kavitha

[1]Zoology Wing, Faculty of Science, Annamalai University, Annamalai Nagar- 608 002.
[*2]Department of Biotechnology, Sri Ganesh College of Arts and Science, Salem.

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ABSTRACT

Vermicomposting has recently emerged as a simple but efficient biotechnological tool for recycling wide ranges of organic wastes to produce better end products with the help of some specific groups of earthworms. Here we evaluated the efficiency of *Eudrilius eugeniae* at converting four organic wastes (vegetable waste, municipal wastes, sago wastes and dairy wastes) into vermicompost. These chosen substrates were mixed with cow dung and soil in the ratio of 3:1:1 (w/w) to initiate the waste conversion process into a useful product. Physical and biochemical activity, occurring during the 45 days of vermicomposting period were analyzed. During this process pH, organic carbon, and C:N ratio were found to be decreased, whereas, the total nitrogen, available phosphorus and exchangeable potassium content were increased with vercomposting period. 15 days precomposting of three different substrates (wastes + cow dung) and subsequent vermicomposting upto 45 days, clearly indicate the potential of earthworm biotechnology in reduction of biomass of the waste, addition of the nutrient pool (nutrient enrichment) and more availability of animal protein in the form of earthworm number and biomass. An experimental study is also conducted in which the effects of different types of vermicompost on plant growth, in terms of plant heights and stem diameter are examined in a experiment with maize plant. Towards the end, the positive outcomes substantiated that vermicomposting biotechnology is a powerful tool for the decomposition of different types of organic wastes into value-added material.

Keywords: *Eco-Biotechnology, Eudrilius eugeniae, Sago wastes, dairy wastes, municipal wastes, vegetable waste, cow dung.*

1.INDRODUCTION

Environmental degradation is a major threat confronting the world, and the rampant use of chemical fertilizers contributes largely to the deterioration of the environment through depletion of fossil fuels, generation of carbon dioxide (CO2) and contamination of water resources. It leads to loss of soil fertility due to imbalanced use of fertilizers that has adversely impacted agricultural causes soil degradation. Now there is a growing realization that the adoption of ecological and sustainable farming practices can only reverse the declining trend in the global productivity and environment protection (Aveyard, 1988, Wani and Lee, 1992, Wani *et al*., 1995).

On one hand tropical soils are deficient in all necessary plant nutrients and on the other hand large quantities of such nutrients contained in domestic wastes and agricultural byproducts are wasted. It is estimated that in cities and rural areas of India nearly 700 million t organic waste is generated annually which is either burned or land filled (Bhiday 1994). Such large quantities of organic wastes generated also pose a problem for safe disposal. Most of these organic residues are burned currently or used as land fillings. In nature's laboratory there are a number of organisms (micro and macro) that have the ability to convert organic waste into valuable resources containing plant nutrients and organic matter, which are critical for maintaining soil productivity. Microorganisms and earthworms are important biological organisms helping nature to maintain nutrient flows from one system to another and also minimize environmental degradation. The earthworm population is about 8–10 times higher in uncultivated area. This clearly indicates that earthworm population decreases with soil degradation and thus can be used as a sensitive indicator of soil degradation.
Vermicomposting is a simple biotechnological process of composting, in which certain species of earthworms are used to enhance the process of waste conversion and produce a better end product. Vermicomposting differs from composting in several ways (Gandhi et al. 1997). It is a

Corresponding* author: ***Dr. P.Karthikeyan,* *Zoology Wing, Faculty of Science, Annamalai University, Annamalai Nagar- 608 002*

mesophilic process, utilizing microorganisms and earthworms that are active at 10–32°C (not ambient temperature but temperature within the pile of moist organic material). The process is faster than composting; because the material passes through the earthworm gut, a significant but not yet fully understood transformation takes place, whereby the resulting earthworm castings (worm manure) are rich in microbial activity and plant growth regulators, and fortified with pest repellence attributes as well! In short, earthworms, through a type of biological alchemy, are capable of transforming garbage into 'gold' (Vermi Co 2001, Tara Crescent 2003).

In this present study, a simple biotechnological process, which could provide a 'win-win' solution to tackle the problem of safe disposal of wastes, is being implemented in a positive manner for recycling of different solid organic wastes (vegetable waste, municipal wastes, sago wastes and dairy wastes) into useful products by the action of earthworm species *Eudrilus eugeniae.*

2.MATERIALS AND METHODS

Collections and culturing of earthworm

The earthworm *Eudrilus eugeniae* which is commonly known as the African nightcrawler was used in this study and was obtained from a vermiculture unit, faculty of agriculture, Annamalai University, Chidambaram. The worms were stocked in large plastic trays and cow dung was used as substrate to maintain the earthworms. Moisture content of 60 - 70% was continuously maintained by sprinkling the water. This stock culture was covered with moisture gunny bag and maintained at room temperature (27± 2^0C) inside the culture room, Department of Biotechnology, Sri Ganesh College of Arts and Science, Salem.

Collection of organic wastes

Vegetable market waste was collected from a waste disposal yard of vegetable market, salem Dt. The daily trading of vegetables and fruits in this city is approximately 150-200 tons/day. Such a huge quantity of vegetables and fruit trading produces a great quantity of wastes (approximately 2.5-5.0 tons/day) in the form of discarded vegetables/fruits, fresh/dried leaves, peeled-off material, paper packing, etc. the fresh vegetable waste was collected in large – sized plastic bags and brought to the laboratory.

Municipal sewage sludge (contained 35% dried matter) was collected from the thirumani muthaaru at old bus stand, salem Dt, after filtering the municipal black waste water sludge. The sludge was collected in plastic buckets. Collected material was brought into the laboratory and filtered through a mesh. The sludge remained at the top of the filter was further used for vermicomposting experiments.

The sago wastes were obtained from sago factory from the nearby village for the experimental purpose. The industry is surrounded by good agricultural environment but the solid wastes from the industry are dumped in the surrounding area. The dairy effluents were collected from the aavin co-operative society at Ponnarampatti village near Valapadi. Feed materials such as farm soil and cow dung were also obtained from the same village.

Experimental setup

The experiments were conducted in plastic trays of size (21cm height and 30 cm diameter), each of capacity 1kg waste, with a hole at the bottom.

The composting mixture consisted of different kinds of wastes (vegetable waste, municipal wastes, sago wastes and dairy wastes) mixed individually with cow dung and soil in the ratio 3:1:1 (on dry weight basis). Total 1000 gm (i.e. 600 gm waste + 200 gm cow dung + 200 gm soil) of composting mixture was taken in each experimental container to provide initial favorable environmental conditions for the worms.

Treatments (T)

(T_1): (600 gm vegetable waste + 200 gm cow dung + 200
(T_2): (600 gm municipal wastes waste + 200 gm cow dung + 200 gm
(T_3): (600 gm sago wastes waste + 200 gm cow dung + 200 gm
(T_4): (600 gm dairy waste + 200 gm cow dung + 200 gm soil)
In the treatment containers, ten healthy earthworms of approximately the same size (5-6 cm) and weight (0.6-0.8 gm) were introduced after 15 days of partial decomposition of organic wastes. This was done to avoid exposure of worms to high temperature during the initial thermophilic stage of composting. The duration of experiment was 45 days. Water was sprinkled daily on container to maintain the moisture level of 55– 60%. The experimental containers were kept under shade and covered with the gunny bags to avoid direct sunlight. There were three replicates for each feed mixture. The control (i.e. untreated) container had no earthworm.

Collection of vermicompost samples for analysis

Vermicompost samples were drawn at 0^{th} day and at the end of experimental period ie. on 60^{th} day. The 0 day refers to the time of initial mixing of waste with cowdung and soil before preliminary decomposition. The earthworms were removed manually at the end of the experiment. The Total number and biomass of earthworms were determined.

Then all the vermicompost produced were taken out from the containers individually and the samples were air dried, sieved and stored in polythene bags for analysis.

Physico – Chemical analysis of vermicompost

Analysis of physico – chemical characters of pH and EC were determined by the method described by ISI Bulletin (1982). The organic carbon was determined by the empirical method followed by Walkely and Black (1934). The total nitrogen (N%), Total phosphorus (P%), Total Potassium (K%) content of the sample was estimated, by Kjeldahl method as per Tandon (1993), Colorimetric method for phosphorus and flame photometric method 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.

Cultivation of maize plant and growth parameters

Approximately 15-20 maize seeds were sown in individual plastic trays carrying respective vermicompost on day 61. After sowing, the plastic trays were kept under optimum temperature and humidity to obtain maximum growth rates. All the vermicomposts were sprinkled with water every day. On day 75, the height of plants and stem diameter were measured from all the experimental substrates.

Statistical analysis

The data on various chemical characteristics of samples were computed and mean values with standard deviation (S.D) were obtained and recorded.

3.RESULTS AND DISCUSSION

The physical and chemical parameters were determined for the starting day (day 0) and final day of degradation. The time taken for the degradation process to be complete was 45 days.

Total number and biomass of earthworms

Growth and reproduction rate of earthworms were determined after 45 days of experimentation. Results showed that the number of earthworms and their lengths and Weights were increased drastically in all the vermicomposts. The maximum increase in growth and reproduction of earthworms was observed in vermicompost prepared by using vegetable waste. This positive outcome substantiated the potentcy of *Eudrilus eugeniae* to utilize different solid organic wastes as a nutrient for their growth and reproduction and produces high quality vermicompost as an end product.

Table – 1: Multiplication of earthworms (Lengths, Weights and Numbers) in different substrates during the experimental period.

Substrates	Number of earthworms	Length of earthworms (cm)	Weight of earthworms (g)
Vegetable Waste			
0^{th} day	10	5.5	0.68
20^{th} day	15	8.6	1.28
40^{th} day	34	15.2	2.15
60^{th} day	43	20.3	2.70
Municipal			
Waste	10	5.3	0.78
0^{th} day	16	8.0	1.5
20^{th} day	38	15.8	2.18
40^{th} day	40	19.2	2.52
60^{th} day			
Sago Waste			
0^{th} day	10	5.5	0.84
20^{th} day	14	7.5	1.42
40^{th} day	29	13.5	1.78
60^{th} day	33	17.8	2.06
Dairy Waste			
0^{th} day	10	5.3	0.70
20^{th} day	15	8.2	1.56
40^{th} day	30	14.3	2.08
60^{th} day	36	17.3	2.48

*The data represented for lengths and weights of earthworms is an average taken out of 10 species released in each compost mixture.

pH

The pH of the substrate material was lower in all treatments than their initial values (Table 3-6). These decreased pH values at the final stage of vermicomposting can be attributed to the production of CO_2 and organic acids by microbial metabolism during decomposition of different substrates in the feed mixtures (Albanell *et al*., 1988; Chan and Griffiths, 1988). It was also reported that different substrates could result in the production of different intermediate species resulting in different behavior in pH shift.

Table-2: Physio-Chemical Characteristics of Vermicompost Prepared from Vegetable Waste at Start and End of Experimentations

Parameters	Control		Treated	
	At start	At end	At start	At end
pH	8.3 ±0.02	7.6±0.01	9.0±0.3	7.3±0.03
Electrical conductivity	0.32±0.04	0.38±0.02	0.28±0.03	0.48±0.04
Organic C	386.4±0.5	307.3±0.3	336.1±0.9	196.3±0.5
Total N	6.89±0.02	8.79±0.2	8.34±0.02	20.4±0.4
Available P	4.20±0.03	5.62±0.02	4.16±0.06	7.62±0.08
Exchangeable K	5.18±0.02	9.21±0.02	7.11±0.03	16.4±0.4
C:N ratio	45.6±0.9	32.8±0.16	34.2±0.6	14.7±0.5

The values are mean and standard deviations of three replicates. (Mean± SD) (N=3). All values are given in percentage except electrical conductivity

Table 3: Physio-Chemical Characteristics of Vermicompost Prepared from Municipal Waste at Start and End of Experimentations.

Parameters	Control		Treated	
	At start	At end	At start	At end
pH	8.6 ±0.02	7.7±0.03	8.9±0.2	7.2±0.03
Electrical conductivity	0.28±0.06	0.36±0.02	0.26±0.04	0.50±0.04
Organic C	289.4±0.2	216.8±0.4	268.4±1.3	158.3±6.0
Total N	9.62±0.02	12.19±0.2	10.8±0.02	21.6±0.9
Available P	3.19±0.04	4.69±0.02	3.92±0.2	5.8±0.1
Exchangeable K	4.68±0.01	7.82±0.03	5.69±0.4	18.6±0.2
C:N ratio	38.1±0.6	27.8±0.09	29.7±0.06	10.4±0.6

The values are mean and standard deviations of three replicates. (Mean± SD) (N=3). All values are given in percentage except electrical conductivity (ms/cm).

Table 4: Physio-Chemical Characteristics of Vermicompost Prepared from Sago Waste at Start and End of Experimentations.

Parameters	Control		Treated	
	At start	At end	At start	At end
	8.9 ±0.01	7.9±0.06	8.6±0.4	7.3±0.04
pH				
Electrical conductivity	0.25±0.02	0.31±0.1	0.36±0.02	123.5±0.04
Organic C	242.4±0.04	187.3±0.9	264.2±1.3	123.5±1.8
Total N	7.16±0.05	9.08±0.02	7.48±0.03	18.7±0.04
Available P	4.89±0.02	5.86±0.02	4.79±0.2	6.08±0.04
Exchangeable K	4.06±0.2	6.04±0.2	5.16±0.3	15.8±0.5
C:N ratio	39.8±0.9	30.6±0.9	36.8±0.4	17.8±0.5

The values are mean and standard deviations of three replicates. (Mean± SD) (N=3). All values are given in percentage except electrical conductivity (ms/cm).

Electrical Conductivity (EC)

Gradual increase in EC was recorded in all the feed substrates under decomposition (Tables 3 - 6). This may be attributed due to freely available ions and minerals that are generated during ingestion and excretion by the earthworms.

Total organic carbon (TOC)

Total organic carbon decreased more significantly with time in all the feed substrates as compared to control at the final stage of vermicomposting (Tables 3 - 6). The maximum reduction in TOC was obtained in vegetable waste and sago waste in comparison to municipal and dairy wastes in earthworm inoculated containers than control. The final reduction in TOC values of all types of wastes was possibly due to the rapid respiration rate that leads to the loss TOC in terms of CO2 or was probably due to the fact that the organic carbon was utilized as by the worms and resulted to TOC reduction.

Table-5: Physio-Chemical Characteristics of Vermicompost Prepared from Dairy Wastes at Start and End of Experimentations.

Parameters	Control		Treated	
	At start	At end	At start	At end
pH	8.6 ±0.3	7.6±0.4	8.8±0.3	7.2±0.3
Electrical conductivity	0.44±0.02	0.49±0.02	0.41±0.03	0.62±0.04
Organic C	334.4±1.6	289.3±1.8	244.2±1.9	187.3±1.3
Total N	7.08±0.03	10.18±0.6	8.06±0.6	18.7±0.4
Available P	5.16±0.04	8.78±0.7	4.86±0.4	7.17±0.8
Exchangeable K	6.20±0.03	9.63±0.5	7.76±0.8	15.8±0.4
C:N ratio	36.8±0.8	22.4±0.9	26.8±0.9	12.6±0.5

The values are mean and standard deviations of three replicates. (Mean± SD) (N=3). All values are given in percentage except electrical conductivity

Table-6 : Growth characteristics of maize plants cultivated in different vermicomposts. (15 days after seed inoculation)

Treatment	Mean plant heights(cm)	Mean plants diameters(mm)
Sago waste vermicompost	23.5*	1.0*
Dairy waste vermicompost	22.2*	1.2*
Vegetable waste vermicompost	24.5*	1.5*
Municipal waste vermicompost	20.6*	0 .8*
Control	14.0	0.5

*significant difference from control ($p \leq 0.05$)

Total nitrogen (TKN)

Total Kjeldhal nitrogen content of the compost increased significantly with time in all the substrates in the presence of earthworms. This could be probably due to mineralization of the organic matter (Tables 3 - 6). The highest increase of TOC was in vegetable waste and the lowest reduction was in dairy waste. Decrease in pH may be an important factor in nitrogen retention as this element is lost as volatile ammonia at higher pH (Hartenstein and Hartenstein, 1981). Increase in nitrogen content in the final product in the form of mucus, nitrogenous excretory substances, growth stimulating hormones and enzymes from earthworms have also been reported (Tripathi and Bhardwaj, 2004). According to Viel et al. (1987) loss in organic carbon might be responsible for nitrogen enhancement. Earthworms also have a great impact on nitrogen transformations in manure, by enhancing nitrogen mineralization, so that mineral nitrogen may be retained in the nitrate form Atiyeh *et al*. (2000). However, in general the final N content of compost is dependent on the initial N present in the waste and the extent of decomposition. (Gaur and Singh, 1995).

Total Phosphorus (TP)

Results revealed that available phosphorous increased significantly in all the substrates with worm inoculated waste than in control i.e. treatment without earthworms (Tables 3 - 6). The highest increase in P was observed in vegetable waste vermicompost. Mansell et al. (1981) observed that plant litter was found to contain more available P after ingestion by earthworms, which may be due to the physical breakdown of the plant material by worms. Increase in TP during vermicomposting is probably due to mineralization and mobilization of phosphorus as a result of bacterial and faecal phosphatase activity of earthworms (Edwards and Lofty, 1972).

Total Potassium (TK)

The total potassium values increased in all the feed substrates at the final stage of vermicomposting. This increased levels of TK at the final product than in the initial feed substrates indicating that the microbial flora also influences the level of available potassium. Acid production by the microorganisms seems to be prime mechanism for solubilizing the insoluble potassium.

Carbon-to-nitrogen ratio (C:N)

The C:N ratio of all the substrate materials showed drastic change during vermicomposting. A decrease in C:N ratio was observed in all the treated wastes during experimentation. The highest decrease in C:N ratio was in vegetable waste followed by municipal wastes, sago wastes and dairy wastes. The C:N ratio traditionally considered as a parameter to determine the degree of maturity of compost. C:N ratio below 20 is indication of acceptable maturity, while a ratio of 15 or lower being preferable (Morais and Queda, 2003). Referring to this study, vermicompost from all the substrates is preferable as C:N ratio within the acceptable limit (Table 3-6).

Plant growth characteristics

The germination efficiency of maize seeds was shown to be higher in all the vermicomposts when compared to the control. Plant height and stem diameter were also found to be increased in plants grown at different vermicomposts as compared to control. The maximum height and stem diameter was observed in plants grown at vegetable waste vermicompost. The increase in growth parameters might be due to availability of nutrients like free aminoacids and plant growth promoting substances auxin and cytokinins in vermicomposts prepared by using different wastes and earthworms.

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