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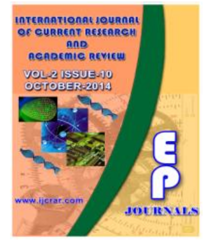

Earthworms: significant contributors to bioconversion process of agro-industrial wastes

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A B S T R A C T

Earthworms contribute to bioconversion process as agents in breaking down of agro-industrial wastes that are otherwise hard to undergo degradation. The compost that is formed during the earthworm activity is termed as vermicompost. Only selected species of earthworms which feed exclusively on organic matter can be used for this process of composting of agro-industrial wastes. The species in genus *Perionyx sp*.(abundantly reported in Sagar, Madhya Pradesh) are good compsoters, though not as efficient as *E. eugeniae* or *Eisenia foetida.* Vermicomposting will be economical venture when it is taken up at the vicinity of the waste generating places. It has to be practiced by the farmer himself rather than buying the compost produced by others. With the available natural resources in the field vermicompost can be produced and it has to be a part of the integrated farming system. Present study revealed some examples of duration of vermi-bioconversion process of agro-industrial wastes namely, banana waste and bagasse with dung and other microbial additives.

Introduction

The green revolution in India has led to indiscriminate use of fertilizers to obtain two to three crop yields per annum in lands with good irrigation. In the course of time, the tropical soils which are prone to depletion in carbon level and other nutrients are turning unproductive due to lack of proper organic amendments. A tenfold increase in use of fertilizers, pesticides and machinery compared to a mere two fold increase in agricultural production is economically not viable in the country with marginal and medium land holders. It is known that for every tonne of food grains produced, 50 kg N, 30 kg P and 90 kg K are being utilized as chemical fertilizers. Organic Farming with use of manures is the only way to make country sustainable agriculture system. Dependency on only cattle dung as the organic manure source is not viable in the existing situations. The current need is to make best use of the available unutilized organic biodegradable resources into compost, in minimum time. The study reviewed the bioconversion process of various agro-industrial wastes into organic manure.

Earthworm Species Selection for Organic Waste Decomposition

Of many species of epigeic earthworms sp. for mass cultivation all over the world, including the tropical and temperate regions *Eisenia foetida* (Savigny), *Eudrilus eugeniae* (Kinberg) and *Perionyx excavatus* (Perrier) came in the order of preference for their ability to degrade the wastes (Kale, 1994). *Eisenia foetida* and *Eudrilus eugeniae* are exotic species (Lee, 1985; Sunitha, 1995). Their high biomass production attained an increase of 40 to 90 times in a period of 3 to 6 months with adequate space and food (Mba, 1978; Neuhauser *et al*, 1988; Kale *et al*, 1982; Viljoen and Reinecke, 1989; Reinecke and Hallatt, 1989). These three earthworm species are reported to be very efficient and adoptable in cultures under semi-natural conditions in India (Table 1.0; Kale, 1993). During the present investigation measured quantity (2.5 kg/unit) of partially decomposed organic wastes were inoculated with counted number of worms (1p pairs/box). Each treatment was repeated three times. At harvest of compost observations were recorded. Data so obtained were used to work out mean (%) increase in clitellate worm population and weight for each treatment.

Table.1 Comparative study of three vermicomposting epigeic sps. of earthworms

Characters	*Eisenia foetida*	*Eudrilus eugeniae*	*Perionyx excavatus*
Duration of life cycle (days)	+70	+60	+46
Growth rate (mg worm^{-1} day^{-1})	7	12	3.5
Maximum body (mg/worm)	1500	4294	600
Maturation attained at age (clays)	150	+40	+21
Start of cocoon production (days)	+55	+46	+24
Cocoon production (worm^{-1} day^{-1})	0.35	1.3	1.1
Cocoon incubation period (days)	+23	+ 16.6	+ 18.7
Mean number of hatchings (cocoon^{-1})	2.7	2.7	1.1
Number of hatchings from one cocoon	1.9	1.5	1.3

However, according to published data the increased attention has been given to *Eisenia foetida* as a potential waste decomposer. Earthworm *Eisenia foetida* has also been used at large for laboratory investigations and for commercial activities by in our earlier studies. It is most promising worm for vermicomposting, its biology and environmental requirements have been extensively reported (Graff and Makeschin 1980; Watanabe and Tsukamoto 1976; Hartenstein *et al.*, 1979; Reinecke and Venter, 1987; Edwards, 1988). Research work have been done by Kaplan *et al.* (1990) and Edwards and Lofty (1996) have shown that it grows in a wide range of agricultural wastes. *Eisenia foetida* worms have also been shown to have a wide tolerance range for temperature *i.e.* 0^{o}C-40^{o}C (Hallat *et al.*,1992).

Microbial and Enzymatic Activities of Earthworms

Researches were found focused on earthworm casts, since casts provide a good substrate for the growth of micro-organisms (Satchell, 1967). Watanabe and Tsukamoto (1976) and Parle (1963) showed that casts do harbour more microbial flora than the surrounding soil, especially in cast formed from soil containing added organic matter. Because of rich nitrogenous compounds and high microbial load, casts stimulates the microbial decomposition (Kulkarmi, 2002). Actinomycetes, bacteria and selective fungi increase in numbers during passage of food through worm gut as well as in cast, was reported by Parle (1963) who also reported that oxygen consumption remained higher in vermicompost than in soil, indicating an increased microbial activity. Increase in nutrient availability by earthworms depends on microbial activities of earthworm gut. The interaction between earthworms and micro-organisms are of major importance in the degradation of organic matter and release of mineral nutrients into soil (Edwards and Lofty, 1977; Lee, 1953). Earthworms have also been reported to increase the availability of plant nutrients in soil (Kaplan *et al.*,1980) increase the production of plant growth regulators (Reinecke *et al.*,1994) and also increase foliar concentration of Ca, Na, Mn, Cu, Fe and Al in wheat (Giraddi, 2000). An increase in the density of microbes and nitrogen fixers due to vermicompost application was reported by Kale (1993).

Earthworm Bioconversion process of Organic Wastes

Three abundantly available organic wastes *viz.* dung, banana waste and bagasse were selected and subjected to bioconversion by the red compost worms *(Eisenia foetida)* in our earlier studies. Bioconversion efficiency for various agro-industrial wastes of this worm in relation to the organic matters and seasonal changes was assessed by using various parameters (Table 2,3,4). In terms of vermistabilisation both dung and bagasse mixed and alone partially decomposed for 14 days, were found to be easily acceptable for the worms on release in the rearing box . Within 12.3 to 172 minutes after their release, the worms entered into the culture media. But the banana waste (pseudostem and leaves) was not accepted by the worms so readily. However, when mixed with dung and bagasse after partial decomposition of 15 days it became more easily acceptable for the worms which took 28.3 to 172 minutes to enter into the culture media. It was also found that when these organic matters subjected with *Azotobacter* consumed lesser time in decomposition in comparison to other additives. The results indicated that *Eisenia foetida* does not feed on freshly voided organic matters and, it must undergo biological and chemical alterations during 6 to 15 days at least. As regards the duration of bioconversion it was greatly influenced by the type of organic materials and the additives as well. Among the organic materials bioconversion was quickest (45 days) after inoculation of worms to cow dung with *Azotohacter* and it was slowest taking longest duration (92.7 days) in banana waste alone. On the use of additives duration of bioconversion varied from 45 to 79.3, 61 to 81.7, 73.7 to 87.7, 61 to 80.3, 56.3 to 78.3. 69.3 to 84.3, 62.3 to 74 days in the case of dung, bagasse, banana waste, dung + banana waste (2:1), dung + bagasse (2:1), bagasse + banana waste (2:1), dung + bagasse + banana waste (2:1:1) respectively depending upon the types of additives. Total duration taken in complete bioconversion varied widely from 50 to 108 days. The shortest and longest days of bioconversion were recorded in dung, banana waste respectively. Use of the additives did not show marked difference in total number of days required for complete bioconversion of the respective organic materials. From the experimental findings discussed above, it became obvious that use of *Azotohacter*, *Trichoderma*, *PSB(phosphate solublizing bacteria)*, bone meal, *2%* as additives brought about improvement in efficiency of *E. foetida* for bioconversion of different organic matters. On addition of additive composting process hastened up especially in case *of Azotobacter* and it was considerably enhanced.

Table.2 Bioconversion period (days) of Dung with use of microbial additives and *Eisenia foetida*

Organic matter	Months	Age of organic matter (days)	Vermi-stabilization	Rate of bioconversion of various organic matters	
				Period of complete bioconversion	Total duration of vermicomposting
Dung	J-M	7	22.3±2.851	74.0±0.531	81.0±4.531
	A-J	7	32.3±2.851	71.3±2.616	78.3±2.616
	J-S	7	31.3±3.461	75.0±3.398	82.0±3.398
	O-D	7	19.7±1.730	70.0±2.265	77.0±2.265
Dung + *Azotobacter*	J-M	5	25.3±1.730	45.0±3.398	50.0±3.398
	A-J	5	27.7±2.851	50.0±2.265	55.0±2.265
	J-S	5	24.0±1.962	48.0±2.265	53.0±2.265
	O-D	5	17.3±1.308	51.0±2.997	56.0±2.997
Dung + *Trichoderma*	J-M	7	22.7±2.851	69.7±5.108	76.7±5.108
	A-J	7	21.0±3.398	70.3±4.578	76.0±5.887
	J-S	7	25.3±1.730	69.0±4.084	76.0±4.084
	O-D	7	20.3±2.358	74.0±4.531	81.0±4.531
Dung+ Phosphate solubilizing bacteria	J-M	10	19.7±1.730	60.0±5.664	67.0±5.664
	A-J	14	21.7±1.730	77.3±3.461	84.3±3.461
	J-S	14	26.7±1.730	71.0±4.084	78.0±4.084
	O-D	10	20.0±1.132	50.0±2.265	56.3±1.308
Dung + Bone meal	J-M	12	15.0±3.398	71.7±3.987	85.7±3.987
	A-J	14	21.3±1.730	78.0±4.531	92.0±4.531
	J-S	14	20.0±2.265	79.3±1.308	93.3±1.308
	O-D	12	23.3±1.730	68.0±5.887	82.0±5.887

Table.3 Bioconversion period (days) of Banana waste with use of microbial additives and *Eisenia foetida*

Organic matter	Months	Age of organic matter (days)	Vermi-stabilization	Rate of bioconversion of various organic matters	
				Period of complete bioconversion	Total duration of vermicomposting
Banana waste	J-M	15	92.0±0.086	87.3±3.461	102.0±3.461
	A-J	15	84.0±0.040	87.7±2.851	103.0±2.851
	J-S	15	92.0±0.032	86.0±1.962	101.0±1.962
	O-D	15	83.0±0.032	92.7±4.578	108.0±4.578
Banana waste+ *Azotobacter*	J-M	10	50.0±5.664	73.7±3.641	83.7±3.641
	A-J	10	41.7±3.270	75.0±3.398	85.0±3.398
	J-S	10	56.7±3.270	76.0±1.962	86.0±1.962
	O-D	10	43.3±4.716	79.3±1.308	89.3±1.308
Banana waste+ *Trichoderma*	J-M	15	90.0±0.056	79.3±1.308	91.3±1.308
	A-J	15	85.0±0.056	87.7±6.239	103.0±5.887
	J-S	12	97.0±0.032	86.7±3.270	102.0±3.270
	O-D	12	102.0±0.032	82.3±2.851	94.3±2.851
Banana waste+ Phosphate Phosphate solubilizing bacteria	J-M	12	95.0±0.013	76.0±1.962	88.0±1.962
	A-J	15	98.0±0.032	81.7±3.270	96.7±3.270
	J-S	15	86.0±0.059	81.7±3.270	96.7±3.270
	O-D	12	85.0±0.056	84.0±1.962	88.0±1.962
Banana waste+ Bone meal	J-M	12	82.0±0.065	86.0±5.995	95.7±1.730
	A-J	15	78.0±0.032	83.3±3.270	101.0±5.995
	J-S	15	96.0±0.045	78.0±2.265	98.3±3.270
	O-D	12	79.0±0.013	84.0±2.430	90.0±2.265

Nutritive Value of Manure and Vermicompost

The nutrient levels of vermicompost depends largely on the nature of the organic wastes used as food source for earthworms and a heterogeneous waste mix would have balanced level of nutrients than from only one particular waste (Kale, 1993). Edwards (1998) reported that during feeding by earthworms, the C:N ratio in the organic matter falls progressively and moreover, the nitrogen is converted into the ammonium or nitrate form. At the same time the other nutrients P and K are converted into a form available to plants. Kale (1995) reported vermicompost contains organic carbon - 9.15 to 7.98%, total nitrogen 0.5 to 1.5%, available phosphorus - 0.1 to 0.3%, available potassium - 0.15 to 0.56%, available sodium - 0.06 to 0.3%, calcium and Magnesium - 22.67 to 46.70 MEC/100g, Copper 2.0 to 9.5 ppm, iron 2.0 to 9.3 ppm. Zinc 5.7 to 11.5 ppm and available sulphur 128.0 to 548.0 ppm. It acts as an excellent base for the establishment and multiplication of beneficial/symbiotic microbes.

Table.4 Bioconversion period (days) of Bagasse with use of microbial additives and *Eisenia foetida*

Organic matter	Months	Age of organic matter (days)	Vermi-stabilization	Rate of bioconversion of various organic matters	
				Period of complete bioconversion	Total duration of vermicomposting
Bagasse	J-M	6	20.7±1.308	80.0±4.531	86.0±4.531
	A-J	6	26.7±3.270	81.7±3.270	87.7±3.270
	J-S	6	21.0±4.084	84.0±1.962	90.0±1.962
	O-D	6	20.0±2.265	78.0±2.265	84.0±2.265
Bagasse + *Azotobacter*	J-M	4	15.3±0.654	67.7±2.851	75.0±4.084
	A-J	4	20.7±1.308	72.3±2.851	76.3±2.851
	J-S	4	15.33±1.308	76.0±1.962	77.0±7.075
	O-D	4	12.3±2.851	61.0±7.42	65.0±7.429
Bagasse + *Trichoderma*	J-M	6	16.0±7.849	76.0±1.962	82.0±1.962
	A-J	7	31.7±3.270	81.7±3.27	87.7±3.270
	J-S	6	35.0±5.66	76.7±3.270	82.7±3.270
	O-D	6	23.3±4.716	72.7±4.578	82.0±1.962
Bagasse + Phosphate solubilizing bacteria	J-M	6	35.0±5.664	66.7±3.270	72.7±3.270
	A-J	6	40.0±5.664	81.7±3.270	87.7±3.270
	J-S	6	39.3±1.308	78.7±1.308	84.7±1.308
	O-D	6	27.7±2.851	70.3±4.578	76.3±4.578
Bagasse + Bone meal	J-M	6	25.0±3.398	69.0±4.084	75.0±4.084
	A-J	6	32.3±2.851	80.0±2.265	86.0±2.265
	J-S	6	30.0±5.664	76.0±1.962	82.0±1.962
	O-D	6	43.3±3.270	68.3±3.270	74.3±3.270

Vermicompost being a complex biofertilizers, it would not be desirable to compare its status as a mere supplier of NPK nutrients (Viljoen *et al.*, 1992). However, vermicompost was found to contain an average of 1.60, 2.20 and 0.67 percent of N, P_2O_5 and K_2O respectively as against the same being 0.80. 0.41 and 0.74 percent in FYM. The increase in phosphorous was attributed to greater phosphatase activity in earthworm casts (Satchell, 1967). Increase in the potassium, calcium, magnesium and sulphur in the vermicompost prepared from different sources of organic materials has been reported by Kretzschmar (2002).

Conclusions

Composting with use of various agro-industrial wastes with earthworms may help to increase the availability of N. P and K in the compost materials as compared to traditional method of composting. In view of wide variation in available nutrient status of vermicompost prepared from various organic wastes, attention is required to produce quality compost, which depends on base materials to be composted.

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