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Chapter

Efficacy of Different Substrates on Vermicompost Production: A Biochemical Analysis

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Abstract

The rapid increase in the volume of waste is one aspect of the environment crisis, accompanying global development. Earthworms play an important role in the decomposition of organic matter and soil metabolism through feeding, fragmentation, aeration, turnover and dispersion. The type of substrates used and species of earthworms introduced plays a significant role in plant growth and yield. The waste to be stabilized should support an adequate biomass needed for effective processing. In the present study the vermicompost produced from banana as a substrate did not show a significant increase in NPK content from that of the control. On the other hand poultry waste and vegetable waste with goat dung showed significant increase in the NPK content. The enhancement of the vermicompost was probably due to mineralization of the organic matter containing proteins and conversion of ammonium nitrogen into nitrite. Mineralization and consequent mobilization of phosphorous by enhanced bacterial and phosphatase activities during vermicomposting leads to increase in Phosphorus. The earthworm processed waste materials contain high concentration of exchangeable potassium, due to enhanced microbial activity during the vermicomposting process, which accordingly enhanced the rate of mineralization. Vermicompost tends to hold more nutrients over larger periods without adverse effects on the environment.

Keywords: vermicompost, nitrogen, phosphorus, potassium, substrates, organic matter

1. Introduction

Solid waste is one of the growing problems in both developed and developing countries. Due to the rapid growth in industrialization, most of the rural populations have shifted towards the urban area in search of employment. The rapid increase in the volume of waste is one aspect of the environment crisis, accompanying global development.

Earthworms play an important role in the decomposition of organic matter and soil metabolism through feeding, fragmentation, aeration, turnover and dispersion [1]. Earthworms are involved in the recycling of nutrients, soil structure, soil productivity and agriculture, and their application in environment and organic waste management is well understood [2, 3]. They help in the degradation of substrate indirectly by affecting microbial population structure and dynamics and also directly since their gut is capable of undertaking cellulolytic activity. Thus products of cellulose hydrolysis are available as carbon and energy sources for other microbes that inhabit the environment in which cellulose is degraded and this availability forms the basis of many biological interactions.

There are about 3627 species of terrestrial earthworms in the world [4]. Sixty three species of earthworm from Sri Lanka of which 47 are considered as zoogeographically important to the Asian region have been recorded [5]. Vermiculture biotechnology promises to contribute in the 'second green revolution' by completely replacing the destructive agrochemicals which did more harm than good to both farmers and their farmland during the 'first green revolution' of the 1950–1960s.

Three major groups of earthworms based on ecological strategies have been recognized: the epigeics (Epiges), anecics (Aneciques) and endogeics (Endoges) [6]. Epigeic earthworms live in the soil surface and are litter feeders. Anecic earthworms are top soil species, which predominantly form vertical burrows in the soil, feeding on the leaf litter mixed with the soil. Endogeic earthworms preferably make horizontal burrows and consume more soil than epigeic and anecic species, deriving their nourishment from humus.

Vermicomposting is a mesophilic procedure, using microorganism and earthworms that are dynamic at 10–32°C. Vermiculture provide for the use of earthworms as a natural bioreactor for cost effective and eco-friendly waste management. Earthworm fecundity is based on the rate of cocoon production, hatching success of cocoons and number of offspring's emerging from each cocoons. The success of the composting depends upon the fecundity of the earthworm.

The type of substrate used and species of earthworms introduced plays a significant role in plant growth and yield. The waste to be stabilized should support an adequate biomass needed for effective processing. The time, cost and space requirements could compete economically with conventional methods of composting [7].

2. Substrates used for vermicomposting

2.1 Cow and goat dung

Vermicomposting of cattle and goat manure by *Perionyx excavatus* and their growth and reproduction performance was studied [8]. They concluded that cattle manure provided more nutritious and friendly environment to the earthworm than goat manure. The effects of Goat manure sludge, sewage and effective microorganisms on the composting of pine bark was studied [9]. The pine bark goat manure compost had more desirable nutritional properties than the pine bark and pine bark sewage sludge composts. It had neutral pH, C\N ratio and high amount of inorganic constituents.

2.2 Poultry waste

Poultry litter is the mix of bedding material, manure and feathers that result from intensive poultry production. This includes litter from meat chickens (broilers), egg laying chickens (layers) kept under barn conditions, turkeys, ducks and quails.

Limited available data presents numerous challenges while vermicomposting poultry litter. High ammonical nitrogen concentration, auto heating, and high bulk density are some of the major concerns that need to be addressed while vermicomposting poultry litter [10]. Poultry wastes contain significant amount of organic salts and ammonia that kill worms. So it is necessary to neutralize freshly deposited wastes by $CaCO_3$.

2.3 Fruit waste

The Indian state of Tamil Nadu is the largest producer of bananas in the country cultivating around 9 million metric tons (MT) annually, but inefficient postharvest practices lead to massive waste every year. An average of 30% or 2.7 million MT of Tamil Nadu's bananas currently goes to waste largely due to the absence of integrated cold chain infrastructure. Banana cultivation produces a huge amount of waste: approximately 30 tonnes of waste is generated per acre in one crop season from banana stem alone.

India produces around 2300 tonnes of papaya annually. In the past decade, the area under papaya cultivation in India has hugely increased following the introduction of Taiwanese and Hawaiian varieties. The processing operation of fruits and vegetables produce significant wastes as by-products, which constitute about 25–30% of a whole commodity group. The waste is composed mainly of seed, skin, rind, and pomace, containing good sources of potentially valuable bioactive compounds, such as carotenoids, polyphenols, dietary fibers, vitamins, enzymes, and oils, among others.

2.4 Paper waste

The Indian paper industry accounts for about 1.6 per cent of the world's production of paper and paper board. It is the 15th largest in the world and is one of the high priority industries having a bearing on the socio-economic development of the country.

India consumes almost 100 lakh tons of paper and paper boards. Paper Mills in the country are increasing their production and renovating their plants. By 2025, the demand for paper would increase to 2.5 crore metric tons. There is no effective collection mechanism for waste paper from offices and households. Newspapers are used for packaging. Muncipalities are not efficient in waste management network. There is lack of space for storage and sorting of waste paper. No proper co-ordination exists between the informal sector and the main supply chain of waste paper to paper industry (**Tables 1** and **2**).

2.5 NPK analysis

In the present study different substrates have been used to culture earthworms and the nutrient content of the vermicompost produced by them has been analysed. The nitrogen content has significantly increased in papaya waste, paper waste, poultry litter and vegetable waste with goat dung. Phosphorus content has significantly increased in all the wastes except banana and levels of potassium have decreased in banana and paper waste. In the study the vermicompost produced from banana as a substrate did not show a significant increase in NPK content from that of the control. On the other hand poultry waste and vegetable waste with goat dung showed significant increase in the NPK content.

In vermicompost, a higher amount of organic carbon is used when compared to the normal compost as the earthworms have higher additional assimilating capacity besides microorganisms. Earthworms also modify the conditions which subsequently lead to increased carbon losses as CO_2 due to microbial respiration in organic matter being converted to vermicompost [11].

Samples	Banana waste			Papaya waste			Paper waste		
	N	P	K	N	P	K	N	P	K
Control 45 days	0.48 $\pm$ 0.03*	1170 $\pm$ 5.83*	23 $\pm$ 0.37*	0.42 $\pm$ 0.06*	787 $\pm$ 6.12*	21 $\pm$ 0.32*	0.53 $\pm$ 0.30*	211.23 $\pm$ 4.38*	628.50 $\pm$ 93.04^{NS}
Treated 45 days	0.41 $\pm$ 0.07*	840 $\pm$ 2.55*	17.1 $\pm$ 0.32*	0.47 $\pm$ 0.05*	974 $\pm$ 9.08*	19.10 $\pm$ 0.28*	0.57 $\pm$ 0.09*	270.13 $\pm$ 21.92*	526 $\pm$ 149.66^{NS}

*Values are mean $\pm$ SD. *- $p \leq 0.05$; NS – Not significant. Refs. [30, 31]*

Table 1.
NPK analysis of vermicompost produced from banana waste, papaya waste and paper waste.

Samples	Poultry waste			Cow dung and vegetable waste			Goat dung and vegetable waste		
	N	P	K	N	P	K	N	P	K
Control 45 days	1.08 $\pm$ 0.07^{NS}	0.39 $\pm$ 0.05*	0.22 $\pm$ 0.02*	6.31 $\pm$ 469.077^{NS}	846 $\pm$ 48.256*	16.89 $\pm$ 127.71^{NS}	6.31 $\pm$ 469.077^{NS}	846 $\pm$ 48.256*	16.89 $\pm$ 127.71^{NS}
Treated 45 days	2.5 $\pm$ 0.1^{NS}	0.67 $\pm$ 0.14^{NS}	0.65 $\pm$ 9.11^{NS}	6.14 $\pm$ 434.925^{NS}	896 $\pm$ 40.329*	17.74 $\pm$ 80.233^{NS}	6.84 $\pm$ 1104.70^{NS}	1024 $\pm$ 25.292*	18.76 $\pm$ 83.66^{NS}

*Values are mean $\pm$ SD. *- $p \leq 0.05$; NS – Not significant.*

Table 2.
NPK analysis of vermicompost produced from poultry waste, cow dung and vegetable waste and goat dung and vegetable waste.

The pH reduction may be due to the mineralization of nitrogen into nitrates/nitrites and phosphrous into orthophosphates as well as bioconversion of organic wastes into organic acids [12]. Studies where *Bacillus* has been reported to be isolated from the gut of *Eisenia foetida* [13] and these gut associated miroflora assists the earthworms significantly to hasten the decomposition of organic matter by producing certain enzymes namely cellulase, amylase, protease etc. Although dependent upon earthworm species, it is known that earthworms interact with microorganisms (fungi, bacteria and actinomycetes) on three broad spatial scales-burrow linings, casts and earthworm gut or intestine. Importantly, the increased gut associated microflora are then excreted throughout the media within earthworm casts and via microbial adherence to earthworm skin whilst the transit and dispersal mechanisms associated with the water flow also help to further dissipate microorganisms [14].

2.6 Nitrogen

The enhancement of the vermicompost was probably due to mineralization of the organic matter containing proteins [15, 16] and conversion of ammonium nitrogen into nitrite [17, 18]. The final N content of the compost as well as the vermicompost depends on the initial content of N in the substrate and the extent of its decomposition [19, 20]. The earthworms can enhance N levels during vermicomposting through the digestion of substrate in their gut and simultaneous addition of nitrogenous excretory products, mucous, body fluid, enzymes; besides the decay of dead tissues of worms in vermicomposting system [21]. This nitrogen content value could have been due to the nitrogenous metabolic products of earthworms which are returned to the vermicompost as casts.

2.7 Total phosphorous

Mineralization and consequent mobilization of phosphorous by enhanced bacterial and phosphatase activities during vermicomposting leads to increase in P [22]. An increase of 25% P in paper waste sludge after the activities of earthworms was reported [23]. They further suggested that the consequent increase in P after the earthworm's activities may be due to the direct action of worm gut enzymes and due to enhanced microbial activity in the vermicompost. Increase in P content in vermicompost could be due to enhanced mineralization and mobilization of phosphorous as a result of increased bacterial and fecal phosphatase activity of earthworms [22].

Plant litter was found to contain more available P after ingestion by earthworms, which may be due to the physical breakdown of the plant materials by worms. An increase of 25% in P in paper waste sludge after worm activity was observed. They attributed this increase in P to the direct action of worm gut enzymes and indirectly by stimulation of the microflora [23].

The increased phosphorous level was due to mineralization of phosphorous. The release of phosphorous in the available form is performed partly by earthworm gut phosphatases and further release of phosphorous might be assigned to the phosphorous solubilizing microbes present in vermicast. The earthworm affects phosphorous mineralization in wastes during passing organic matter through its gut.

2.8 Total potassium

Decrease in potassium content in the vermicompost may be due to the leaching of this soluble element through the action of excess water draining through the mass [24].

The rate of nutrient loss was directly related to the initial concentrations [25]. The selective feeding of earthworms on organically rich substances which breakdown during the passage through the gut, biological grinding, together with enzymatic influence on finer soil particles, were lightly responsible for increasing the different forms of K [26]. The increase of soil organic matter resulted in decrease K fixation and subsequent increase K availability [27].

The available micro-nutrients like potassium (K) are required for assimilation by earthworms during the vermicomposting, although the quantity required is very low as compared to the initial content present in the parent feed material. The production of acids by the microorganisms and enhanced mineralization rate through increased microbial activity during the vermicomposting process play a key role in the solubilizing of insoluble potassium [28, 29].

The increase of potassium in the treated might be due to changes in the distribution of potassium between exchangeable and non-exchangeable forms. The earthworm processed waste materials contain high concentration of exchangeable potassium, due to enhanced microbial activity during the vermicomposting process, which accordingly enhanced the rate of mineralization.

When organic matter passes through the gut of earthworm, unavailable potassium is transformed to more soluble forms with enhanced rate of mineralization. Decomposition of organic material by microorganisms produces acid products that increase the available soluble potassium. On the other hand, the gut of earthworm has a big population of microflora that could enhance potassium content in the vermicompost.

3. Conclusion

Vermicomposting has many applications such as increasing water holding capacity, crop growth and yield, improves the physical, chemical and biological properties of the soil. It increases the production of plant growth regulators. Vermicompost is pollution free and cost effective. The texture of vermicompost is homogenous, contains many plant growth hormones and soil enzymes and tends to hold more nutrients over larger periods without adverse effects on the environment.

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Conflicts of interest

There is no conflict of interest.

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