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Bioconversion of herbal industry waste into vermicompost using an epigeic earthworm *Eudrilus eugeniae*

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Abstract

The aim of the present study was to investigate the potential of bioconversion of industrial herbal waste to vermicompost using *Eudrilus eugeniae*. Vermibeds were made using a mixture of herbal waste and cowdung (1 : 1) in comparison with the use of cowdung alone as substrate, resulting in vermicomposts 1 and 2, respectively. Different parameters were studied and it was observed that the nutrient profile of vermicompost 1 strongly influenced the growth of pea (*Pisum sativum*) and marigold plant (*Tagetus erectus*). The dry and fresh weight of shoots and roots, number of flowers, total yield in terms of fruit showed significant increase with vermicompost 1. Furthermore, vermicompost 1 (herbal waste and cow dung as substrate) resulted in a significant reduction in TOC by 58% in comparison with vermicompost 2 (cowdung as substrate). The C : N ratio was less than 20 in vermicompost 1 as well as in vermicompost 2, which indicated an advanced degree of stabilization and mineralization. The ability of earthworms to survive, grow and breed in the vermibed fed with the herbal waste indicates the sustainability and efficiency of a heterogeneous kind of organic waste. The results of the study suggested that bulk industrial herbal waste can be utilized as a substrate for vermicomposting and this can be proposed as an alternative for waste disposal in a clean green manner, promoting the concept of organic farming.

Keywords

Organic waste, vermicompost, *Eudrilus eugeniae*, chlorophyll and carotene, C : N ratio

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Introduction

High rates of industrialization and increasing population lead to major problems concerning the disposal of industrial solids and household waste, which is further augmented by the shortage of landfills. Moreover, strict environmental legislations and public consciousness have made landfilling increasingly expensive and irresolute (Gupta et al. 2007). Therefore there is a need for cost-effective and eco-friendly solid waste management alternatives. In this context, vermicomposting is becoming popular as an appropriate, safe, hygienic and cost-effective method for the disposal of biodegradable waste that is rich in organic matter. Although the practice of vermicomposting is centuries old it is now being revived with ecological objectives such as waste management, soil detoxification, sustainable agriculture and a demand for organic products that are free of chemical fertilizers (Suthar 2007, Pattnaik & Reddy 2010).

Vermicompost has a special place among the sources of organic manures as it has a greater quantity of readily available plant nutrients (Tejadaa & González 2009), growth-enhancing substances with soil conditioner properties that facilitate the establishment of plant roots and improve water retention (Gajalakshmi et al. 2001a). It is much more fragmented, porous and microbially active than the parent material due to humification and increased decomposition.

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Eudrilus eugeniae species of earthworm was selected for vermicomposting of herbal industry waste. It is an epigeics or humus feeding earthworm (Abbasi & Ramaswamy 2001) which is extensively used in North America and Europe and recently in India for vermicomposting because of its voracious appetite, high rate of growth and reproductive ability (Gajalakshmi et al. 2001b).The action of earthworms in the process of vermicomposting is physical and biochemical. The physical process includes substrate aeration, mixing as well as actual grinding whereas the biochemical process is influenced by microbial decomposition of the substrate in the intestine of the earthworms.

Vermicomposting is one of the pathways towards organic farming which involves replacing excessive use of agrochemicals and fertilizers which threatens the fragile ecosystem. Organic farming conserves soil fertility and restrains soil erosion through the implementation of conservation principles (Kannan et al. 2005). It widely relies on the application of animal wastes or farmyard manure, compost, crop residues, green manure, vermicompost, biofertilizers like vesicular arbuscular mycorrhiza – VAM (a type of symbiotic association in which fungi enhances the accumulation of nutrients available to the host plant), bio-pesticides and biological control. Vermicomposts significantly influence the growth and productivity with respect to field crops, vegetable, flower and fruit crops (Azarmi et al. 2008). In the present study the efficacy of vermicompost 1 and 2 were compared and evaluated in a field study experiment on the growth of pea (*Pisum sativum*) and marigold plants (*Tagetus erectus*).

Material and methods

Industrial herbal waste

The industrial herbal waste sample used in the present study was provided by Ayurvet Industry Ltd., Baddi, Solan (H.P.). The samples of the waste, which is known commercially as Diaroak was dried, ground and stored at room temperature for further use. The waste was amalgamations of various remains of medicinally important herbs after industrial operation (Table 1). Fresh cowdung was procured from an intensive livestock-rearing establishment in a nearby village.

Table 1. Composition of the industrial waste

Plant species	Percentage (%)
Punica granatum (fruit)	24
Symplocus racemosa (bark)	12
Andrographis paniculata (stem)	10
Woodfordia fruticosa (flowers)	14
Salmalia malabarica (bark)	3.5
Berberis aristata (root)	13.5
Aegle marmelos (fruit)	22

Vermiculture

The epigeic species of earthworm, *Eudrilus eugeniae*, which was used in the present study, was procured from a stock culture maintained at Dr Y. S. Parmar University of Horticulture & Forestry, Nauni –Solan (H.P.). *Eudrilus eugeniae* can tolerate temperatures ranging from 0 to 40°C and this attribute proved to be very useful for vermicomposting of herbal waste in a cold hilly terrain located at a height of 1550 m above msl near Shimla, Himachal Pradesh.

In the present study, industrial waste comprising of leftover of processed medicinal plant parts of Ayurvet was used for vermicomposting. Ayurvet industry, which was formerly known as Dabur Ayurvet Ltd., is located in Baddi, Solan, Himachal Pradesh and deals in herbal health care and nutritional products for a range of animal species in India as well as abroad. During the processing & manufacturing of drugs 0.5 to 1.0 ton of medicinal plant waste is discarded daily. Currently, most of it is dried and used as low value cattle feed. However, there is no suitable place for disposal of a substantial part of the waste material. The waste consisted of various plant species and their parts (Table 1). To the authors knowledge this is the first report on the bioconversion of herbal industrial waste into vermicompost.

Application of vermicompost involves the recycling of organic waste materials and this contributes to the production of energy-rich resources and also reduces environmental pollution. The vermicompost helps by: improving the soil pH and the water-holding capacity in sandy soils; improving the size and girth of plant stems and the percolation property of clay soil; increasing the germination rate and growth yield; and promoting early and profuse plant flowering. Moreover, the release of exchangeable and available forms of nutrients increases the oxidizable carbon levels, thereby improving the base exchange capacity of the soil.

Vermicompost beds

For the experiments one cemented vermicompost bed of dimensions 6 feet × 3 feet × 3 feet was used to nurture the population of exotic species of earthworm feeding on cow dung. Two experimental vermicompost beds of dimensions, 50 cm × 50 cm × 15 cm were prepared. One vermicompost bed received 5 kg of the cow dung whereas the other received 5 kg of a substrate comprising a 1 : 1 ratio of cow dung and herbal waste. Both vermicompost beds were inoculated with 200 earthworms with an average initial weight of 38.96 g. Water was sprinkled and a wet gunny bag (coarse jute fabric bag) was placed on it to keep the environment wet and humid. The moisture content was maintained at a level of 60–70% and representative samples were taken from the vermibeds. Finally, the moisture was measured gravimetrically by drying the soil at 105°C until constant weight was obtained. The initial and final weights were used to determine the moisture present.

The average temperature of the vermicompost bed was 30°C. A temporary shelter was erected over the vermicompost beds to protect them from rain water and direct sunshine. After the initial setting the vermicompost beds were left undisturbed for 15 days for precomposting. Subsequently, the gunny bags were removed and contents thoroughly mixed. The maturity of the vermicompost was judged by observing the formation of granular structure of the compost in the vermicompost beds. After a period of 2 months (62 days), vermibed 1 (cow dung & industrial waste 1 : 1) indicated the industrial waste mixed with cow dung had been degraded by the composite action of bacteria, fungi and earthworms in comparison with vermibed 2 (cow dung only) which matured earlier (in approximately 50 days).

Harvesting of the vermicompost

A large sheet of paper was placed on the ground in a well-lit area and the vermicompost was then scooped out of the beds and placed on the paper. As the worms did not like light, they burrowed down towards the dark at the bottom of the heap. The top layer of vermicompost, which was relatively worm free, was removed and placed in the container. The process was repeated until only a small quantity of vermicompost was left along with lots of worms. Using this very procedure (the heap method) all of the vermicompost was harvested from the beds. Finally the vermicompost was sieved through a 2.25 mm sieve to remove the cocoons and other developmental stages of earthworms.

Nutrient analysis

The pH was determined using a double-distilled water suspension of vermicompost in the ratio of 1 : 10 (w/v) which was agitated mechanically for 20 min and filtered through a Whatman no. 1 filter paper (Mclean 1982). Total organic carbon (TOC) was measured using the method of Nelson & Sommers (1982). Total Kjeldahl nitrogen (TKN) was determined after digesting the sample with concentrated sulfuric acid (1 : 20 w/v) followed by distillation (Bremner & Malving 1982). Total phosphorous was estimated by the colorimetric method (Bansal & Kapoor 2000). Total potassium (TK) was determined after digesting the sample in diacid mixture (concentrated HNO_3 : concentrated $HClO_4$, 4 : 1, v/v) by flame photometer (Bansal & Kapoor 2000). The effect of vermicompost 1 (mixture of herbal waste and cowdung 1 : 1) and 2 (cow dung only) on growth and productivity of potted pea (*Pisum sativum*) and marigold (*Tagetus erectus*) plants was investigated. The plant species were selected on the basis of their attributes, for example: high germination capacity, easily procurable seeds and higher flowering capacity. Both the plants were grown in the campus field itself. Plants were observed from initial seed germination until uprooting of the plants (80 days).Seeds were germinated in earthen pots comparing two different treatments with vermicompost 1 and 2. There were two plants per pot during the growing-on phase. The traditional base medium was a mixture of 60% farm soil and 30% sand along with vermicompost 1 and 2, incorporated at the rate of 10%. Equal amount of vermicompost 1 and 2 were added having insignificant variation in their nutrient profile of P and K (Table 2) but differing significantly in their nitrogen content (Table 2). Hence the experiment was planned to see the effect of enhanced nitrogen content on plant growth parameters. Time to flowering was recorded as time from seeding to first open flowers. Flower numbers and pod numbers per pot were counted each 10 days after they appeared. Finally, plant shoot and root were washed with tap water, air dried and their fresh weights were recorded. To obtain the dry weights shoot, root and leaf material were placed in an oven (60°C) overnight and the dry weights were recorded. Chlorophylls *a* and *b* and total carotenoids were determined by spectophotometric methods in acetone solvent (Wellburn 1994). A one-way analysis of variance (ANOVA) was used to analyse the statistical significance at $P < 0.05$ (all in three replications).

Results and discussion

The beds were manually aerated twice a day during the precomposting period. Precomposting is essential in order to

Table 2. Nutrient profile of vermicompost 1 and 2

Parameters	Vermicompost 1 [Herbal waste + Cow dung (1 : 1)]		Vermicompost 2 (only cow dung as substrate)	
	Initial values	Final values	Initial values	Final values
TOC ($g\,kg^{-1}$)[a]	430 ± 0.015	180 ± 0.10	340 ± 0.02	240 ± 0.12
TKN ($g\,kg^{-1}$)[a]	12 ± 0.17	26.3 ± 0.06	6.2 ± 0.08	14.9 ± 0.04
C : N	35.83 ± 0.09	6.84 ± 0.02	54.8 ± 0.06	16.1 ± 0.13
TP ($g\,kg^{-1}$)[a]	2.4 ± 0.05		2.9 ± 0.11	
TK ($g\,kg^{-1}$)[a]	5.6 ± 0.04		5.5 ± 0.09	
pH	8.3 ± 0.02		7.98 ± 0.04	

Data are means of three replication.
[a]Data are ($g\,kg^{-1}$); ± SE (standard error of mean).

eliminate volatile gases that are potentially toxic to earthworms and to get rid off the anaerobic conditions. It also helps in the partial breakdown of the waste, to reduce the lag time for earthworms to feed upon the waste (Gunadi & Edwards 2003, Kaushik & Garg 2003) and to avoid earthworm mortality (Gupta et al. 2007). Initially 200 earthworms were added in each vermibed and approximately 800 and 925 (average of three vermibeds) earthworms were retrieved at the end of the experiment from vermibed 1 and vermibed 2 representing vermicomposts 1 and 2, respectively. There was an average shift of pH value from an initial value of 7.38 to a final value of 8.3 in vermibed 1 and from 7.18 to 7.98 in the case of vermibed 2 (average of three throughout). Most reports have pH values which change from initial alkaline to acidic and so the present results contradict the observations of Mitchell (1997), Gunadi & Edwards (2003) and Garg & Kaushik (2004). The overall increase of pH may be attributed to the decomposition of nitrogenous substances resulting in the production of ammonia and the casts may also cause a temporary increase in pH (Muthukumaravel et al. 2008). The mineralization of the organic matter containing proteins (Atiyeh et al. 2000, Kaviraj & Sharma 2003) and conversion of ammonium–nitrogen into nitrate (Atiyeh et al. 2000, Suthar 2008) also leads to enhancement of N in vermicompost. Earthworms can boost the nitrogen levels of the substrate during digestion in their gut by adding their nitrogenous excretory products, mucus, body fluid, enzymes to the vermicomposting system (Suthar 2008, Muthukumaravel et al. 2008). The nitrogen content of the vermicompost 1 was significantly higher at $P < 0.005$ in comparison with vermicompost 2 (Table 2). The most probable reason for the high content of nitrogen in the vermicompost (Parkin & Berry 1994) was that the industrial waste was rich in nitrogen content. The initial TOC for vermicompost 1 was found to be $430\,g\,kg^{-1}$ and the final value was $180\,g\,kg^{-1}$. Thus a 58% loss of carbon was reported for a period of 62 days. The TOC reduction in vermicompost 1 was significantly higher ($P < 0.05$) than in vermicompost 2. Similar to the present study, Kaviraj & Sharma 2003 reported a 45% loss of carbon during vermicomposting of municipality, or industrial waste. The C : N ratio is one of the most important criteria for judging the maturity of the vermicompost. The initial C : N ratio of vermicompost 1 was 35.83 and the final value was 6.84. In the case of vermicompost 2, the C : N ratio was reduced to a final value of 16.1 from an initial value of 54.8 in 50 days.

A C : N ratio less than 20 indicates an advanced degree of organic matter stabilization and mineralization during the process of decomposition (Senesi 1989, Suthar 2008). The decrease in C : N ratio during the period of study might also be attributed to the increase in the earthworm population which led to a rapid decrease in organic carbon due to the enhanced oxidation of the organic matter (Nedgwa & Thompson 2000). The values obtained supported statistically as it showed significantly higher values from vermicompost 1 in comparison with vermicompost 2 at $P < 0.05$. The total available phosphorus (TAP) and total potassium (TK) content of vermicomposts 1 and 2 were found to be 2.4 and $5.6\,g\,kg^{-1}$ and 2.9 and $5.55\,g\,kg^{-1}$, respectively. The TAP and TKN content of vermicomposts 1 and 2 was found to be within the range of recommended values for ideal vermicompost (Nagavallemma et al. 2004).

Vermicompost 1 (Figure. 1) was further tested on potted pea (*Pisum sativum*) and marigold (*Tagetus erectus*) plants and these plants were found to be better in terms of flowers per plant, root growth, stem height and dry weight of the plant in comparison with those treated with vermicompost 2 (Tables 3 and 4). The chlorophyll *a* and *b* with carotene content were also investigated.

Apart from the better nutrient content of the vermicompost 1, it may also contain plant growth hormones, enhanced levels of soil enzymes and a high microbial population and, due to all these factors, the plant growth trials with vermicompost 1 performed better in comparison with plants treated with vermicompost 2. The present study has also proved the fact that vermicompost has positive influence on both the plants, in terms of morphological and biochemical parameters. The number of flowers obtained from the marigold plants using vermicompost 1 was significantly more in comparison with those grown in vermicompost 2, namely 16 and 4, respectively (Table 4; Figure. 2). Similarly, the yield obtained from the pea plants (no. of pods) using

Figure 1. Commercial pack of vermicompost 1.

Table 3. Effect of vermicompost 1 and 2 on pea plant and comparing their different physical and chemical parameters

Pea plant	Fresh weight (g)		Dry weight (g)		Fruit yield		Plant height (cm)	Leaf biomass (g)		Chlorophyll content (mg g^{-1})		Carotene (mg g^{-1})
	Root	Shoot	Root	Shoot	No. pods	Weight (g)		Fresh	Dry	Chl *a*	Chl *b*	
VC1	0.41 ± 0.03	5.2 ± 0.04	0.2 ± 0.006	1.40 ± 0.02	21 ± 0.01	45.7 ± 0.03	60 ± 0.1	4.33 ± 0.001	1.02 ± 0.08	0.016 ± 0.09	0.01 ± 0.01	0.30 ± 0.004
VC2	0.08 ± 0.015	0.64 ± 0.001	0.008 ± 0.01	0.16 ± 0.001	3 ± 0.002	1.9 ± 0.04	30 ± 0.5	0.35 ± 0.03	0.16 ± 0.005	0.014 ± 0.05	0.008 ± 0.11	0.22 ± 0.006

VC1, vermicompost 1; VC2, vermicompost 2. Data are means for three replications ± SE (standard error of mean) with a significant variance ($P < 0.05$). One-way ANOVA was applied in between the different parameters of the initial and final vermicompost.

Table 4. Effect of vermicomposts 1 and 2 on marigold plant and comparing their different physical and chemical parameters

Marigold plant	Fresh weight (g)		Dry weight (g)		Total no. of flowers	Plant height (cm)	Leaf biomass (g)		Chlorophyll content (mg g^{-1})		Carotene (mg g^{-1})
	Root	Shoot	Root	Shoot			Fresh	Dry	Chl *a*	Chl *b*	
VC1	2.53 ± 0.003	8.49 ± 0.1	1.35 ± 0.02	6.10 ± 0.01	16 ± 0.11	40 ± 0.36	2.79 ± 0.001	1.22 ± 0.07	0.0117 ± 0.012	0.007 ± 0.05	0.30 ± 0.003
VC2	0.29 ± 0.001	2.22 ± 0.04	0.144 ± 0.03	1.10 ± 0.12	4 ± 0.09	20 ± 0.008	1.89 ± 0.09	0.42 ± 0.009	0.009 ± 0.052	0.071 ± 0.32	0.284 ± 0.01

VC1, vermicompost 1; VC2, vermicompost 2. Data are means for three replications ± SE (standard error of mean) with a significant variance ($P < 0.05$). One-way ANOVA was applied in between the different parameters of the initial and final vermicompost.

Figure 2. Comparison of growth of marigold plants amended either with (a) vermicompost 1 or with (b) vermicompost 2.

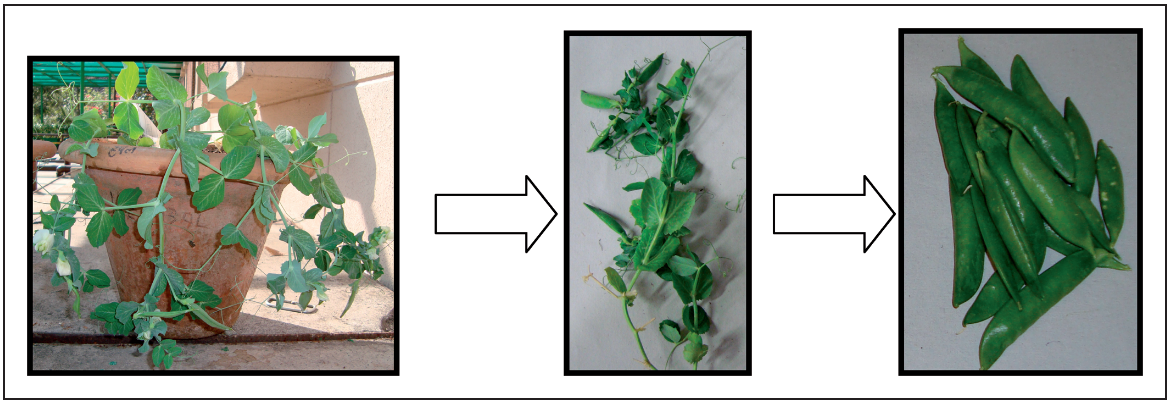

Figure 3. Growth of a test pea plant in presence of vermicompost 1.

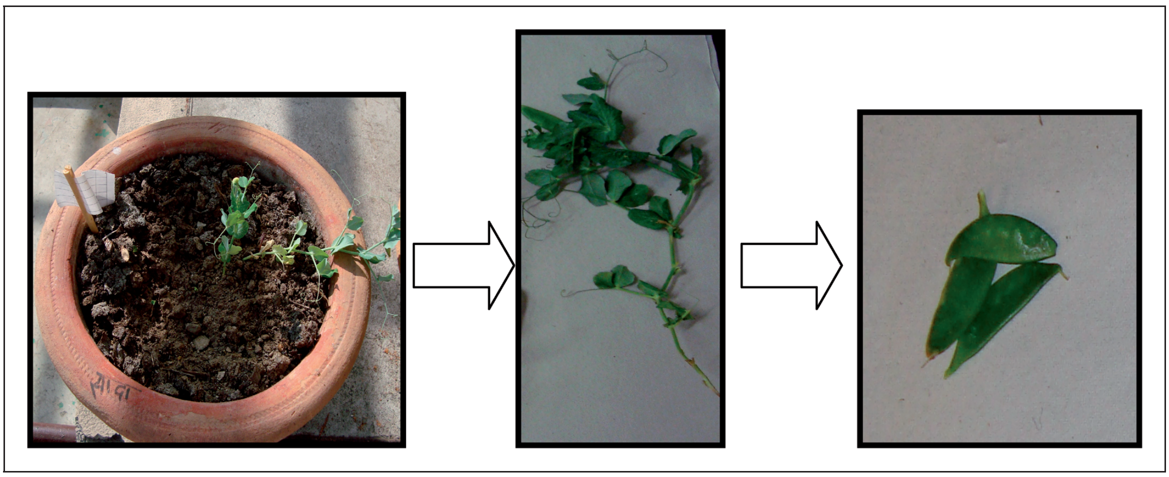

Figure 4. Growth of a test pea plant in presence of vermicompost 2.

vermicompost 1 was significantly higher in comparison with the yield obtained using vermicompost 2 (Table 3; Figures 3 and 4).

Hidlago et al. (2006) reported that incorporation of earthworm castings increased plant (including root) growth, stem diameters, and numbers of flowers of the marigold plants. Aracnon et al. (2004) and Malathi and Uma (2009) showed similar results with respect to growth (physical and chemical) parameters on the strawberry crop. Other authors (Atiyeh et al. 2000, 2002, Chamani et al. 2008, Kolton & Baran 2008) have shown similar results using different plant species.

Conclusion

From the results, it was concluded that vermicompost 1 was especially high in nitrogen content and showed a positive effect on the growth of plants tested. Earthworms degraded the organic waste disposed of by the industry to produce good humus which is the most precious material to fulfill the nutritional needs of the crops apart from a better way of solid waste management. The utilization of vermicompost results in several benefits to farmers, industries, environment and overall national economy. Vermicomposting of the bulk of the industrial waste of Ayurvet and other similar units have dual advantages: first in terms of safe disposal of waste and second in terms of production of sellable nutrient-rich vermicompost. However, the viability of vermicomposting of industrial scale depends on multiple factors such as the availability of land, cost and time analysis of the process, environmental policies, willingness of industrial management, etc. Experiments to scale up the vermicomposting of industrial waste in vermireactors and vermibeds are in progress.

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