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Earthworm Culture for Vermicompost and Vermimeal Production and for Vermiceutical Application in the Philippines (1978-2008) – A Review

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ABSTRACT

The culturing of earthworms or vermiculture began in the Philippines around 1970s. The epigeic species, *Perionyx excavatus* and *Eudrilus eugeniae*, were found to be suitable for vermicompost (earthworm manure and other organic material) and vermimeal (earthworm meal) production using biodegradable farm wastes as culture material. Studies conducted on the use of vermicompost for fertilizing vegetable crops, corn and upland rice have clearly indicated the feasibility of reducing the application of the recommended chemical fertilizers up to l00% for the cultured plants. Vermimeal produced from cultured *P. excavatus* and *E. eugeniae* has been found to be an efficient and cost-effective replacement for fishmeal in the diets of the cage-cultured freshwater fish (*Oreochromis niloticus*) and poultry (chicken and quail). Feeding of dried earthworms (*E. eugeniae*) to the freshwater shrimp (*Macrobrachium idella*) also gave better results compared to feeding with dried fish (*Therapon plumbeus*) in ponds. The presence of a blood clot delaying factor, important saturated and unsaturated fatty acids and a fibrinolytic enzyme was demonstrated in the extracts of *E. eugeniae* which could be potential vermiceuticals (pharmaceuticals) for human medicine application.

Keywords: organic agriculture, vermiceutical, vermicomposting, vermiculture, vermimeal

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INTRODUCTION

Earthworms are generally beneficial terrestrial invertebrates that contribute to soil fertility and conservation with their humus-producing and burrowing activities. Commercial earthworm culture or vermiculture is believed to have started around 1950s for fish bait production (Edwards and Lofty 1972). Use of the 'manure worm' (*Eisenia fetida*) for the production of vermicompost (earthworm manure and other organic material) from household kitchen wastes began around the 1940s (Appelhof 1981). The value of cultured earthworms as source of vermimeal (earthworm meal) for animal feeds was reported by Sabine (1988). The common commercially cultured earthworm species are the *E. fetida* in temperate countries and *Eudrilus eugeniae* in the tropics (Kale 1994). Substances with therapeutic properties were discovered in earthworms around 1970s (Elicano 2004). The culture of earthworms began in the Philippines around 1970s with the introduction of '*Pheretima asiatica*' from Taiwan by the private sector. While there was strong interest in the activity as a 'livelihood project' initially, the industry did not prosper because of pyramid selling and a questionable market (Manuel-Santana 1982).

Through a study funded by the Asia Foundation during 1977-1979, a survey was conducted in 21 provinces of the Philippines to collect and identify suitable species of earthworms to develop for culture. From 39 locations, 11 species belonging to four families were identified by E.G. Easton of the British Museum (unpublished data). Of the three species (*Perionyx excavatus*, *Metaphire pequana* and *M. houletti*) that were tested for rearing in culture units using Murrah buffalo manure as substrate, only *P. excavatus* showed promise for culture with good growth and survival.

In 1982, the author received cocoons of the *E. eugeniae* sent by Prof. Otto Graff of West Germany through the mail. Only four of the 10 cocoons received produced juveniles that were cultured for the first time in the Philippines and in Southeast Asia.

This paper reviews the published and unpublished literature on the culturing of earthworms in the production of vermicompost for food crops, vermimeal for fish, poultry and shrimp feeds, and vermiceuticals for human medicine in the Philippines from 1978 to 2008.

EARTHWORMS FOR VERMICOMPOST PRODUCTION

The ability of earthworms to process organic materials into manure through their digestive system is well-recognized. Vermicompost produced with 'epigeic' (surface-dwelling) earthworms is considered an excellent soil amendment for use in agriculture. Although vermicompost does not contain

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high amounts of plant macronutrients (i.e. NPK) unlike chemical fertilizers, it is high in organic matter and contains microorganisms (e.g. bacteria, yeast and fungi) that produce plant growth-promoting substances. Soil structure and water-holding capacity are also improved by vermicompost.

To produce vermicompost, organic or biodegradable materials such as crop residues (e.g. rice straw) are first dried and shredded and/or pulverized to reduce their particle size and then mixed with animal manures at the proper carbon to nitrogen ratio of 25-30: 1. The materials are then watered to a moisture content of 60-80% to hasten anaerobic decomposition (fermentation) in a covered pile or container. After 2-3 weeks of the anaerobic process, earthworm biomass is stocked at the recommended rate (e.g. 0.5 to 1 kg/m^2) and cultured under aerobic conditions for 4-6 weeks till harvest (Guerrero 2008).

Dacayo (pers. comm.) conducted field experiments on corn (*Zea mays*) and rice (*Oryza sativa*) using vermicompost produced by *E. eugeniae* with substrate consisting of cow manure, *Leucaena leucocephala* leaves and sawdust at 1: 1: 1 proportions. With the application of 5 t/ha of vermicompost on corn, there was a 14% increase in ear yield of the plants which was comparable to that of the plants fertilized with the recommended rate of inorganic fertilizer (60-40-0 kg/ha). For rice, the yield was not affected with application of vermicompost at 4 t/ha but at 2 t/ha in addition to the recommended rate of inorganic fertilizer, the grain yield was 40% more than that of the control (no fertilization).

Guerrero *et al.* (1984) tested the efficiency of vermicompost produced with *E. eugeniae* in wooden boxes using 75% pig manure and 25% sawdust. The highest yield of the vegetable *Brassica compensis*, was obtained using 50% vermicompost and 50% of the recommended complete fertilizer (14-14-14) in garden plots. Yields of the plant with 25 and 75% vermicompost fertilization in combination with 75 and 25% of the recommended complete fertilizer, respectively, were significantly greater compared to that of the plant fertilized with 100% complete fertilizer (**Table 1**). The cost of fertilization with 100% vermicompost was the lowest.

The number of fruits of eggplant (*Solanum melongena*) fertilized with vermicompost produced with *E. eugeniae* using 75% grass and 25% animal manure at 75 and 100% in pots with garden soil was not significantly different from that of plants fertilized with chemical fertilizer at 40-150-100 kg/ha (**Table 2**). For cauliflower (*Brassica botrytis*), only the height of plants fertilized with l00% vermicompost was not significantly different from that of plants with chemical fertilizer (14-14-14) at 120 kg/ha (Guerrero *et al.* 1999).

Guerrero and Guerrero (2006a) found the fruit yield of eggplant (*S. melongena*) to be significantly higher with fertilization using a combination of vermicompost at 100 g/container (6 t/ha) and 50% of the recommended chemical fertilization (14-14-14 and 46-0-0 at 600 kg/ha) compared to those fertilized with 100% of the recommended chemical fertilizers only and vermicompost only. The combination of vermicompost and chemical fertilization also gave the highest net income.

Salamanca and Aihara (2006) determined the nutrient content of compost (without earthworms) and vermicompost (with *E. eugeniae*) using 75% (by weight) of *Gliricidia sepium* and *Leucaena leucocephala* leaves and twigs and 25% cattle manure. They found that the vermicompost had higher concentrations of total nitrogen, phosphorus, potassium, calcium, magnesium, copper, manganese and zinc than the traditionally-made compost. The composting period was only six weeks with the earthworm compared to 12 weeks for the traditional method.

In a test on the effect of vermicompost on upland rice in outdoor containers, the grain yields of plants fertilized with a combination of the equivalent of 5 t/ha of vermicompost and 50% of the recommended chemical fertilization (14-14-14 at 100 kg/ha and 46-0-0 at 100 kg/ha) were significantly higher than that of plants fertilized with 100% of the recommended chemical fertilizers only. While fertilization with vermicompost alone did not provide for the nutrient need of the plant even at 10 t/ha, it had a 'sparing effect' on the chemical fertilizers by possibly reducing the loss of the latter to leaching and volatilization (Guerrero and Guerrero 2008).

Lacson (2006) reported vermicompost recovery of 71% from seven tons of substrate (70% sugarcane trash and 30% chicken manure by weight) after 90 days in a 40-m^2 outdoor culture unit initially stocked with 20 kg of *E. eugeniae.* With the harvest of 140 kg of the earthworm, a ratio of 50 kg of substrate to 1 kg of earthworm was determined.

The quality (nutrient content) of vermicompost largely depends on the materials used for vermicomposting and the biomass of earthworm stocked. The amounts of macronutrients (NPK) were the highest with grass (75%) and *Gliricidia sepium* leaves (25%) compared to those of the other mixtures of vermicomposting material (**Table 3**). As the harvest of earthworm biomass increased, the vermicompost recovery decreased due to bioconversion (Guerrero *et al.* 1999).

Table 1 Yield *of Brassica compensis* in plots fertilized with vermicompost (VC) and chemical fertilizer after 30 days of culture.

Fertilizer	Yield/plot (kg)
100% 14-14-14	3.7 a
100% VC	4.1 b
25% VC + 75% 14-14-14	4.6 b
50% VC + 50% 14-14-14	4.7 b

Note: Means with the same superscripts are not significantly different at P<0.05.
Source: **Guerrero RD, Guerrero LA, Cargado AU** (1984) Studies on the culture of the earthworm *Eudrilus eugeniae* and its use as feed for *Macrobrachium idella* and fertilizer source for *Brassica compensis. Transactions of the National Academy of Science and Technology (Philippines)* **4**, 33-40.

Table 2 Yield response of eggplant (*Solanum melongena*) to different levels of vermicompost (VC) and chemical fertilizer.

Fertilizer	No. of fruit
25% VC	1.40 a
50% VC	1.40 a
75% VC	2.40 b
100% VC	2.13 b
40-150-100	2.86 b

Note: Means with the same superscript are not significantly different at P<0.05.
Source: **Guerrero RD, Villegas LG, Guerrero LA** (1999) Studies on the production and utilization of vermicompost produced with the African nightcrawler (*Eudrilus eugeniae*) in the Philippines. *Philippine Technology Journal* **24**, 57-63

Table 3 Comparative analyses of vermicompost (30% moisture) using different materials.

Determinations (%)	Material			
	A	B	C	D
Total nitrogen	0.80	0.91	1.15	2.95
Total phosphorus	0.37	2.23	2.08	1.43
Total potassium	0.20	0.84	0.30	3.81
Total magnesium	0.17	0.70	0.32	0.56
Total iron	0.42	0.64	1.23	0.46
Total manganese	0.04	0.17	0.13	0.03
Total copper	0.001	0.03	0.10	0.005
Total zinc	0.01	0.04	0.02	0.01

A= Grass; B= Pig manure; C= Grass (75%) + Animal manure (25%); D= Grass (75 leaves (25%)
Source: **Guerrero RD** (2004) *Handbook of Vermicompost and Vermimeal Prod* Aquatic Biosystems, Laguna, Philippines, 42 pp

EARTHWORMS FOR VERMIMEAL PRODUCTION

The production of earthworm biomass (*P. excavatus* and *E. eugeniae*) in different substrates for vermimeal was carried out in the Philippines. In the 4-week culture of *P. excavatus* stocked at 200 earthworms per concrete tank with 20 kg of Murrah buffalo manure, the highest growth gain and production of juveniles was attained (Guerrero (1983). With stocking of *E. eugeniae* at 200 g/wooden box containing

Table 4 Biomass production (kg/m^{2}) of *E. eugeniae* with three stocking rates after 35 days of culture in boxes with 75% grass and 25% animal manure.

Biomass stocked	Net biomass produced
0.7	2.0 b
1.3	1.3 a
2.0	1.8 b

Note: Means with the same superscript are not significantly different at P<0.05.
Source: **Guerrero RD, Villegas LG, Guerrero LA** (1999) Studies on the produ vermicompost produced with the African nightcrawler (*Eudrilus eugeniae*) in the *Technology Journal* **24**, 57-63

75% pig manure and 25% sawdust, the weight increase of the earthworm was more than 9X compared to 8X and 5X with 50% pig manure + 50% sawdust and l00% pig manure, respectively, after 30 days of culture (Guerrero *et al.* 1984). The highest net production of 2.7 kg/m^2 of culture bed was obtained by Guerrero *et al.* (1999) for *E. eugeniae* after 35 days with stocking at 0.7 kg/m^2 using 75% grass and 25% animal manure (**Table 4**). A net earthworm biomass (*E. eugeniae*) of 0.7 kg/m^2/mo was reported by Cruz (2006) from outdoor culture beds with 70% bagasse and 30% cow manure.

The processing of earthworm biomass into vermimeal is done by washing and fixing the earthworms prior to drying and grinding. A 20% recovery of the fresh biomass was obtained by Guerrero (l983) with blanching of *P. excavatus* at 55°C and oven drying at 50°C for 6 hr. Ulep (unpublished data) reported an 18.94% recovery for *P. excavatus* with blanching at 55°C followed by sun drying while Barcelo (1988) showed recovery of 18.33% recovery for *E. eugeniae* by freezing the earthworms overnight and sun drying.

The use of earthworm meal or vermimeal as a substitute for fishmeal in the diets of the freshwater fish *Tilapia nilotica* (*Oreochromis niloticus*), the domestic chicken (*Gallus gallus*), Japanese quail (*Coturnix coturnix*) and the freshwater shrimp (*Macrobrachium idella*) has been studied in the Philippines (Guerrero 1983; Guerrero *et al.* 1984).

Guerrero (1983) found from the cage culture of *T. nilotica* that a practical diet consisting of 15% earthworm meal (*P. excavatus*), 10% fish meal and 15% fine rice bran gave the best weight gain, feed conversion and survival of the fish compared to those of the diets with 25% fish meal + 75% fine rice bran and 10% earthworm meal + 15% fish meal + 75% fine rice bran. The earthworm meal that was analyzed had 64.7% crude protein, 14% fat, 13.9% carbohydrates, 3.2% ash and 4.2% moisture.

Ulep (unpublished data) fed broilers with earthworm meal (*P. excavatus*) at three levels (3, 5 and 10%) in the diet and showed that the body weight of the birds increased with increasing level of earthworm meal. The feed consumption of the birds was lower than in those given meat and bone meal and fish meal in the diet, and the commercial ration. It was also found that the feed conversion efficiency of birds fed with the 3 and 5% levels of earthworm meal was significantly higher than that in those fed with meat and bone meal, and fish meal.

In feeding broilers with earthworm meal (*E. eugeniae*) at 6, 10 and 14%, Barcelo (1988) reported that the gain in weight of birds given 14% vermimeal was comparable to those given the commercial ration (with fish meal). It further indicated that 10% earthworm meal could completely substitute for fish meal in the broiler feed. Similarly, Oarde (unpublished data) found that broilers fed with vermimeal (*P. excavatus*) to replace 25 to 100% of fish meal in the diet had higher weights and average gain than those fed with the diet containing fish meal only. The birds fed with vermimeal replacing 100% of fish meal in the diet had the highest body weight and gave the maximum net income.

The weight gain, feed conversion and net return for the Japanese quail (*C. coturnix*) improved with increasing levels of earthworm meal (*P. excavatus*) in the diet. The best results were obtained in which fish meal was totally replaced with vermimeal at 10% in the diet (Guerrero 1983).

The freshwater shrimp (*M. idella*) fed with dried earthworm (*E. eugeniae*) in fertilized ponds had higher total weight gain, lower feed conversion and greater juvenile production compared to those of the shrimps fed with dried freshwater fish (*Therapon plumbeus*). The dried earthworm had greater values of crude protein and fat on a moisture-free basis than those of the dried fish (Guerrero *et al.* 1984).

The cost of production being relatively high for vermimeal use in commercial aquafeeds, Cruz (2006) recommended the use of unprocessed earthworm biomass for replacing 'trash fish' as feed for high-value carnivorous fishes and for farm-made moist feeds. The cost of vermimeal production, however, can be offset by the income that will be derived from the sale of vermicompost, a by-product of the earthworm production process (Guerrero 2006).

EARTHWORMS FOR VERMICEUTICALS APPLICATION

The presence of bioactive compounds in earthworms that have pharmaceutical or medicinal value has been reported by several authors (Mihara *et al.* 1991; Sun 2003). In the Philippines, indigenous communities have used earthworms in traditional medicine (Ang-Lopez pers. comm.). Limited studies on the presence of potential pharmaceuticals or vermiceuticals in earthworms have been conducted.

Among the native Bukidnons of Panay Island in the Philippines, an earthworm decoction is drunk by patients for stomach problems, labor pains, toothache, rheumatism and arthritis. The decoction is prepared by thoroughly washing and drying 8-10 earthworms and then heating them in a pot until dark brown or almost burnt. The prepared material is then ground in a mortar and mixed in a liter of boiled water. When cool, the mixture is decanted and the clear fluid is given to the patient for drinking (Ang-Lopez and Alis 2006).

Ang-Lopez and Alis (2006) tested the effect of different concentrations of *E. eugeniae* extract for thinning human blood by mixing the earthworm extract with the same volume of blood in vials and determining the clotting time. While the normal clotting time was only six minutes for the control (blood only), the clotting times for the mixtures of blood and 25, 50, 75 and 100% of earthworm extract required more than an hour indicating that the earthworm extract contains a blood clot delaying factor.

An analysis of the fatty acid content of *E. eugeniae* showed it to contain 32.66% of saturated and unsaturated fatty acids per 100 g oil. Among the important fatty acids identified were the saturated lauristic and myristic fatty acids and the unsaturated oleic and linoleic fatty acids (Ang-Lopez and Alis 2006).

The presence of a thrombolytic enzyme (blood clot dissolving) has been found in the dried extract of *E. eugeniae* by Guerrero and Guerrero (2006b). In a fibrinolytic activity test, the activity (units/mg) of samples from *E. eugeniae was* comparable to that of the imported Chinese product. Elicano (2004) identified the thrombolytic enzyme to be lumbrokinase which has been confirmed to have a blood clot dissolving effect in humans.

CONCLUSION

Earthworms are important in the production of vermicompost, vermimeal and potential vermiceuticals in the Philippines. Studies on the use of vermicompost produced with *E. eugeniae*) using biodegradable wastes for culture have indicated its efficiency and cost-effectiveness in reducing the application of chemical fertilizers up to 100% for various vegetables and crops. Use of vermimeal produced with the culture of *P. excavatus* and *E. eugeniae* has been shown to be highly feasible for replacing fish meal as a source of animal protein in the diets of the freshwater fish (*T. nilotica*), domestic chicken (*G. gallus*), Japanese quail (*C. coturnix*) and freshwater shrimp (*M. idella*). The cost of producing vermimeal can be offset by the proceeds from the vermicompost which is a by-product of the earthworm production process. The presence of a blood clot delaying factor, important saturated and unsaturated fatty acids, and a thrombolytic enzyme in the extracts of *E. eugeniae* has indicated potential vermiceuticals for human medicine application.

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