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PRODUCTION OF VERMICOMPOST AND EARTHWORM BIOMASS (*Eudrilus eugeniae*) FOR ORGANIC *Nile tilapia* (*Oreochromis niloticus*) CULTURE IN FRESHWATER PONDS

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Abstract- Three studies were conducted. In Study 1, paragrass (*Brachiaria mutica*) was processed and used as substrate for vermicomposting in outdoor beds with 1 kg/m^2 of the composting earthworm, "African night crawler" (*Eudrilus eugeniae*) or ANC. After 30 days, 41.8 kg of processed vermicompost (VC) with 18% moisture and 2.2 kg of ANC biomass was obtained per m^2 of bed. The cost of producing the VC was PhP 2.50 (US$0.06)/kg based on direct expenses only. In Study 2, the VC was tested as an organic fertilizer for *Nile tilapia* (*Oreochromis niloticus*) culture in freshwater ponds. The effects of two application rates of VC (2.5 t/ha and 5 t/ha) were determined. Sex-reversed tilapia fingerlings were stocked at 2/m^2 and cultured for 120 days. The results showed that the net yield of marketable-size fish was significantly higher with VC at 2.5 t/ha compared to those with 5 t/ha and the control. The cost of producing the fish was lowest with VC at 2.5 t/ha. No off-flavor of the fish was detected in a simple organoleptic test. In Study 3, only VC at 2.5 t/ha was applied for the first 60 days of culture in the ponds stocked with tilapia fingerlings at 1/m^2. Processed earthworm biomass (EB) was tested as an animal protein source in the moist feeds (85% fine rice bran and 15% EB) fed to the tilapia fingerlings in the next 60 days of culture. The highest net yield of fish was obtained with the feeding of fermented moist feed compared to those of the fish fed with the fresh moist feed and that of the fish in the ponds with VC fertilization only for the entire 120-day period. The cost of production of the fish was lowest with the feeding of the fermented moist feed. There was no apparent difference between the fresh moist feed and the fermented one.

Keywords- Vermicompost, Earthworm biomass, Organic *Nile tilapia*, Freshwater ponds

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Introduction

Vermiculture, the husbandry of earthworms, is a relatively new technology in the Philippines which began in the late 1970s. Aside from the Philippines, earthworm culture is applied worldwide particularly in the United States and India for the production of fish baits and vermicompost, respectively. Another major product of vermiculture is earthworm meal or vermimeal produced from earthworm biomass.

Earthworms like the "African night crawler" (*Eudrilus eugeniae*) or ANC is an efficient composting species in tropical countries such as the Philippines. Using agro-wastes (*e.g.*, rice straw and animal manures) as substrate for vermicomposting with the ANC, vermicompost and earthworm biomass can be produced. Vermicompost (VC) is applied as a soil amendment for improving soil texture and water-holding capacity, and as an organic fertilizer for crop production. Vermimeal (VM), on the other hand, is an excellent substitute for imported fish meal used in animal and fish feeds.

With the development of vermiculture technologies in the Philippines, there are now thousands of small and large farms producing VC either for self-use or commercial purpose. Studies have shown the feasibility of reducing the application of the recommended chemical fertilizers up to 100% for fertilizing vegetables and rice with VC [1-3]. Although VM is not yet commercially produced in the country, research has indicated it be an efficient and cost-effective replacement for fish meal in the diets of quails and cage-cultured *Nile tilapia* [4].

In implementing the Organic Agriculture Law in the Philippines, the use of organic fertilizers to reduce the need for chemical fertilizers that are detrimental to the environment is promoted. For organic aquaculture, the use of organic fertilizers such as VC and the reduced use of fish meal from wild stocks are prescribed.

While organic agriculture is now practiced commercially in the Philippines, organic aquaculture has still to come about. To contribute to the development of organic aquaculture (without use of chemicals and fish meal), we conducted studies on the production of VC and VM for organic *Nile tilapia* culture in freshwater ponds to: (1) determine the efficiency and cost-effectiveness of producing VC and VM using on-farm materials, and (2) to determine the efficacy and cost-effectiveness of using VC and VM for organic *Nile tilapia* production in freshwater ponds.

To produce VC, organic or biodegradable materials such as crop residues are first dried and shredded 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 80% to hasten anaerobic decomposition in a covered pile or container. After 2-3 wks of the anaerobic process, the live earthworms are stocked at the recommended rate of 1 kg/m^2 and cultured under aerobic conditions in 4-6 wks for production of vermicompost and earthworm biomass [5].

The use of VC at 0.75 t/ha to fertilize freshwater ponds for the breeding of *Nile tilapia* (*O. niloticus*) with a production of 80 fry/ fingerlings per breeder in a 30-day cycle has been reported [6]. Worm casts at 20% in the diet of *Nile tilapia* in floating net cages can replace 25% of wheat middling in the standard diet [7]. The use of VC as supplemental feed up to 25% as replacement for fermented rice bran was more efficient than use of fermented rice bran alone or a combination of 50% fermented rice bran and 50% VC for *Nile tilapia* fingerlings in aquaria [8]. No studies on the use of VC as a supplemental feed for tilapia in ponds have been reported in the Philippines.

The production of earthworm biomass using different substrates for VM production has been done in the Philippines. In the 4-wk culture of *Perionyx excavatus* stocked at 200 per concrete tank with buffalo manure, the highest growth gain and production of juveniles was attained [4]. With *E. eugeniae* at 200g per wooden box containing 75% pig manure and 25% sawdust, the weight increase of the earthworm was more than 9x compared to 5x with 50% pig manure and 50% sawdust [1]. The highest net production of 2.7 kg/m^2 of culture bed was obtained for *E. eugeniae* after 35 days with stocking at 0.7 kg/m^2 and using 75% grass and 25% rat manure [9].

A net yield of 110 kg of *E. eugeniae* was produced after 90 days from 40 m^2 of outdoor beds with 7 t of substrate consisting of 70% dried sugarcane trash and 30% chicken manure [10]. Cost and return analysis showed that with the price of PhP 5/kg for VC and PhP 36/kg for the VM produced, a return of investment of 28.5% was obtained with the total investment of PhP 20,000 (US$ 479.62).

A net earthworm biomass (*E. eugeniae*) of 0.7 kg/m^2 was produced from a 130-m^2 outdoor culture area with 52 beds each measuring 2.5 m^2 stocked at 1 kg/bed and cultured for 60 days using 70% bagasse and 30% cow manure as substrate [11]. The culture produced 21,840 kg of VC valued at PhP 109,200 (US$ 2,600) and 166 kg of VM valued at PhP 1,092 (US$ 26.19) with a total investment of PhP 80,401.79 (US$ 1,928.10), net return of PhP 31,819.21 (US$ 763.05) and a return of investment of 37%.

The processing of earthworm biomass into VM is done by washing and killing the earthworms in 55°C water prior to drying and grinding. A 20% recovery of the fresh biomass was obtained with blanching of *P. excavatus* and oven-drying at 55°C for 6 hrs. [4].

The use of VM as a substitute for fish meal in the diet of *O. niloticus* in freshwater floating cages and the freshwater shrimp, *Macrobrachium idella*, in freshwater ponds has been studied in the Philippines. It was found from the cage culture of *Nile tilapia* that a practical diet consisting of 15% VM, 10% fish meal and 75% 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% VM + 15% fish meal + 75% fine rice bran [4]. The *M. idella* fed with dried earthworms in fertilized ponds had higher weight gain, lower feed conversion and more juvenile production compared to those of the shrimps fed with dried freshwater fish [1].

In a 9-wk feeding trial in tanks, the growth of sex-reversed Mozambique tilapia (*O. mossambicus*) fingerlings fed with 50% VM to replace 50% of the imported Peruvian fish meal (PFM) in the positive control diet was not significantly different from that of the fish fed with 100% PFM in the diet [12].

Freshwater pond fertilization with VC applied every 15 days at 4 t/ ha for 90 days gave the highest yield of fish (*O. mossambicus*) compared to chemical fertilization with superphosphate only and a combination of superphosphate and urea. The VC was noted to be a direct feed and pond fertilizer for autotrophic and heterotrophic production of fish food organisms in the water [13].

The on-farm production and use of VC and VM for the culture of organic *Nile tilapia* in freshwater ponds have not been studied.

Materials and Methods

The studies were conducted at the Aquatic Biosystems fish farm which has about a hectare of fishponds. Water is pumped from a shallow well to supply the ponds.

Study 1 - Production of VC and Earthworm Biomass

Thirteen tent-type culture beds, each measuring 2 x 2 x 0.3 m (4 m^2), were constructed using laminated mat (Sakolin), bamboo slats and fine wire. Each bed had top and bottom covers and was open at both ends for aeration. Slits were made at the bottom to allow for drainage of excess water.

Paragrass (*Brachiaria mutica*), a common weed in the farm, was gathered by means of a mechanical cutter and shredded with a machine. The fresh shredded grass was then ensilaged (fermented) in closed sacks for 3-5 days before being placed in the earthworm beds at 200 kg/m^2.

The ANC (*E. eugeniae*), initially procured from a commercial source and mass-produced in the farm, was stocked in the beds at 1 kg/m^2. The beds were watered to maintain the desired moisture content (80%) of the substrate and protected from predators (*e.g.*, rats, toads and skinks).

After 30 days, the VC and earthworm biomass (EB) were manually harvested from each bed. The VC was air-dried on the concrete floor of a covered shed for 1-2 wks to a moisture content of 16-20% measured with a moisture meter, sieved and stored in sacks. The EB recovered from the beds was weighed and restocked in prepared beds for further vermicomposting or processed for on-farm feeds used in the subsequent studies.

The costs for producing the VC and EB were determined based on direct expenses only for fuel and labor. The VC produced was analyzed at the Soil Analytical Laboratory of the University of the Philippines Los Banos in Laguna.

Study 2 - Use of VC as Organic Fertilizer for Culture of *Nile tilapia* in Freshwater Ponds

Nine 200-m^2 earthen ponds were prepared for the first pond trial to test VC as organic fertilizer for *Nile tilapia* (*O. niloticus*) production in freshwater ponds. To avoid reproduction of the fish, sex-reversed fingerlings (1 g avg. wt.) procured from a commercial hatchery were stocked at 2/m^2 in the ponds with 0.75 m mean depth.

Two VC applications, Treatment 1 (2.5 t/ha) and Treatment 2 (5 t/ ha), and the Control (0 t/ha) with three ponds each (replicates) were tested. The VC was applied by broadcast on a weekly basis. Water quality in the ponds was monitored by measuring pH, transparency and plankton density. The fish was harvested after 120 days of culture (August to November).

At harvest, the total number and total weight of the fish in each pond were determined. The presence of other fishes, if any, was also noted. A simple organoleptic test of the fish in the various treatments was conducted with a Taste Panel of four members. The cost of producing the fish using VC as organic fertilizer based on direct expenses only was also determined.

Study 3 - Use of EB for Feeding of *Nile tilapia* in Ponds

From the culture beds, the live EB was cleared of adhering VC, placed in plastic bags and kept in a freezer for storage. When used for the preparation of the on-farm feeds, the frozen EB was thawed, hand-mashed and mixed with fine rice bran (RB). Fresh moist feed was prepared by mixing 850 g of RB and 1 kg of EB (15% dry matter) and directly given to the fish. Fermented moist feed was prepared using the same mixture and kept in closed plastic bags for fermentation in 5-7 days before being fed to the fish.

The same nine ponds used in the first pond trial were used but were more thoroughly prepared than before using an electro-fishing device and gill nets for predator fish control. The ponds were stocked with sex-reversed *Nile tilapia* fingerlings (2 g avg. wt.) at 1/m^2. Three treatments with three ponds each were tested, namely: Treatment 1 - VC applied as organic fertilizer at 2.5 t/ha for the whole 120-day culture period; Treatment 2 - Same application of VC only as in Treatment 1 for the first 60 days of culture and feeding with 100 g of fresh moist feed in each pond per day on an every other day basis for the third month of culture and feeding with 150 g of the same feed and frequency in each pond per day on the fourth month of culture; and Treatment 3 - Same application of VC and feeding as in Treatment 2 but using the fermented moist feed instead of the fresh moist feed. To avoid wastage of the sinking moist feed which was given in the form of balls, suspended feed trays made of plastic sheets tied to bamboo stakes were used. Samples of the moist and dry feeds were submitted to the Feed Analytical Laboratory of the University of the Philippines Los Banos for proximate analyses.

After 120 days of culture, the ponds were drained and the fish was harvested by hand-picking. The total number of fish recovered in each pond was counted and weighed. The presence of other fish species which entered the ponds unintentionally was noted. The fish data were statistically analyzed using the Completely Randomized Design.

Results

The yields of air-dried VC and fresh EB harvested from the beds after 30 days of culture with 200 kg/m^2 of processed *B. mutica* and 1 kg/m^2 of ANC were 41.8 kg/m^2 and 2.2 kg/m^2, respectively. This showed that it takes about 100 kg of the fresh substrate to produce 1 kg of fresh EB.

The results of Study 2 [Table-1] showed that the highest net yield of *Nile tilapia* was with Treatment 1 followed by those with Treatment 2 and the Control. With 50 g as the least marketable-size for the fish, the fish produced with Treatments 1 and 2 were of marketable-size while that of the Control was not. The survival rates of the fish in all treatments were low because of the incursion of fish predators (*e.g.*, *Channa* striata and *Clarias* batrachus). The estimated cost of producing the fish was lowest with Treatment 1 followed by those with Treatment 2 and the Control. The processed VC had 1.9% nitrogen, 0.6% P_2O_5, 0.7% K_2O, 2.08% Ca and 0.18% Mg.

Table 1- Production of *Nile tilapia* in freshwater ponds fertilized with vermicompost

Treatment	Avg. Wt.* (g)	Net Yield* (kg/ha)	Survival Rate* (%)	Cost of Production (PhP/kg)
Control	41.1	19.2	5.2	468.7
1	58.4	139.6[a]	11.5	62.5
2	68.1	48.4	3.6	166.7

**Means of 3 replicates are significantly different at p<0.05*

The results of Study 3 showed that the highest net yield of the fish was with Treatment 3 followed by those of Treatments 2 and 3 [Table-2]. The differences in the treatments, however, were not significant (p>0.05). Marketable-size fish were obtained with Treatments 1 and 2. The highest survival of the fish was with Treatment 3 that had lesser fish predation compared to the other treatments. The estimated cost of production was lowest with Treatment 3 followed by those of Treatments 2 and 3. The organoleptic test conducted showed that 50% of the Taste Panel preferred the fish cultured in the VC-fertilized ponds compared to 25% of the panel preferring the fish in the Control ponds. No off-flavor of the fish was detected in all the fish sampled.

Plankton blooms were observed in ponds fertilized with VC. Plankton sampling showed the presence of moderate to heavy densities of zooplankton in the ponds. A phytoplankton count of 10,000 cells/ml for *Pediastrum* sp., a green alga, was recorded. Pond water pH and transparency were measured to be 8.5 and 20 cm, respectively.

Table 2- Production of *Nile tilapia* in VC-fertilized and EB-fed Ponds

Treatment	Avg. Wt.* (g)	Net Yield* (kg/ha)	Survival Rate* (%)	Cost of Production (PhP/kg)
1	82.1	44.8	7	388
2	62.8	79.4	16	133.5
3	30.7	170	64	62.3

**Means of 3 replicates*

The analyses of the two moist feeds in comparison with the dry feed [Table-3] showed that there were only slight differences between the moist feeds.

Table 3- Proximate analyses of the Dry and Moist Feeds

Feed	% Crude Protein	% NFE	% Fat	% Crude Fiber	% Ash	% Moisture
Dry	16.3	34.6	17.3	6.6	9.8	15.3
Fresh	9.4	16.3	10	4	5	55.2
Fermented	9.3	15.9	9.5	5	5	55.2

Discussion

The paragrass (*B. mutica*) is a common weed in water-logged areas of the Philippines that is used for feeding livestock. The fresh grass contains about 80% water and 1-3% crude protein. It required about 0.5 hr for a worker to gather 200 kg of the fresh grass in the farm and another 0.5 hr to shred it mechanical ly. The ensilaging of the shredded grass in the closed sacks before placement in the culture beds was necessary to pre-decompose the substrate under anaerobic conditions.

The cost of constructing a 2 x 2 x 0.3 m culture bed (with a lifetime of 2 years) was PhP 750 for materials and labor. The price of the initial stock of ANC procured was PhP 200/kg. The cost of producing the VC was determined to be PhP 2.50/kg. With the EB being a by-product of the vermicomposting process, there was no cost determined for the additional 1 kg of ANC produced per m^2 per month from the culture beds stocked at 1 kg/m^2.

The incursion of fish predators came about with the overflow of a nearby irrigation canal during heavy rains. With the low survival rates, it was not possible to determine the real cost and value of the harvested fish. Only estimates are therefore made. Under favorable conditions, the survival of *Nile tilapia* in freshwater ponds is 80% or better.

The moist feed used had a cost of PhP 9.20/kg with only the RB as the purchased input. The cost of producing the fish with Treatment 3 in Study 2 was the lowest because of the higher fish survival. The results indicated that the use of on-farm produced feeds was more efficient and cost-effective than using VC only for the culture of fish in ponds.

The effectiveness of the fermented feed was apparently not different from that of the fresh feed. Using moist feeds is more convenient and practical for farmers than dry feeds. The lower nutrient content of the moist feed compared to the dry feed on a weight basis can be adjusted by increasing the amount given to the fish of the former after considering its moisture content. For instance, if a dry feed with 15% moisture is given to the fish at 100g per feeding, the equivalent amount of moist feed with 59% moisture would be 393g. Based on the results of Study 3, the use of moist fermented feed is preferred over that of fresh moist feed in terms of convenience and practicality.

Conclusion

The yields of air-dried VC and live EB using 200 kg/m^2 of processed *B. mutica* and 1 kg/m^2 ANC were 4l.8 kg/m^2 and 2.2 kg/m^2, respectively, after 30 days of culture. The application of VC as organic fertilizer in freshwater ponds for culture of sex-reversed *Nile tilapia* fingerlings at 2.5 t/ha for 120 days, was more efficient and cost-effective than using VC at 5 t/ha. The use of on-farm produced EB processed into moist feeds (fresh and fermented) fed to cultured sex-reversed *Nile tilapia* fingerlings in the last 60 days of culture in freshwater ponds that were fertilized only with VC in the first 60 days of culture produced more fish and had lower costs of production than growing the fish with the use of VC alone for 120 days. With no apparent difference between fresh moist feed and fermented moist feed, use of the latter is preferred. Further research is recommended to verify the results of our studies.

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Conflicts of Interest: None Declared.

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