The use of vermicompost as an organic pond fertilizer in recirculating aquaculture system: effect on water quality and survival rate of catfish fry (Clarias sp.)

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Abstract. The main objective of this study was to determine whether vermicompost can be used as an organic pond fertilizer to improve water quality and survival rate of catfish fry (Clarias sp.). The experiment was conducted for 4 weeks (28 days) with duplicates in two ponds. The control (pond C) did not apply any vermicompost, while the treated pond (pond V) was administered by the vermicompost. Vermicompost dose of 2.56 g/L was found to be a suitable dose for catfish fry. The results showed that the total nitrogen content in the control pond was decreased from 0.45 mg/L to 0.25 mg/L. In the experimental tank, the total nitrogen content was increased from 0.25 mg/L to 0.45 mg/L. Likewise, the fish length and weight of the two treatments were significantly different.

Keywords: vermicompost, pond fertilizer, water quality, catfish fry

1. Introduction

Vermicompost is an organic fertilizer produced from the degradation of organic waste with the help of earthworms [1]. Vermicompost contains macro and micro nutrients, vitamins, enzymes, antibiotics, hormones to increase growth [2] which is useful for increasing soil fertility and plant growth [3]. Vermicompost is added to plant media for sufficient nutrients needed, so that plants are able to grow well [4].

Like other organisms, fish also need food and supplements for their survival. Nutrients needed by fish include carbohydrates, proteins, fats, vitamins, enzyme and minerals [5], which can be found in vermicompost [6]. Vermicompost broken down by bacteria into organic materials to stimulate growth of phytoplankton. Phytoplankton is a primary producer or a food resource for fish [7]. The presence of phytoplankton can encourage zooplankton population growth so as to increase the availability of natural foods that contain natural protein. The addition of vermicompost as a fertilizer for fish pond water will increase its growth and help to reach the desired weight. Vaneet and Meera [8] studied the effect of vermicompost on water quality, zooplankton, production and growth of exotic carp, Cyprinus
carpio (L.). Three ponds were added with 202 koi fish each and vermicompost was administered of 0.312 kg/week (pond A), 0.468 kg/week (pond B) and 0.625 (pond C). The results of this study showed that until 90 days, the number of vermicompost did not affect DO, pH, ammonia, phosphate and the amount of zooplankton.

Kostecka and Pączka [9] examined the effect of commercial feed and vermicompost feed on guppy fish growth. This study showed that the survival rate of guppy fish given vermicompost was higher than that of commercially fed guppy fish, even though the growth of guppy fish fed with the commercial feed was faster compared to guppy fish fed with vermicompost.

For fish farming, zooplankton such as Rotifera, Cladocera and Copepoda, as well as phytoplankton such as Bacillariophyceae, Chlorophyceae, Cyanophyceae and Bacillariophyceae are required. Chakrabarty et al. [10] conducted a comparative study of the content of zooplankton, phytoplankton and water quality of carp ponds that were given vermicompost fertilizer, diammonium phosphate and compost from animal manure. This research showed that zooplankton and phytoplankton were most commonly found in ponds that were given vermicompost (680 nos./L), followed by diammonium phosphate (448 nos./L), compost (326 nos./L) and control (43 nos./L). The effect of zooplankton and phytoplankton presences increases the growth rate of carp fish.

In this research, vermicompost (organic fertilizer containing microbes and enzymes) was used for rearing of catfish larvae. Fertilization in rearing ponds was carried out 2 weeks before the fish seeds were sown and this study was conducted for one month with prior acclimatization period. This study aimed to determine the amount of zooplankton and phytoplankton and water quality during fish farming administered with vermicompost.

2. Materials and Methods

2.1. Quality of the Vermicompost

Vermicompost was produced at the Department of Biology, Jakarta State University, Indonesia. Before the application of organic pond fertilizers to the aquaculture system, the vermicompost was dried at 60 °C about 3 days. Then, they were crushed and sieved using 2 mm sieve. Drying can reduce the stickiness of wet vermicompost and for easier application into the fish tanks. These vermicompost were analyzed in the Analytical Chemistry Laboratory, Department of Chemistry, Jakarta State University for their characteristics of pH, electroconductivity, dry matter, C:N ratio, nitrogen, and phosphorus.

2.2. Experimental setup

The experiment was conducted for 4 weeks (28 days) with duplicates in two ponds. The control (pond C) was not administered with any vermicompost. Meanwhile, the vermicompost treatment pond (pond V) was administered by vermicompost. The experimental setup consisted of two polythene tanks (50 L capacity) provided with a filter.

Aerators were provided to each culture tank and the water volume was maintained at 30 L and stocks density was 100 fish per tank, in which the total fish weight per tank ranged between 1.25-1.28. Each tank was supplied with anti-chlorine tap water and aerated continuously throughout the experiment.

Water recirculation was applied in each tank. Fish waste was trapped in a wool filter and cleaned twice a week. Vermicompost was constantly dosed at 2.56 g/L which was found to be a suitable dose for catfish fry. This experiment was conducted indoor at the Environmental Laboratory, Department of Chemistry, Jakarta State University. Each tank was protected with a green net on top to avoid fish jumping out.
2.3. Fish Diet
The commercial diet brand (Prima Feed) was used in this experiment. Feeding was carried out twice daily at 10 am and 4 pm. Feed was given according to 4% of the fish body and amount of feed input into each culture tank were recorded.

2.4. Fish Handling Prior the Experiment
The same local species of catfish fry was used in this study. The fish were obtained from a local hatchery in Parung, Bogor, Indonesia. Fish length was ranging from 13-15 cm/fish with weight around 14-16 g/fish. Catfish were acclimatized for two weeks in polythene tank (50 L) situated indoors prior to the experiment.

2.5. Fish Handling During the Experiment
Fish were randomly assigned into their respective tank at a stocking density of 100 fish per tank. Fishes were bulk weighed in batches of 10 fish once a week for calculation of fish growth. The pond C was not administered by any vermicompost and 25% of water exchange was performed if needed as in the commercial catfish fry culture practice. The water qualities were measured daily. The pond C was used to determine whether the vermicompost treatment showed a significant difference with commercial aquaculture practice.

3. Results and Discussions
This section is divided into two parts which are vermicompost dose-effect on water quality and the growth of catfish fry.

3.1. Quality of the Vermicompost
The physico-chemical characteristics of vermicompost as an organic pond fertilizer are summarized in Table 1.

Table 1. Physico-chemical characteristics of vermicompost.

| No. | Element          | Content |
|-----|------------------|---------|
| 1   | Carbon organic (5) | 37.20   |
| 2   | Nitrogen (%)     | 3.17    |
| 3   | Organic material (5) | 64.76  |
| 4   | P (g/g)          | 4.98    |
| 5   | K (g/g)          | 0.38    |
| 6   | Ca (g/g)         | 1.96    |
| 7   | Mg (g/g)         | 0.34    |
| 8   | Na (mg/kg)       | 890     |
| 9   | Zn (mg/kg)       | 86.50   |
| 10  | Mn (mg/kg)       | 2.18    |

3.2. Vermicompost Dose-Effect on Water Quality of Catfish Fry
Table 2 and Table 3 show the water quality parameters in different treatments during a 4 weeks culture period. Table 2 shows the concentration of soluble phosphate, nitrite, total nitrogen and ammoniacal nitrogen in pond C during the experiment. Ammoniacal nitrogen and soluble phosphate concentrations were increased from first week to fourth week. Total nitrogen and nitrite concentrations were decreased in the second week and then were increased until the end of experiment. The nutrients increased might be primarily due to uneaten feed and metabolic wastes from the fish [11].
Table 2. The concentration of soluble phosphate, nitrite, total nitrogen and ammoniacal nitrogen in pond C during 4 weeks experiment (mean ± SD) (n=2).

| Parameter               | Culture Week |
|-------------------------|--------------|
|                         | 1            | 2            | 3            | 4            |
| Ammoniacal Nitrogen (mg/L) | 0.05±0.01 | 0.11±0.00  | 0.23±0.01  | 0.30±0.03 |
| Nitrite (mg/L)          | 0.11±0.02 | 0.07±0.00  | 0.08±0.01  | 0.08±0.00 |
| Total Nitrogen (mg/L)   | 0.45±0.07 | 0.17±0.04  | 0.23±0.01  | 0.25±0.01 |
| Soluble Phosphate (mg/L) | 0.00±0.00 | 0.04±0.01  | 0.07±0.01  | 0.75±0.07 |

Table 3 shows the concentration of soluble phosphate, nitrite, total nitrogen and ammoniacal nitrogen in pond V during the experiment. Ammoniacal nitrogen was increased during the experiment until the fourth week. The concentration of nitrite was the highest value on first week because low dissolved oxygen in the tank. Lower dissolved oxygen concentrations in pond V could be due to the higher respiration demand of aerobic bacterial activities working on vermicompost decomposition [12];

Table 3. The concentration of soluble phosphate, nitrite, TN and ammoniacal nitrogen in vermicompost block during 4 weeks experiment (mean ± SD) (n=2).

| Parameter               | Culture Week |
|-------------------------|--------------|
|                         | 1            | 2            | 3            | 4            |
| Ammoniacal Nitrogen (mg/L) | 0.03±0.01 | 0.18±0.06  | 0.43±0.02  | 0.45±0.01 |
| Nitrite (mg/L)          | 0.45±0.00 | 0.12±0.01  | 0.16±0.01  | 0.13±0.01 |
| Total Nitrogen (mg/L)   | 0.22±0.85 | 0.03±0.04  | 0.43±0.02  | 0.45±0.04 |
| Soluble Phosphate (mg/L) | 0.29±0.04 | 0.76±0.01  | 0.84±0.05  | 0.85±0.02 |

During this experiment, dissolved oxygen concentrations in pond C was slightly higher than pond V which may be due to the low organic load in water and lower bacterial activities in tanks without organic fertilizer. Total nitrogen was high in the fourth week due to the increase of accumulated nutrients because of uneaten feed and feces from fish [13]. High total phosphorus concentration can be associated with the increase in soluble phosphate produced during decomposition of organic matter [14]. Organic matter releasing both soluble organic phosphorus and orthophosphate during the process of organic fertilizer decomposition under aerobic conditions [15]. Since this study was conducted in a short duration, the nutrients accumulation mostly remained well within tolerance limits for fish.

3.3. Vermicompost Dose-Effect on Fish Growth of Catfish Fry

Table 4 shows the fish growth under different treatments. Based on the daily growth rate through determination of relative growth rate (RGR), length increment, specific growth rate (SGR) and fish survival, the results showed that there was no significant difference (P ≥ 0.05) in growth rates of fish in both treatments, except for survival rate. The ANOVA test (P ≥ 0.05) showed that both treatments were similar and did not show any differences (the same superscript letters between treatments), except for fish survival in which pond V was higher than pond C with values of 99.4% and 94.3%, respectively.
Table 4. Fish growth parameters (mean ± SD, n=2) in different treatments during culture period (4 weeks).

| Parameters                        | Treatments          |
|-----------------------------------|---------------------|
|                                   | Pond C              | Pond V              |
| Stocking Density                  | 100                 | 100                 |
| Initial average individual length (cm) | 13.40±0.11 a             | 13.40±0.14 a             |
| Initial average individual weight (g) | 12.58±0.21 a           | 12.53±0.18 a           |
| Final average individual length (cm) | 15.21±1.20 a           | 15.52±1.60 a           |
| Final average individual weight (g) | 25.60±8.75 a            | 30.48±13.16 a          |
| Relative Growth Rate (RGR) %      | 98.30±65.90 a          | 140.0±104.4 a          |
| Length increment (cm)             | 1.50±1.20 a           | 1.90±1.60 a           |
| Feed Conversion Ratio (FCR)       | 0.70±0.53 a           | 0.49±0.31 a           |
| Specific growth rate (SGR) %      | 4.22±2.92 a           | 4.86±2.87 a           |
| Survival (%)                      | 94.30±3.92 b          | 99.40±0.97 a          |

*Mean values with different superscript letters in a row were significantly different (P ≤ 0.05)

This study revealed that production rate of fish was not significantly different in pond V compared to pond C (without fertilizer). Percentage of daily growth in SGR analysis indicated pond V treatment had higher SGR than the pond C and the RGR was higher as well. FCR is an important parameter for the determination of effective use of feed [16] and from Table 4, FCR in pond V was lower compared to pond C because fish might have eaten organic matter directly [17]. The proper understanding of FCR can help farmers to feed the fish to satiation, and when fish are fed exactly the quantity of feed required, they are not stressed and they provide high quality meat for human consumption [18].

Figure 1 shows the change in fish RGR in different treatments. There was no significant difference between both treatments (P ≥ 0.05), in which the RGR increased with culture weeks. RGR for pond V was 280.61 %, while for pond C it was 163.98 %. High RGR in this experiment was due to small fish having been used. Feeding rates and frequencies are in part a function of fish size. Small larval fish need to be fed frequently and usually in excess which is not a problem as in overfeeding of larger fish [19]. Akinwole and Akinnuoye [20] conducted a 84-day laboratory experiment to determine the effects of different tank sections on production of the African catfish, *Clarias gariepinus* juveniles of average weight at 10.65 g, and RGR in their work was 1,286.93 %.

Ghosh [21] also reported that the vermicompost treated fish pond had better relative growth rate (RGR) value (30.6%) compared to chemical fertilizer treated fish (25.9%). This type of fortnightly application of vermicompost in his study was well suited for fish culture in maintaining a constant availability of nutrients for algae and zooplankton.
Figure 1. Changes in fish RGR in different treatments during 4 weeks experiment.

Figure 2 shows the changes in fish SGR in different treatments during the experiment. There was no significant difference between both treatments (P ≥ 0.05), in which the SGR was increased with culture weeks. SGR was the highest peak in the first week of culture and dropped slightly until the end of experiment. This might be caused by deterioration of water quality with time. According to Dwyer et al. [22], both over or under feeding may also affect the specific growth rates and the efficiency of feed conversion. Priestley et al. [23] mentioned that over or under feeding can be detrimental to the health of the fish and may cause a marked deterioration in water quality, reduced weight, poor food utilization, and increased susceptibility to infection. According to Ng et al. [24], overfeeding disrupts the water quality leading to low dissolved oxygen levels, increased biological oxygen demand, and increased bacterial loads. The use of organic or chemical fertilizer can provide an opportunity to balance the use of supplementary feeding in correlation with the natural food availability and hence reduce the production cost [25].
Figure 2. Change in fish SGR in different treatments during 4 weeks experiment.

4. Conclusions

The administration of vermicompost in a recirculating aquaculture system (RAS) of pond V could maintain water qualities, i.e., dissolved oxygen, pH, electroconductivity, ammoniacal nitrogen, nitrite, total nitrogen and soluble phosphate at the acceptance level. There was no significant difference in growth of catfish fry between pond V and pond C. It was recommended that vermicompost be used in a recirculating aquaculture system (RAS) because pond V achieved higher fish survival of 99.40 % compared to pond C of 94.30 %.

From this study, the water quality employing vermicompost within doses ranged 2-50 g/L were feasible to be used in aquaculture systems. This work showed that vermicompost was functioned as a pH corrector and it complied with water quality requirements for the freshwater aquaculture of catfish fry.

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