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Effect of processing pig manure through a biodigester as fertilizer for fish ponds on water quality and growth performance of three fish species

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Abstract

An on-farm experiment was carried out in a village near Hue in Central Vietnam, from May to August, 2004, to evaluate the effect of two methods of fertilizer input (raw pig manure [RM] and effluent from a biodigester charged with the same manure [EF]) on physico-chemical and biological parameters of the pond water and on the growth performance of three fish species in a polyculture system. There were two treatments and three replicates of each. Six ponds (1.2m in depth) were allocated according to a Completely Randomized Design (CRD), the pond area ranging from 42.9 to 55.0 m^2. Three fish species were stocked: Tilapia (*Oreochromis niloticus*), Silver Carp (*Hypophihalmichthys molitrix)*, and Hybrid Catfish (*Clarias macrocephalus* x *C. gariepinus*) in the proportions 50, 30 and 20 %, respectively. The ponds were fertilized at three day intervals at the rate of 2kg N/ha/day. Dissolved oxygen concentration was higher ($P<0.05$) when the ponds were fertilized with biodigester effluent and Biochemical oxygen demand was tendency lower in effluent ponds ($P=0.073$). Other physico - chemical and biological parameters namely: water temperature, pH, Chemical oxygen demand, ammonia and chlorophyll-a concentrations were not significantly different between treatments ($P>0.05$). Tilapia and Hybrid Catfish grew faster in RM than EF ($P<0.05$) whereas the growth rate of Silver Carp was similar on both treatments. Specific growth rates of Tilapia for RM and EF were 2.7 and 2.4%/ day, respectively, and for Hybrid Catfish were 2.6 and 2.3 % / day, respectively ($P<0.05$). The total net fish yield was somewhat higher in RM ponds than in EF ponds (2.1 and 1.7 ton/ha, respectively) but the difference was not significant ($P >0.05$).

Key words: Biodigester, Catfish, effluent, growth, manure, physico-chemical and biological parameters, pond, Silver Carp, Tilapia, water quality.

1. Introduction

Aquaculture has been practiced as a highly developed art form for a very long time. As the information about aquaculture expands there is increasing interest worldwide in moving from the practice of aquaculture as an art form towards a true agriculture technology (Lannan *et al.*, 1986).

Aquaculture has great potential for the production of food, alleviation of poverty and generation of wealth for people living in coastal areas, many of who are among the poorest in the world. Aquaculture production is growing at more than 10% per year, and this growth is expected to continue. Unfortunately, problems have sometimes been associated with its development. These include: unsuccessful development, where the potential for development is not realised, especially among the poorer sectors of society; the vulnerability of aquaculture to poor water quality and aquatic pollution; and disease, social and environmental impacts (Barg, 2002).

Sustainable aquaculture depends upon eco-friendly and economically and socially viable culture systems. The recycling of organic wastes for fish culture serves the duel purpose of cleaning the environment (by avoiding the problem of wastes disposal) and improving economic benefits. The recycling of animal dung/wastes in fish ponds for natural fish production is important to sustainable aquaculture and to reduce expenditure on costly feeds and fertilizers which amount for more than 50% of the total input cost. However, the indiscriminate used of these manures in fish ponds, instead of improving the pond productivity, may also lead to pollution (Dhawan *et al.*, 1997). Considerable research has been done on the utilization of animal manures in fish culture ponds particularly farmyard manure, poultry dropping, cow dung and biogas slurry which are suitable substitutes for costly feeds and fertilizer (Schoeder 1980; Dhawan and Toor 1989). However, there are few reports on the recycling of pig manure in fish ponds. The low-cost biodigester, constructed from polyethylene tubular film, has been promoted in many developing countries in recent years. This technology was introduced to Vietnam in 1992. The effluent from the biodigester can be applied as fertilizer for crops or fish ponds and water plants (Bui Xuan An, 2002).

Therefore the present study was conducted to determine the effect of fresh pig manure and biodigester effluent on physico-chemical and biological parameters of pond water and on the growth of three fish species (Tilapia, Silver Carp and Hybrid Catfish) in a polyculture system, thus providing data on the integration of fresh water aquaculture and biogas utilization.

2. Materials and methods

2.1. Location

The experiment was conducted at Phu Mau village, 10 km Northeast of Hue city, Phu Vang district, Thua Thien Hue Province. The climate is tropical monsoon with a yearly rainfall from 2500 to 3500mm, most of which occurs from September to February. The soil in the farm where the experiment was conducted is clay loam.

2.2. Treatments and design

Two treatments were allocated at random to six earthen ponds, each with an area ranging from 42.9 to 55.0 m^2 according to a Completely Randomized Design (Table 1). The treatments were:

- RM: raw pig manure added directly to the fish ponds.
- EF: effluent from a biodigester charged with the same manure added to the ponds.

The amount of fertilizer input to each pond was calculated based on a nitrogen input of 2 kg N / ha / day. Fertilizer was applied to every pond one week before the experiment started, and thereafter manure and effluent were applied twice a week. The amount of manure and effluent applied to the ponds is shown in Table 4. The experiment lasted 120 days.

Table 1. Experimental layout

Pond number	1	2	3	4	5	6
Area, m^2	55.0	42.9	45.1	44.0	46.2	51.7
Treatment	EF	RM	EF	EF	RM	RM

EF = effluent
RM = raw pig manure

2.3. Manure

Pig manure was collected daily in the morning from the Cross breed pig pen. The pigs were being fed a mixture of concentrate (46% CP) and maize (9% CP) with crude protein content in the diet of 200g/kg DM.

2.4. Installation and management of the biodigester

A biodigester was installed in March, 2004 in a household at Phu Mau Village, Phu Vang District. It was made from tubular polyethylene film (internal diameter 1.11 m). A trench was dug near the pig pen with the following dimensions; 5 m length, 1.1 m depth and 1.1 m width. The total volume of this biodigester was about 4.74 m^3. The liquid fraction is about 75% of the total tube volume which is equivalent to 3.56 m^3. A hole was dug at the outlet of the biodigester to collect the effluent. Details of the biodigester are shown in Table 2.

Table 2. Details of the biodigester and loading rates.

	Dimensions
Manure DM, %	
Range	15.8-22.7
Mean value	19.6
Biodigester details	
Length, m	5.0
Diameter, m	1.11
Volume of biodigester, m^3	4.74
Liquid volume, m^3	3.56
Retention time, days	20
Liquid applied daily, litres	178
Manure added, kg/day	36.3
Water added, litres/day	142

DM = dry matter

2.5. Manure input

The biodigester was charged daily in the morning and with the amount of fresh manure and water of 36.3 kg/day and 142 litres/day, respectively (Table 2).

2.6. Pond preparation and management

The ponds were newly built in mid-March, 2004. Firstly lime ($CaCO_3$) was spread on the bottom and sides of all ponds at a rate of 500 kg/ha. Liming is common practice in fish culture, to increase the rate of bacterial decomposition and the pH. It also accelerates decomposition by bacteria, kills pathogens and eradicates predators (Boy, 1979). The ponds were left to dry for 7 days, then filled with water up to a level of 1.2 m.

2.7. Fish stocking.

Three species of fish were stocked: Tilapia (*Oreochromis niloticus):* 50%; Silver Carp (*Hypophihalmichthys molitrix):* 30% and Hybrid Catfish (*Clarias macrocephalus* x *C. gariepinus*): 20%, with a density of 2 fish / m^2 of the pond. Mean initial weight of Tilapia fingerling was 3.35 g (0.34) and 7.9 cm (0.81); Silver Carp of 2.5 g (0.33) and 7.9 cm; and Hybrid Catfish of 7.9 g (0.34) and 10 cm (0.97).

2.8. Measurements

2.8.1. Samples of manure and effluent

Samples of fresh manure, slurry and effluent were taken before application to the fish ponds and then once a month for determination of pH, dry matter (DM), organic matter (OM), nitrogen (N) and ammonia-N. Analysis of N and ammonia-N were done using a Foss-Tecator Kjedahl apparatus and for organic matter by ashing the samples in a furnace oven at 550^{o}C (AOAC, 1990). DM content was determined by microwave radiation. The pH of the manure, slurry and effluent was measured by using a glass electrode and digital meter.

2.8.2. Physico-chemical and biological parameters

Physico-chemical and biological parameters were measured and recorded as: dissolved oxygen (DO), water temperature, Hydrogen Ion concentration (pH), water transparency, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and concentration of primary production (Chlorophyll-a) and ammonia . The DO level of the pond water, water temperature, and pH were measured two days a week, at two times during the day, in the early morning at 06:00h and in the afternoon at 14:00h. Water samples were collected at the same place in each pond at 20 cm depth and analyzed immediately. The Aqua DO Text kit, Aqua Ammonia text kit, and pH text kit were used to measure DO, ammonia, and pH, respectively. Water temperatures were measured by thermometer at a water depth of 20 cm. Water transparency was measured on two days each week, once a day at 10:00h by a Secchi disc. The disc was lowered into the water until it just disappears and the depth is recorded. The disc was lowered a little more and then raised until it just reappears, and then the depth in cm recorded. The average of these two depths is the Secchi disc visibility. BOD and COD were measured every 15 days according to standard techniques (Boyd, 1979). The measurement of COD is based on the principle that almost all organic compounds in water can be oxidized to carbon dioxide and water by the action of strong oxidizing agents under acid conditions. Chlorophyll-a was measured every 15 days after concentration by filtration through a membrane filter. The pigments contained in the phytoplankton are extracted in acetone and the concentration of Chlorophyll-a determined spectrophotometrically (Boyd, 1997).

2.8.3. Fish growth rate

Fish sampling was done monthly in order to determine the growth rate of the fish by recording the length and weight of a sample. The fish were caught with a seine net and ten fish of each species were taken randomly as the sample and weighed by using a weigh scale (±1.0 g). The length from the tip of the mouth to the caudal fin was measured with a ruler. At the end of the experiment the total net fish yield was determined and the weight and length of each species of fish were recorded.

Daily weight gain and daily length gain were measured by the following equations:

$DWG (g/day) = (Wt - Wo)/t$

Where: Wo: initial weight (g)

Wt: final weight (g)

t: days of Experiment

$DLG (mm/day) = (lt - lo)/t$

Where: lo: initial length (mm)

lt: final length (mm)

t: days of experiment

Specific growth rate (SGR) was calculated as follows:

$$SGR = 100 \times (\ln(Wt) - \ln(Wo))/t$$

Where : Wt : Final body weight

Wo : Initial body weight

ln (Wt): natural logarithm of final body weight

ln (Wo): natural logarithm of initial body weight

t: number of culture days

2.8.4. Survival rate

The survival rate of the fish was determined by the following equation:

$$X (\%) = (Nt/No) \times 100$$

Where: No: initial number of fish

Nt: final number of fish

2.9. Statistical analysis.

Data were analyzed by ANOVA using the General Linear Model in Minitab Statistical Software version 13.31 (Minitab, 2000). The variables were treatment and error.

3. Results

3.1.Biodigester subsystem, manure and effluent input

The liquid volume of the biodigester was 3.56 m^3, with mean retention time of 20 days. The DM content of the manure ranged from 15.8 to 22.7 %, with a mean value of 19.6% and mean content of N of the manure was 3.1% in DM (Table 2 and 3). The mean value of the N content of the effluent was 627 mg/litre. The average amount of fresh manure added to the biodigester was 36.3 kg/day (Table 2).

3.2. Physico-chemical and biological parameters

During the 120 days of culture, physico-chemical and biological parameters were measured and are shown in Table 5. Water temperature ranged from 20 to 34 ^oC, and did not differ between treatments (P>0.05). pH varied from 6.0 to 7.7 in the morning and from 8.0 to 9.5 in the afternoon, and did not differ among treatments (P>0.05). Dissolved oxygen ranged from 1.5 to 7.0 mg/l and from 2.0 to 7.0 mg/l in RM and EF, respectively. The mean value was significant higher in EF than in RM ($P<0.05$). Water transparency ranged from 17 to35 cm, and the mean value was higher in EF than in RM ($P<0.05$). BOD varied from 1.2 to 10 mg/l and the mean value was higher in RM ($P<0.1$). COD varied from 24.0 to 82.9 mg/l, chlorophyll-a from 14.0 to 299 μg/l and ammonia from 0.0 to 0.2. The between treatment difference in these chemical-biological parameters, however, was not significant ($P>0.05$).

Table 3. Characteristics of manure and effluent

	Manure	Effluent
DM, %	19.6	4.5
pH	7.5	7.5
OM, % of DM	73.0	55.5
N, % in fresh matter	0.81	-
N, % of DM	3.1	-
N, mg/litre	-	627
N-NH_3 (mg/litre)	-	467

DM= dry matter, OM = organic matter, N = nitrogen, N-NH_3 = ammonia nitrogen

Table 4. Total quantities of fertilizer added to the ponds over the 120 days period of the experiment

Pond number	1	2	3	4	5	6
Area, m^2	55.0	42.9	45.1	44.0	46.2	51.7
Fresh pig manure, kg	-	128	-	-	138	154
Effluent, liters	2123	-	1741	1699	-	-

Table 5. Effect of fertilizing fish ponds with biodigester effluent (EF) or raw manure (RM) on water quality parameters

	RM		EF		SEM	P-value
	Range	Mean	Range	Mean		
pH						
06.00 h	6.0-7.7	6.8	6.0-7.7	6.8	0.03	0.648
14.00 h	8.0-9.5	8.6	8.0-9.5	8.7	0.04	0.118
Water temperature, oC						
06.00 h	20-28	23.6	20-28	23.6	0.15	0.942
14.00 h	30-34	32.4	30-34	32.4	0.08	1.000
DO, mg/l						
06.00 h	1.5-4.0	2.6	2.0-4.0	3.0	0.05	0.000
14.00 h	4.0-7.0	5.6	5.0-7.0	6.0	0.06	0.000
Water transparency, cm	17-26	20.3	18-35	21.9	0.21	0.000
BOD, mg/l	2.6-13.0	8.12	1.2-10.0	6.06	0.78	0.073
COD, mg/l	24.0-82.9	46.32	4.8-66.0	42.3	4.67	0.550
Chlorophyll-a, μg/l	14.0-299	124	14.0-289	139	23.2	0.635
Ammonia, mg/litre	0.0-0.2	0.09	0.0-0.2	0.06	0.02	0.344

DO = Dissolved oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand

3.3. Fish growth

Daily weight gain and specific growth rate (SGR) of Tilapia and Hybrid Catfish were significantly higher in RM than in effluent ponds (P<0.05). SGR of Silver Carp were not different between treatments (P>0.05) (Table 6). Final body weight of Tilapia and Hybrid Catfish were significantly higher (P<0.05) in RM ponds, whereas Silver Carp was not significantly different among treatments (Table 8).

Table 6. Effect of fertilizing fish ponds with biodigester effluent (EF) or raw manure (RM) on daily weight gain (DWG, g/day) and daily length gain (DLW, mm/day) of three fish species

	RM	EF	SEM	P- value
DWG, g/day				
Tilapia	0.97	0.72	0.05	0.029
Silver Carp	1.13	1.12	0.10	0.984
Hybrid Catfish	0.07	0.47	0.04	0.015
DLG, mm/day				
Tilapia	0.82	0.73	0.03	0.107
Silver Carp	1.23	1.21	0.08	0.841
Hybrid Catfish	0.89	0.72	0.03	0.015

Table 7. Effect of fertilizing fish ponds with biodigester effluent (EF) or raw manure (RM) on daily weight gain (DWG, g/day) and daily length gain (DLW, mm/day) of three fish species

	RM	EF	SEM	P- value
SGR, %/day				
Tilapia	2.70	2.38	0.06	0.009
Silver Carp	3.33	3.23	0.05	0.955
Hybrid Catfish	2.58	2.26	0.06	0.009

Table 8. Effect of fertilizing fish ponds with biodigester effluent (EF) or raw manure (RM) on final weight and length of fish at 120 days

	RM	EF	SEM	P- value
Final weight, g				
Tilapia	120	90	6.07	0.026
Silver Carp	137	137	13.2	0.981
Hybrid Catfish	87.4	60.4	4.81	0.017
Final length, cm				
Tilapia	17.7	16.7	0.29	0.113
Silver Carp	22.7	22.4	0.35	0.848
Hybrid Catfish	20.7	18.6	0.44	0.014

3.4. Fish survival rate and total net fish yield.

Raw pig manure and effluent had no any affected on survival rate, which was quite high (from 84.2 to 91.4%) for all fish species and for both treatments (Table 9). The total net fish yield was higher in RM ponds than in EF ponds (2.1 and 1.7 tons/ha, respectively) but the difference was not significant (P=0.134).

Table 9. Effect of fertilizing fish ponds with biodigester effluent (EF) or raw manure (RM) on fish survival rate and net fish yield.

	RM	EF	SEM	P- value
Survival				
Tilapia	90.1	91.4	1.31	0.543
Silver Carp	89.6	84.2	2.87	0.252
Hybrid Catfish	85.2	84.9	1.57	0.899
Total net fish yield, ton/ha	2.1	1.7	0.15	0.134

4. Discussion

4.1. Physico-chemical and biological parameters.

Physico-chemical and biological conditions play a significant role in the biology and physiology of fish. In the present study the physico-chemical parameters of pond water in the different treatments were within the range required by Catfish and Silver Carp (Duodoroff and Shumway, 1970; Hora and Pillay, 1962), by Tilapia (Balarin and Hatton, 1979). Water temperature, pH, COD, BOD, chlorophyll-a, ammonia did not differ significantly between treatments. This suggests that raw pig manure applied at a level of (91 tons / ha/ year) did not have any adverse effect on these parameters of water quality. Raw pig manure applied into fish ponds needs to under go a process of decomposition before its nutrients can be absorbed and utilized by phytoplankton. The decomposition of this organic matter must consume a certain amount of oxygen (Han Yugin *et al.*, 1983), and they also found that the DO in effluent ponds was 43.5% higher than in fresh manure ponds. This indicates that fermentation of manure in a biodigester improves the chemical property of water only with respect to dissolve oxygen.

4.2. Fish growth

The growth rate of the three fish species cultured show that in Tilapia and Hybrid Catfish, DWG and SGR were significantly higher in RM whereas, in Silver Carp there was no effect of treatment. The higher growth rates of Tilapia and Catfish in RM ponds may be due to higher availability of suitable food as they feed directly on organic matter, which, although low in nutrient value includes microorganisms adhering to the particles that are of high protein value (Schroeder, 1980).

Tang's (1970) polyculture experiment indicated that only half of the total fish growth (30 kg / ha / day) could be attributed to the consumption of natural food organisms like plankton or insects. The other half came from the direct consumption of organic materials. Silver Carp grew at the same rate in both treatments, which probably reflected the ready availability of food for them, mostly as phytoplankton. Even thought DO was significantly higher in EF this did not effect the growth of Silver Carp, as it lives in the upper layer of the pond water, oxygen is absorbed from the atmosphere, and the concentration on both treatments was within the range required by Silver Carp (Duodoroff and Shumway, 1970; Hora and Pillay, 1962).

4.3. Total net fish yield

The result of this experiment showed that the productivity of the ponds was rather high (1.7 and 2.1 tons/ha) for EF and RM, respectively. Yang *et al.* (1987) found that treatments with fermented pig manure, fresh pig manure and control (chemical fertilizer) gave total net fish yields of 1.1, 1.5, and 0.7 ton/ha, respectively. However which are less than 50% of the yields recorded in our study. Pich Sophin and Preston (2001) reported that extrapolated net fish yield in polyculture of 5 fish species (Tilapia, Silver Carp, Bighead Carp, Silver Barb and Mrigal in the percentages of 35, 30, 15, 15 and 5%, respectively) was highest in effluent ponds, followed by chemical fertilizer and manure, with extrapolated net fish yields of 1.5, 1.3 and 0.89 ton/ha, respectively, with fertilizer applied at the rate of 1 kg N / ha / day. In our study the rate of manure or effluent application was based on isonitrogenous and was 2 kg N / ha/ day was much higher, which explains to the higher total net fish yield in our study. Also Pich Sophin and Preston (2001) culture five different species so it is difficult to compare the two studies.

It is probable that the fresh manure contained appreciable quantities of feed residues. In the effluent ponds, the feed residues would not be present as they would have been fermented in the biodigester. Tilapia and Catfish can use directly organic matter such as in feed residues, hence they would have a comparative advantage in ponds fertilized with manure. By contrast, Silver Carp depend on phytoplankton, which appeared to be similar in RM and EF ponds, so the growth rate was similar on both treatments.

5. Conclusions and recommendations

Tilapia, Silver Carp and Hybrid Catfish can be successfully cultured in ponds fertilized with either raw pig manure or biodigester effluent, without supplementary feeding.

Fermented manure (biodigester effluent) compared with fresh manure

- Increased the dissolved oxygen in pond water
- Did not affect water temperature, pH, COD, chlorophyll-a and ammonia
- Tendency decreased BOD
- Reduced the growth rates of Tilapia and Hybrid Catfish
- Had no effect on growth of Silver Carp

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