Growth, Production, Feed Conversion Ratio, Water Quality and Nutrient Budget of Hybrid Catfish (*Clarias macrocephalus* x *C. gariepinus*) Cultivation in Earthen Ponds Without Water Exchange

Grin Swangdacharuk and Yont Musig*

ABSTRACT

The potential of closed culture system of hybrid catfish (*Clarias macrocephalus* x *C. gariepinus*) without water exchange and without aeration was evaluated whether it can still produce fish in high production rate. The study was done in three earthen ponds in a private fish farm. Growth performance of hybrid cat fish was investigated. Pond water quality and pond nitrogen and phosphorus budgets were also studied. Results from this study indicated that closed culture system of hybrid catfish in earthen ponds without water exchange and without aeration with minimum pond management practice both between crops and during grow out period can give high production rate of hybrid catfish. Production of hybrid catfish was 22.3-29.4 t/rai/crop or 139.2-183.7 t//ha/crop. FCR and survival rate of hybrid catfish were 3.7-4.2 and 44.7-59.4% and daily weight gain was 1.7-2.7 g/fish/day. Water quality parameters varied between 30.3-4,552.0 NTU for turbidity, 0.03-7.23 g/l for total suspended solids (TSS), 0.02-1.48 g/l for particulate organic matter (POM), 138.8-827.7 µg/l for chlorophyll *a* content, 6.7-8.6 for pH, 0.27-132.58 mgN/l for total ammonia nitrogen (TAN), 4.70-295.8 mgN/l for total nitrogen (TN), 0.04-0.74 mgP/l for soluble orthophosphate (SOP), 0.39-10.40 mgP/l for total phosphorus (TP), 0.10-14.60 mg/l for midday surface dissolved oxygen (DO), and 0.10-4.61 mg/l for midday bottom DO. Midday bottom and surface DO concentrations were at low level most time during grow out period indicating the absence of DO during night time.

Major input of nitrogen and phosphorus budgets in hybrid catfish ponds were applied feed (98.0+0.6% of nitrogen input and 99.7±0.1% of phosphorus input). Major sinks for nitrogen were harvested hybrid catfish (36.2±6.10%) and pond effluent (35.8±4.14%). Major sinks for phosphorus were pond bottom soil absorption (84.3±2.53%), harvested hybrid catfish (13.6±2.06%), and pond effluent (2.1±0.57%). Hybrid catfish incorporated 36.3±6.4% of nitrogen and 13.4±2.0% of phosphorus inputs from feed.

Keywords: hybrid catfish, closed culture system, nitrogen budget, phosphorus budget.

Department of Aquaculture, Faculty of Fisheries, Kasetsart University, Bangkok 10900 Thailand
*Corresponding author, e-mail address: ffisyon@ku.ac.th

INTRODUCTION

Hybrid catfish (*Clarias macrocephalus* x *C. gariepinus*) is the second most important economic freshwater fish species of Thailand with annual production of 140,000 tons in 2010 (Department of Fisheries, 2012). Hybrid catfish is an air breather which can be grown at extremely high density (100-125 fish/m^2) with minimal water quality management. Pond water is exchanged at later stages of the culture period (120–150 days) (Yi, *et al*, 2003). Production rate in earthen pond culture without aeration can be as high as 100 tons/ha (Areerat, 1987; Little *et al*, 1994). Trash fish, chicken offal or pelleted feed are used as fish feeds which generally cause poor water quality and excessive phytoplankton blooms throughout most of the grow-out period (Ingthamjit, *et al*, 1992; Lin and Diana, 1995). Generally, 50% of the pond water is changed monthly in the last three months of grow out period (Little *et al*, 1994).

Some farmers in Thailand claimed that they can obtain high production of hybrid catfish by culturing them in earthen ponds using closed culture system with neither aeration nor water exchange using minced chicken offal as a major feed supplemented by small amount of pelleted feed. Water is added into the ponds periodically only to compensate the loss from evaporation. Stocking rate is high in order to get high production rate. However, there is still no published data about this culturing system of hybrid catfish. Even though this culturing system is definitely resulted in the deterioration of pond environment it is possible that high production of hybrid catfish might be obtained from this culturing system because hybrid catfish is very tolerance to poor pond environment.

In this study we investigated the potential of this closed culture system whether it can still be able to produce hybrid catfish in high production rate. Survival rate, growth rate, feed conversion ratio, and production rate of hybrid catfish were also studied. Water quality in hybrid catfish cultured ponds was also monitored and nutrient budgets were estimated.

MATERIALS AND METHODS

The study was conducted in an intensive hybrid catfish farm in Saraburi province. The farm used the closed culture system without aeration nor water exchange. Three 411-600 m^2 ponds were randomly selected for this study. Water depth in these ponds was 1.80-2.15 m. After harvesting fish in the previous crop, the ponds were drained and limed with 25 kg hydrated lime per pond, and left empty for a day before being refilled with water. After 3-7 days, the ponds were stocked with 1.5-3.0 g hybrid catfish at a stocking rate of 80-120 fish/m^2. The fish were fed to satiation mainly with chicken offal (mostly chicken internal organs plus small amount of chicken head) supplemented with small amount of pelleted feed. Water is added into the ponds periodically to compensate the loss from evaporation. Culture period was 130-159 days.

Water quality analysis was done weekly by taking integrated water column samples from five sampling stations in each pond between 11:00 a.m. and 02:00 p.m. using water column sampler. Water sampling for the last week of culture period of each pond was done on harvest. Pond water was analyzed for total phosphorus (TP), soluble orthophosphate (SOP), total ammonia nitrogen (TAN), total suspended solids (TSS), particulate organic matter (POM), and chlorophyll *a* using Standard Methods (APHA *et al*., 2005). Total nitrogen (TN) was analyzed using Brucine Method (APHA *et al*., 1975). Turbidity was measured using HACH Turbidity Meter model 2100Q. pH was measured using YSI pH Meter model 100. Dissolved oxygen (DO) and temperature were measured during 11:00 a.m. and 01:00 p.m.at 30 cm below water surface and at 30 cm above pond bottom, using YSI model 85: Salinity, Conductivity, Dissolved Oxygen & Temperature Meter. Pond effluents were also sampled and analyzed for total nitrogen and total phosphorus. Fish and fish feed were sampled and analyzed for nitrogen and phosphorus content using methods recommended by AOAC (2000).

Nitrogen and phosphorus budgets in the culture system were calculated based on inputs from water, stocked fish and fish feed; and losses in harvested fish and discharged water. Average weights of fish at harvest were determined by bulk weighing 50 fish randomly sampling from each pond. Data were analyzed for means and standard deviations. Production per unit area, survival rate, daily weight gain and feed conversion ratio of fish were calculated.

RESULTS AND DISCUSSION

Pond characteristics, stocking, feeding, and pond management

Surface area of pond-1, pond-2, and pond-3 were 600, 665, and 411 m^2, respectively, and depths were 2.15, 1.90, and 1.80 m, respectively (Table 1). After draining and harvesting fish from the previous crop, ponds were limed with hydrated lime at the rate of 25 kg/pond and left for a day and then refilled.

Fish were stocked 3-7 days after refill. Initial weights of fish stocked were 1.5 g for pond-1 and 3.0 g for pond-2 and pond-3. Stocking rates of fish were 80 fish/m^2 (37 fish/m^3) for pond-1, 120 fish/m^2 (63 fish/m^3)

Table 1. Pond characteristics, number of fish stocked, culturing period, and the amount of given feed

Parameter	Pond-1	Pond-2	Pond-3	Mean±S.D.
Pond area (m^2)	600	665	411	
Pond depth (m)	2.15	1.90	1.80	
Culturing period (day)	145	159	130	
Stocking rate				
fish/pond	48,000	80,000	48,000	
fish/m^2	80	120	117	
fish/m^3	37	63	65	
Amount of given feed				
Chicken offal (kg)	34,450	46,775	27,500	
(%)	98.7	99.0	98.8	98.8±0.2
Pelleted feed (kg)	440	480	340	
(%)	1.3	1.0	1.2	1.2±0.2

for pond-2, and 117 fish/m^2 (65 fish/m^3) for pond-3. Fish were fed to satiation once a day. Minced chicken offal was used as main feed (98.7-99.0% of total feed used) supplemented by a small amount of pelleted feed (1.0-1.3% of total feed used). There was no aeration and no water exchange during grow out period but water was added periodically to compensate the loss by evaporation. Culture periods for pond-1, pond-2, and pond-3 were 145, 159, and 130 days, respectively (Table 1).

Pond water quality

At stocking date, water turbidity was 30.3-43.0 NTU with Secchi disc reading of 22.6-37.0 cm. Water contained 0.03-0.05 g/l of TSS and 0.02-0.03 g/l of POM. Initial chlorophyll *a* content was 138.8-190.6µg/l. A high amount of chlorophyll *a* content indicated that phytoplankton was already blooming at the stocking date. Initial concentrations of TAN, SOP, and TP were 2.03-5.39 mgN/l, 4.70-12.75 mgN/l, 0.04-0.11 mgP/l, and 0.42-0.47 mgP/l, respectively. Initial water pH at stocking date was 7.26-8.57 and initial dissolved oxygen (DO) measuring at pond surface and pond bottom during 11:00 a.m. and 2:00 p.m. were 11.58-14.60 mg/l and 1.28-4.61 mg/l, respectively.

Water pH fluctuated between 6.71 and 7.93, 6.74 and 7.62, and 6.81 and 7.57 in pond-1, pond-2, and pond-3 from the end of week 1 to harvest date. Average values of pH of pond water were between 6.9 and 7.7 (Figure 1).

Rapid growth of phytoplankton was observed in all three ponds resulting in very dense biomass of microalgae in pond water. Chlorophyll *a* content in pond water increased to levels above 1,000 µg/l within 3-6 weeks. Maximum chlorophyll *a* content in pond-1, pond-2, and pond-3 were 1,610.9, 1,615.4 and 1,815.6 µg/l, respectively. Average values of chlorophyll *a* content in pond water were between 165.4 and 1,555.3 µg/l (Figure 2). Water turbidity also increased rapidly exceeding the level of 340 NTU within 4-7 weeks. Secchi disc visibility decreased to unreadable levels within 7, 11, and 5 weeks in pond-1, pond-2, and pond-3, respectively. Maximum values of water turbidity in pond-1, pond-2, and pond-3

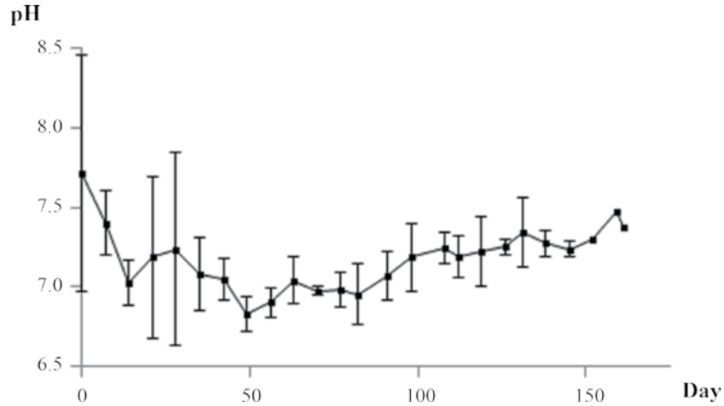

Figure 1. pH of water in hybrid catfish ponds (mean±SD)

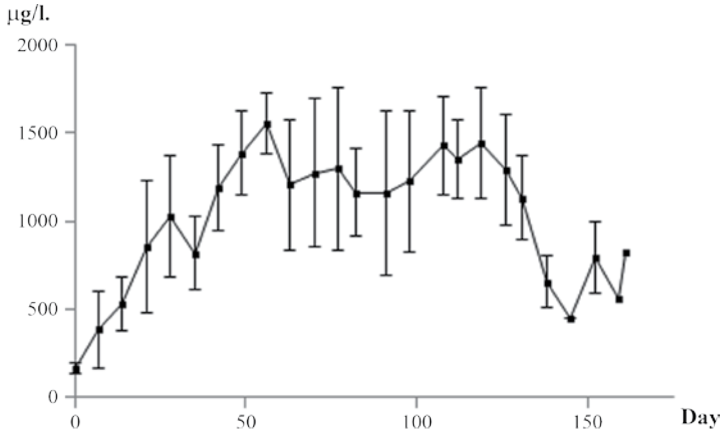

Figure 2. Chlorophyll *a* content in water in hybrid catfish ponds (mean±SD)

were 1,656.7, 4,552.0, and 4,552.0 NTU, respectively. Average values of turbidity of pond water were between 38.2 and 2,111.6 NTU (Figure 3).

TSS concentrations were in the range of 0.05-2.34, 0.03-7.23, and 0.05-5.11 g/l in pond-1, pond-2, and pond-3, respectively, while POM concentrations in pond-1, pond-2, and pond-3 were 0.03-0.71, 0.03-1.48, and 0.02-1.01 g/l, respectively.

Increasing trends of both TSS and POM were also observed in all three ponds along with increasing culture period. TSS in pond water increased to levels above 0.55 g/l within 9-12 weeks while POM increased to levels above 0.30 g/l within 7-10 weeks. During the early culture period, a high percentage of organic matter in TSS was observed. Percentage of organic matter in TSS decreased to lower levels within 6-7 weeks before harvest. Average values of TSS of pond water were between 0.04 and 2.47 g/l and average values of POM in pond water were between 0.03 and 1.48 (Figures 4, 5).

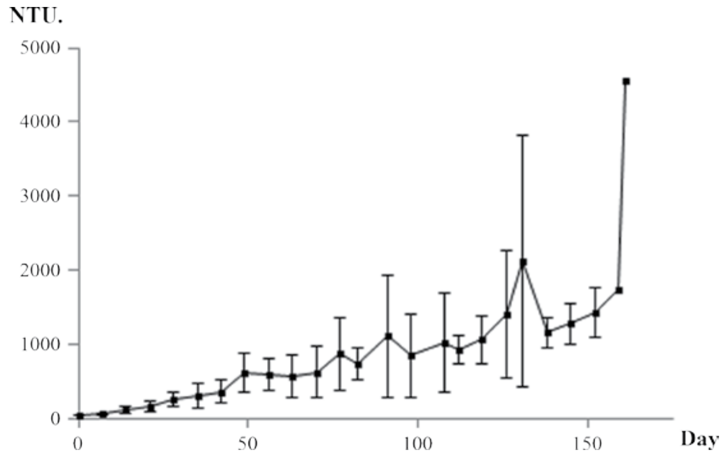

Figure 3. Turbidity of water in hybrid catfish ponds (mean±SD)

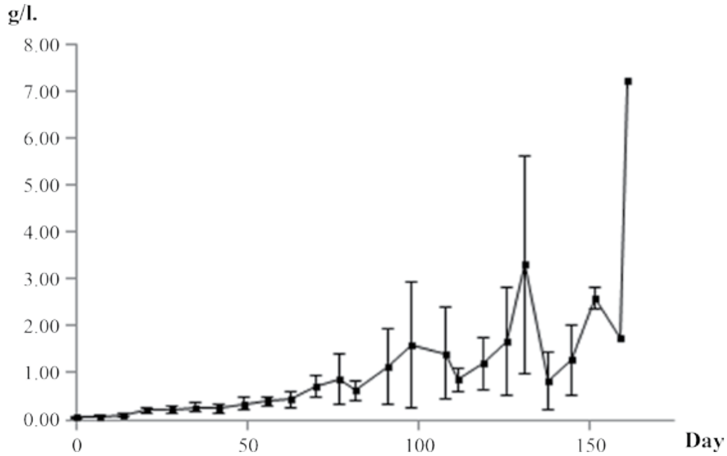

Figure 4. Total suspended solids in water in hybrid catfish ponds (mean±SD)

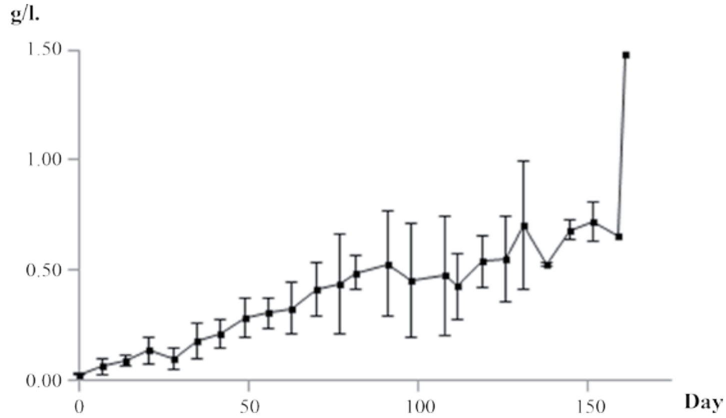

Figure 5. Particulate organic matter in water in hybrid catfish ponds (mean±SD)

High rates of accumulation of nitrogen and phosphorus in pond water were observed. Initial concentrations at stocking date were 4.70-12.75 mg/l for TN and 0.42-0.47 mg/l for TP. At harvest, concentrations of TN and TP in pond water were 203.56-235.13 and 4.99-10.40 mg/l, respectively. Maximum concentrations of TN and TP were observed at harvest date except in pond-2 where the maximum concentration of TN was observed one week before harvest. Average values of TN in pond water were between 9.21 and 217 mgN/l and average values of TP in pond water were between 0.46 and 6.26 mgP/l (Figures 6, 7).

SOP fluctuated between 0.04 and 0.37 mgP/l in pond-1, 0.04 and 0.74 mgP/l in pond-2, and 0.02 and 0.28 mgP/l in pond-3. Average values of SOP in pond water were between 0.04 and 0.31 mgP/l (Figure 8).

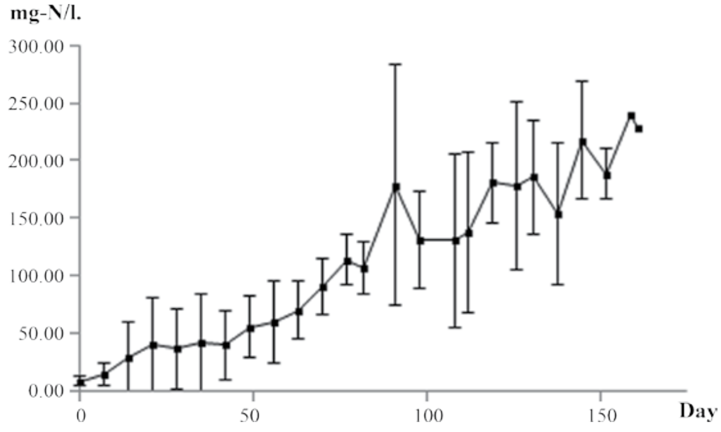

Figure 6. Total nitrogen in water in hybrid catfish ponds (mean±SD)

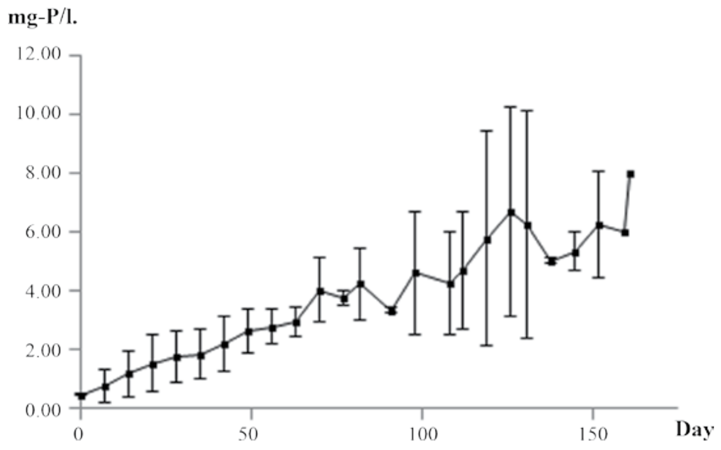

Figure 7. Total phosphorus in water in hybrid catfish ponds (mean±SD)

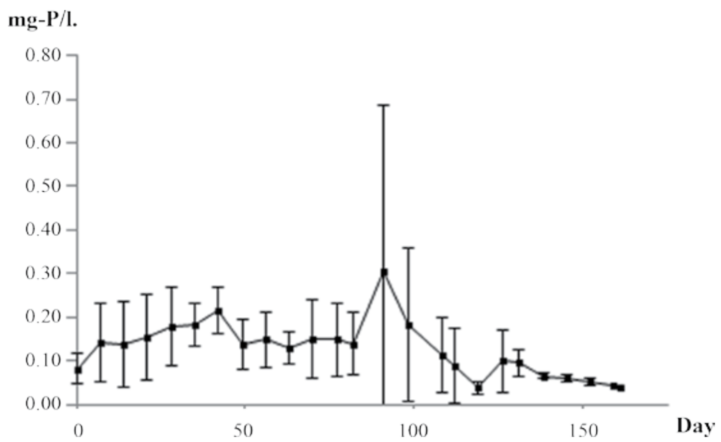

Figure 8. Soluble orthophosphate in water in hybrid catfish ponds (mean±SD)

High concentrations of TAN were found since stocking date in which TAN concentrations were 2.03, 3.19, and 5.39 mg/l in pond-1, pond-2, and pond-3, respectively. In the first five weeks, TAN concentrations fluctuated between 1.22 and 2.41 mg/l in pond-1 and between 1.48 and 3.19 mg/l in pond-2. It then increased to levels above 50.0 mg/l at the end of week 17 and continuously increased to maximum levels at harvest dates. Maximum concentrations of TAN in pond-1 and pond-2 were 84.76 and 132.58 mg/l, respectively. In pond-3, TAN concentration increased to levels above 10.00 mg/l within one week and increased to levels above 100.00 mg/l at the end of week 17. Maximum concentration of 126.05 mg/l of TAN in pond-3 was observed at harvest date (Figure 9). Average values of TAN in pond water were between 3.54 and 132.58 mgP/l (Table 2).

Table 2. Total ammonia nitrogen and dissolved oxygen concentrations (mean ±SD) in catfish ponds (dissolved oxygen were measured between 11:00 a.m. and 01:00 p.m.)

Week	**Surface DO (mg/l)**	**Bottom DO (mg/l)**	**TAN (mg-N/l)**
0	11.78±0.28	2.64±1.75	3.54±1.71
1	13.32±1.32	3.03±1.05	5.15±4.42
2	7.85±3.44	1.49±1.20	5.78±7.01
3	4.98±4.24	1.31±1.26	8.07±11.64
4	4.73±3.65	0.71±0.66	7.96±12.04
5	5.79±1.79	1.21±0.20	11.32±14.85
6	4.14±1.42	0.25±0.10	12.31±13.56
7	1.79±1.82	0.19±0.15	15.03±12.97
8	3.12±3.71	0.61±0.46	16.13±11.32
9	7.25±6.65	0.61±0.54	21.23±17.91
10	2.11±2.70	0.46±0.45	23.76±9.61
11	0.69±0.57	0.20±0.17	43.38±28.92
12	0.10±0.01	0.10±0.00	37.92±6.95
13	2.31±3.72	0.24±0.25	52.07±24.15
14	3.17±3.21	0.59±0.85	49.33±20.79
15	1.09±1.31	0.43±0.53	45.19±20.95
16	0.37±0.46	0.27±0.29	53.14±27.87
17	0.10±0.00	0.10±0.00	72.78±37.26
18	0.10±0.00	0.10±0.00	79.06±31.34
19	0.13±0.05	0.10±0.00	92.56±34.07
20	0.10±0.00	0.10±0.00	88.00±17.56
21	0.10±0.00	0.10±0.00	79.23±2.26
22	0.10±0.00	0.10±0.00	87.56±3.96
23	0.10	0.10	126.44
24	0.10	0.10	132.58

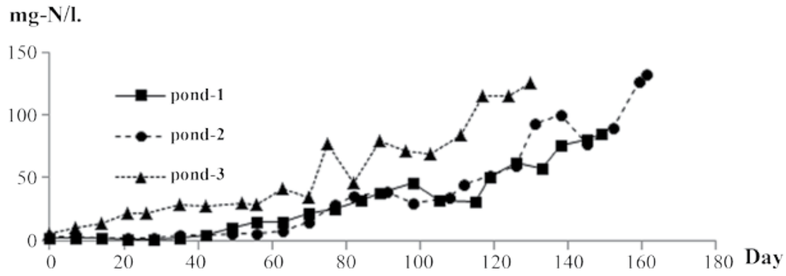

Figure 9. Total ammonia nitrogen in water in hybrid catfish ponds

Average values of surface DO in pond water were between 0.10 and 13.32 mg/l, while those of bottom DO in pond water were between 0.10 and 3.03 mg/l (Table 2). High concentrations of midday surface DO at stocking date indicated that microalgae population was well established at stocking date resulting in high photosynthetic rate of phytoplankton in upper layer of pond water which is confirmed by high concentration of chlorophyll *a* in pond water. Rapid bloom of phytoplankton in these ponds was likely resulted from nutrients and organic matter leftover from previous crops because the ponds were refilled only one day after fish harvest without any major treatment except liming with small amount of hydrated lime.

However, surface DO quickly declined to levels below 2.0 mg/l in pond-1 and pond-3 within the first month, while in pond-2, surface dissolved oxygen was above 3.0 mg/l until the end of week 9 when it dropped to 1.04 mg/l at the end of week 10. Between 6 to 10 weeks before harvest, surface DO concentration in all ponds dropped to a very low level at 0.1 mg/l (Figure 10).

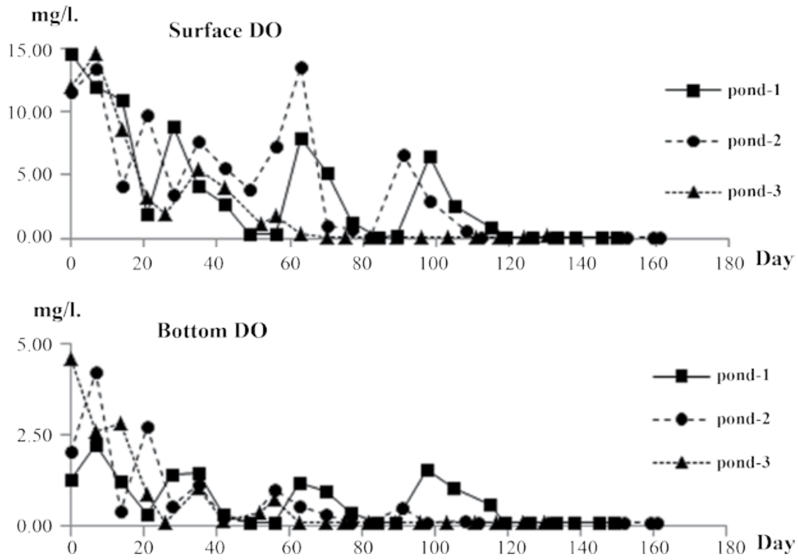

Figure 10. Dissolved oxygen in hybrid catfish ponds

Initial DO readings at pond bottom during 11:00 a.m. and 2:00 p.m. at stocking date were 1.28, 2.03, and 4.61 mg/l in pond-1, pond-2, and pond-3, respectively. From the end of week 2 to harvest date, DO concentrations at pond bottom fluctuated between 0.10 and 2.25 mg/l in pond-1, 0.10 and 4.23 mg/l in pond-2, and 0.10 and 2.61 mg/l in pond-3. DO at surface and bottom of the pond dropped and maintained at minimum level of 0.10 mg/l until harvest beginning at the end of week 6 for pond 1, at the end of week 9 for pond 2, and at the end of week 10 and 11 for pond 3 (Figure 10). These low concentration levels of midday DO in these hybrid catfish ponds indicated that these ponds were likely lacking in oxygen at some period during the night starting from 3 to 4 weeks after stocking and were in anoxic conditions during night time 6 to 10 weeks before harvest.

The only published data available concerning water quality in hybrid catfish culture pond was that of Ingthamjit *et al* (1992) who studied water quality in earthen ponds in commercial farms rearing hybrid catfish using partial water exchange system and using pelleted feed and minced chicken offal as fish feed. Comparing with the results of this study, better water quality in hybrid catfish ponds using partial water exchange system was observed. Water quality parameters fluctuated between the range of 678-1490 mg/l for TSS, 100-376 mg/l for POM, 218-1908 µg/l for chlorophyll *a* content, 0-0.41 mgP/l for soluble orthophosphate, 1.5-5.81 mg/l for total phosphorus, 0.11-17.10 mg/l for TAN and 7.06-7.87 for pH. Midday DO concentration in hybrid catfish ponds measured between 11:00-12:00 a.m. were between 4.8 and 30.8 mg/l, and Secchi disc visibility varied between 6.0 and 21.5 cm (Ingthamjit, *et al*, 1992)

High stocking rates and the use of minced chicken offal as the major feed (98.7-99.0%) together with minimal pond management practices were the likely major causes of poor water quality in hybrid catfish ponds in this study. Without water exchange, all unutilized feed and most of its metabolic products were deposited into the ponds causing deterioration of water quality. Without aeration, DO depleted very quickly resulting in the accumulation of TAN due to the inhibition of nitrification process. Without any pond treatment between crops except water draining and liming, with a small amount of lime and large amounts of organic matter and its metabolites likely remained in pond bottom soil causing poor water quality from the very beginning. No data are available concerning acute and chronic effects of these water quality parameters on hybrid catfish. However, mortality rates of hybrid catfish in this study were considerably high (41.6-55.3%) (Table 3). The European Inland Fisheries Advisory Commission (1973) stated that toxic concentration of ammonia to freshwater fish for short-term exposure are between 0.7 and 2.4 mg/l as NH_3.

Hybrid catfish performance

Despite very poor quality of pond water throughout the whole culture period, production of hybrid catfish in these ponds was still very high. Survival rate of fish was 46.6-59.4%. Average fish weight at harvest was 264.6-389.0 g and average daily weight gain was 1.7-2.7 g/fish/day. Total amount of fish harvested from pond-1, pond-2, and pond-3 were 8,352, 10,200 and 7,550 kg which is equivalent to a production per unit area of 13.9 kg/m^2 (22.3 t/rai or 139.2 t/ha), 15.3 kg/m (24,5 t/rai or 153.4 t/ha), and 18.4 kg/m (29.4 t/rai or 183.7 t/ha), respectively. Feed conversion ratios ranged from 3.7-4.2 (Table 3). Yi, *et al*. (2003) cultured 20.0± 0.1 g hybrid catfish in earthen ponds at a low stocking density of 25 fish/m^2 for 87 days using pelleted feed. Higher fish survival rate (96.3%) and lower FCR (1.25) were obtained but fish production was lower (5.7 kg/m^2). Average concentration of DO at dawn was 0.20±0.00 mg/l and average TAN concentration in pond water was 3.09±0.09 mg/l.

Although there was no concrete data to justify the effect of poor water quality on hybrid catfish, better survival rate and better growth performance could be obtained if pond water quality can be managed within acceptable ranges, especially DO and TAN concentrations which are the two key parameters that inhibit pond fish production.

Nitrogen and phosphorus budget

Average moisture, nitrogen, and phosphorus contents were 75.2±0.7, 11.1± 0.4, and 2.5±0.2% respectively for hybrid catfish, 75.1±0.5, 7.2±0.1, and 1.0±0.2% respectively for minced chicken offal, and 5.2±0.1, 4.1±0.1, and 1.7±0.2% respectively for pelleted feed (Table 4). Nitrogen and phosphorus budgets were prepared from the quantities of nitrogenand phosphorus input to and output from the ponds (Tables 5, 6). The absorption of phosphorus by pond bottom soil was calculated by subtracting the amounts in harvested fish and pond effluent (Sun and Boyd, 2013; Funge-Smith and Briggs, 1998). In this investigation,

Table 3. Growth performance of hybrid catfish reared in closed culture system in earthen ponds

Parameter	Pond-1	Pond-2	Pond-3	Mean±S.D.
Stocking	48,000	80,000	48,000	-
Density (fish/m^2)	80	120	117	105.7±22.3
Total no. of fish	48,000	80,000	48,000	-
Mean weight (g/fish)	1.5	3.0	1.5	-
Total weight (kg/pond)	72	240	144	-
Harvest				
Final weight (g/fish)	389.0+119.1	273.4+87.7	264.6+37.4	309.0±69.4
Total weight kg/pond)	8,352	10,200	7,550	-
Culture period	145	159	130	145±14
Mean weight gain (g/fish)	387.5	270.4	261.6	306.5±70.3
Daily weight gain (g/fish/d)	2.7	1.7	2.0	2.1±0.5
Production per unit area				
(kg/m^2/crop)	13.9	15.3	18.4	15.9±2.3
(t/rai/crop)	22.3	24.5	29.4	25.4±3.6
(t/ha/crop)	139.2	153.4	183.7	158.8±22.7
FCR	4.2	4.7	3.7	4.2±0.5
Survival rate (%)	44.7	46.6	59.4	50.2±8.0

Table 4. Nitrogen, phosphorus and moisture contents of hybrid catfish and fish feeds (%)

Variable	Moisture content	Nitrogen content	Phosphorus content
Hybrid catfish	75.2±0.7	11.1±0.4	2.5±0.2
Minced chicken offal (kg)	75.1±0.5	7.2±0.1	1.0±0.02
Pelleted feed (kg)	5.2±0.1	4.1±0.1	1.7±0.2

Table 5. Nitrogen budget for hybrid catfish ponds: input and output per unit area

Variable		Pond-1	Pond-2	Pond-3	Mean±S.D.
Input					
Fish fry	(kg/ha)	33.17	93.08	102.19	76.15±37.50
Influent water	(kg/ha)	203.40	75.20	204.00	160.87±74.19
Feed	(kg/ha)	10,537.67	12,840.91	12,269.34	11,882.64±1,119.33
Total input	(kg/ha)	10,744.24	13,009.19	12,575.53	12,119.65±1,185.16
Output					
Fish harvest	(kg/ha)	3,837.83	3,958.05	5,356.20	4,384.03±844.07
Pond effluent	(kg/ha)	4,376.50	4,328.27	4,232.36	4,312.38±73.37
Loss to atmosphere+ accumulation in pond bottom soil	(kg/ha)	2,559.91	4,722.87	2,896.97	3,423.25±1,145.58

Table 6. Phosphorus budget for hybrid catfish ponds: input and output per unit area

Variable		Pond-1	Pond-2	Pond-3	Mean±S.D.
Input					
Fish fry	(kg/ha)	7.33	21.65	20.44	16.47±7.94
Influent water	(kg/ha)	8.40	7.04	7.52	7.65±0.69
Feed	(kg/ha)	7,051.33	7,341.50	7,008.03	7,133.62±181.33
Total input	(kg/ha)	7,067.06	7,370.19	7,025.99	7,157.75±184.64
Output					
Fish harvest	(kg/ha)	903.33	888.12	1,120.68	970.71±130.10
Pond effluent	(kg/ha)	107.33	152.63	187.10	149.02±40.01
Absorbed by pond bottom soil	(kg/ha)	6,056.40	6,329.44	5,728.21	6,038.02±301.04

the loss of nitrogen to atmosphere through denitrification and ammonia volatilization and the accumulation of nitrogen in pond bottom soil were not measured.

According to the result of this study, major inputs of nitrogen and phosphorus came from feed. Applied feed accounted for 98.0±0.6% of nitrogen input and 99.7±0.1% of phosphorus input into the ponds. Other minor contributions were influent water (1.3±0.69% for nitrogen and 0.1±0.01% for phosphorus) and fish fry (0.7±0.06% for nitrogen and 0.23±0.11% for phosphorus) (Table 7).

Table 7. Nitrogen and phosphorus budgets (%)

Variable	Nitrogen				Phosphorus			
	Pond-1	**Pond-2**	**Pond-3**	**Mean±S.D.**	**Pond-1**	**Pond-2**	**Pond-3**	**Mean±S.D.**
Input								
Fish fry	0.3	0.7	0.8	0.6±0.3	0.1	0.3	0.3	0.2±0.1
Influent water	1.9	0.6	1.6	1.4±0.7	0.1	0.1	0.1	0.1±0.0
Feed	97.8	98.7	97.6	98.0±0.6	99.8	99.6	99.6	99.7±0.1
Total input	100	100	100	100	100	100	100	100
Output								
Fish harvest	35.6	30.4	42.6	36.2±6.1	12.8	12.0	15.9	13.6±2.1
Pond effluent	40.6	33.3	33.7	35.9±4.1	1.5	2.1	2.7	2.1±0.6
Total input	23.8*	36.3*	23.7*	27.9±7.2*	85.7**	85.9**	81.4**	84.3±2.5**
Incorporated from feed by hybrid catfish	36.1	30.1	42.8	36.3±6.4	12.7	11.8	15.7	13.4±2.0

*Estimated percentage of nitrogen lost to atmosphere + accumulated in pond bottom soil.
**Estimated percentage of phosphorus absorbed by pond bottom soil.

The sinks for nitrogen were harvested hybrid catfish (36.2±6.10%), pond effluent (35.8±4.14%) (Table 7). Part of the unaccounted 27.9±7.24 % of the nitrogen input was the sum of the amount of nitrogen lost to the atmosphere as N_2 or ammonia through denitrification and ammonia volatilization and the amount of nitrogen accumulated in pond bottom soil. According to Funge-Smith and Briggs (1998) nitrogen lost to the atmosphere as N_2 or ammonia from intensive shrimp ponds was 30% of total nitrogen input.

The sinks for phosphorus were harvested hybrid catfish (13.6±2.06%) and pond effluent (2.1±0.57%) (Table 7). Remaining part of the unaccounted 84.3± 2.53% of the phosphorus was absorbed by pond bottom soil. Phosphorus can be strongly absorbed by pond bottom sediment through various processes. Clay particle in soil can absorb phosphorus. In acidic soil phosphorus is bounded as aluminum phosphate and iron phosphate and in neutral and basic soils phosphorus is bound in calcium phosphate (Boyd, 2000 cited by Sun and Boyd, 2013). Funge-Smith and Briggs (1998) reported that 84% of input phosphorus in intensive shrimp ponds was removed by sediment.

Hybrid catfish incorporated 36.3 ±6.4% of nitrogen and 13.4+2.0% of phosphorus inputs from feed (Table 7). Recovery rates of nitrogen and phosphorus by marine shrimp were reported to be in the range of 20-40% for nitrogen and 10-15% for phosphorus (Briggs and Funge-Smith, 1994; Terchert-Coddington *et al*, 2000: Wahab *et al*, 2003; Paez-Ozuna *et al*., 1997; Boyd, *et al*., 2006). Yi, *et al*. (2003) reported that hybrid catfish raising in non-integrated and integrated pen-cum-pond system with tilapia incorporated 40.5-40.9% of nitrogen and 47.6-50.0% of phosphorus from pelleted feed.

CONCLUSION

Hybrid catfish is one of the most tolerant fish to poor pond environment. Intensive closed culture system without water exchange and without aeration was operated successfully in earthen ponds with minimum pond management both between crop periods and during grow out period. Despite the very poor pond water quality this culture system was able to achieve very high production of hybrid catfish (22.3-29.4 t/rai/crop; 139.2-183.7 t//ha/crop). FCR and survival rate of hybrid catfish were 3.7-4.2 and 44.7-59.4% and daily weight gain were 1.7-2.7 g/fish/day.

Dense phytoplankton biomass was observed in most of the culture period and chlorophyll *a* contents rose beyond 1,000 µg/l for several weeks. DO at surface and bottom of the ponds were at low concentrations in most culture periods and quickly decreased to minimum concentration of 0.1 mg/l and stay unchanged until several weeks before harvest. This indicated that these ponds periodically lacked oxygen especially at night time. Ammonia which is another key water quality parameter inhibiting pond fish production was detected in high concentrations since stocking date and increased rapidly to the highest concentration of 84.76-132.58 mg/l of TAN.

Major input of nitrogen and phosphorus budget in hybrid catfish ponds were the feeds (98.0±0.6% of nitrogen input and 99.7 ±0.1% of phosphorus input). Major sinks for nitrogen were harvested hybrid catfish (36.2±6.10%) and pond effluent (35.8± 4.14%). Major sinks for phosphorus were pond bottom soil absorption (84.3±2.53%), harvested hybrid catfish (13.6±2.06%), and pond effluent (2.1±0.57%). Hybrid catfish incorporated 36.3±6.4% of nitrogen and 13.4 ±2.0% of phosphorus inputs from feed.

No data is available on the effect of water quality on growth rate, survival rate, and feed conversion ratio of hybrid catfish. However, considering from available reported data of other fish and aquatic animal species there is a good chance to improve FCR and increase survival rate and growth rate of hybrid catfish cultured in this system by implementing pond management measures between crops and during grow out period, especially, pond cleaning and drying after harvest. Aeration is also a good measure but it has to be cost effective because market price of hybrid catfish is considerably low. This culture system is very useful for farming fish in areas that have limit water supply. In order to improve the efficiency of this culture system further investigation about the effect of water quality parameters on hybrid catfish is recommended.

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