RECYCLING WASTEWATER OF INTENSIVE HYBRID CATFISH CULTURE FOR SEMI-INTENSIVE NILE TILAPIA CULTURE

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Abstract

An experiment was conducted in fifteen 5-m^2 cement tanks for 90 days to determine the effects of water recirculation frequency on fish growth, water quality and nutrient recovery efficiency in an integrated recycling culture system, in which nutrient-rich water from hybrid catfish (*Clarias macrocepharus* x *C. gariepinus*) intensive culture tanks was recirculated to Nile tilapia (*Oreochromis niloticus*) semi-intensive culture tanks. There were three treatments: (A) catfish only without water recirculation; (B) water recirculation at 3-day interval; (C) water recirculation at 7-day interval.

Results showed that water recirculation did not affect catfish growth and yield. Mass mortality of tilapia was observed in two of the three replicates in 3-day interval treatment. Tilapia growth and yield in 7-day interval treatment was significantly higher than that in 3-day interval treatment. Tilapia recovered 2.53% N and 3.68% P, and 3.12% N and 4.47% P from catfish wastes in 3- and 7-day interval treatments, respectively.

The study demonstrated that tilapia can be cultured in an integrated recycling system to recover nutrients from catfish wastewater, and suggested that the ratio of catfish to tilapia can be lowered through either reducing catfish density or increasing tilapia culture area to allow tilapia reusing more nutrients contained in catfish wastewater.

Introduction

Hybrid catfish (*Clarias macrocepharus* x *C. gariepinus*) and Nile tilapia (*Oreochromis niloticus*) are the most popularly cultured freshwater fish in Thailand. Hybrid catfish are commonly cultured intensively in earthen ponds at extremely high density (30-100 fish/m^2) with production of 12.5-100 tons/ha (Areerat, 1987). Most common diets for hybrid catfish are trash fish, chicken offal or pelleted feed, which generally cause poor water quality and excessive phyto- and zooplankton blooms throughout most of the grow-out period (Lin and Diana, 1995). To maintain favorable water quality, the pond water with rich-nutrients and organic matter is periodically changed with new source water, causing pollution in receiving waters and becoming a serious environmental problem, especially in Northeast Thailand where surface waters are in short supply. On the other hand, Nile tilapia culture in Thailand is primarily semi-intensive based on natural foods derived from fertilizers or animal manure (Edwards, 1986, 1991).

The wastes from intensive hybrid catfish ponds can be reused as a nutrient resource in integrated aquaculture systems to generate natural foods for culture of filter feeding species such as Nile tilapia (Lin, 1990; Ye, 1991; Lin and Diana, 1995; Yi *et al*., 1996; Yi, 1997; Yi and Lin, 2001; Yi *et al*., 2003).

The study was conducted to determine the nutrient utilization efficiency at different water recirculation regimes in a hybrid catfish-Nile tilapia integrated recycling culture system.

Materials and methods

The experiment was conducted in fifteen concrete tanks (2.5 x 2 x 1.2 m) at the Asian Institute of Technology, Thailand, for 90 days. There were three treatments with 3 replications: (A) hybrid catfish alone and no water recirculation (control); (B) water recirculation between hybrid catfish tank and Nile tilapia tank once every three days (3-day interval); (C) water circulation between hybrid catfish tank and Nile tilapia tank once a week (7-day interval). The treatments were randomly assigned among the tanks.

Hybrid catfish fingerlings of 7.7-9.5 g in size were stocked at 27 fish/m^2, while sex-reversed male Nile tilapia fingerlings of 6.9-9.2 g in size were stocked at 3 fish/m^2 four days later. Hybrid catfish were fed with commercial floating pelleted feed (30% crude protein, Charoen Pokaphand Co. Ltd., Thailand) twice daily at 0830 h and 1530 h. Feeding rate (% body weight per day) was based on hybrid catfish size: 5% for smaller than 50 g size, 4% for 50-100 g size, and 3% for greater than 100 g size. Daily feed ration was adjusted based on biweekly sampling weight of hybrid catfish and daily observation of catfish mortality. Neither feed nor fertilizer was applied to Nile tilapia tanks. The growth of Nile tilapia was dependent solely on natural foods derived from hybrid catfish wastes.

Water depths in all tanks were maintained at 90 cm. Water was recirculated between hybrid catfish tank and Nile tilapia tank through pumping water from the deepest point of the hybrid catfish tank to the bottom in the far corner of the Nile tilapia tank and overflowing from the Nile tilapia tank to the hybrid catfish tank via a PVC pipe located at 20 cm below water surface. Tap water was added to all the tanks weekly to replace evaporation loss. Tanks were covered with nylon nets to prevent fish losses from jumping or bird predation.

Column water samples were taken biweekly from each tank between 0900-1000 h for analysis of total Kjeldahl nitrogen (TKN), total ammonia nitrogen (TAN), nitrite+nitrate-nitrogen, total alkalinity, total phosphorus (TP), and chlorophyll *a* (APHA *et al.*, 1981). Dissolved oxygen (DO), temperature and pH were measured in situ weekly at dawn.

Contents of moisture, total nitrogen and total phosphorus in pelleted feed, hybrid catfish and Nile tilapia at stocking and harvest were based on the data measured by Ye (1991). Moisture, total nitrogen and total phosphorus content were 10.5%, 5.16% and 1.23% for pelleted feed; 73.44%, 8.69% and 2.30% for hybrid catfish at stocking; 72.62%, 9.11% and 2.56% for hybrid catfish at harvest; 77.49%, 9.05% and 2.78% for Nile tilapia at stocking; and 78.18%, 9.71% and 2.96% for Nile tilapia at harvest, respectively.

Average fish weight was determined biweekly by bulk weighing 30% of both hybrid catfish and Nile tilapia sampled randomly from each tank. All fish were harvested after the 90-day culture period. Survival (%), daily weight gain (g/fish/day), food conversion ratio (FCR), yield (kg/m^2/crop) and extrapolated yield (t/ha/year) were calculated.

Data were analyzed statistically by *t*-test and one-way analysis of variance (Steele and Torrie, 1980) using SPSS (version 6.0) statistical software package (SPSS, Chicago, USA). Differences were considered significant at an alpha level of 0.05. All means were given with ±1 standard error (S.E.). In one replicate of the 3-day interval treatment, all Nile tilapia died in the 10th week, thus hybrid catfish were harvested to terminate the culture in the replicate. In another replicate of the same treatment, all Nile tilapia died in the morning of the last day. Thus, in this treatment, the growth parameters of hybrid catfish and water quality parameters in both hybrid catfish and Nile tilapia tanks were calculated based on two replicates, while the growth parameters of Nile tilapia were calculated based on only one replicate.

Results and discussion

DWG of hybrid catfish was highest in the 3-day interval treatment, intermediate in the 7-day interval treatment, and lowest in the control ($P < 0.05$, Table 1). However, there were no significant differences in final mean weight, survival, net and gross yields, and FCR of hybrid catfish among the three treatments ($P > 0.05$).

Nile tilapia grew steadily in the 7-day interval treatment throughout the experimental period, while the growth of Nile tilapia in the 3-day interval treatment slowed down during the last twenty days. Growth parameters in the 7-day interval treatment were significantly better than those in the 3-day interval treatment ($P < 0.05$, Table 1). All Nile tilapia died before harvest in two of three replicates in the 3-day interval treatment, however, the survival in the remaining third replicate was 100%. Survival rate in the 7-day interval treatment was about 91%.

Most water quality parameters measured in hybrid catfish tanks at the end of the experiment were not significantly different among treatments ($P > 0.05$, Table 2). TAN concentrations were significantly higher in hybrid catfish tanks of the 3-day interval treatment than in the control and the 7-day interval treatment ($P < 0.05$), while there were no significant differences among the latter two ($P > 0.05$). Concentrations of nitrite nitrogen, nitrate nitrogen and chlorophyll *a* in the control were significantly higher than those in hybrid catfish tanks of both water recirculation treatments ($P < 0.05$). Between Nile tilapia tanks, total alkalinity was significantly higher in the 3-day interval treatment than in the 7-day interval treatment ($P < 0.05$), while there were no significant differences in all other measured water quality parameters at the end of the experiment ($P > 0.05$, Table 2).

Table 1. Growth performance of hybrid catfish and Nile tilapia in the integrated recycling culture system over the 90-day culture period. Mean values with different superscript letters in the same row within each species (a and b for hybrid catfish, and x and y for Nile tilapia) were significantly different ($P<0.05$).

Performance	Hybrid catfish			Nile tilapia	
	Control	3-day interval	7-day interval	3-day interval	7-day interval
Initial					
Total weight (kg/tank)	1.15±0.07	1.15±0.01	1.14±0.02	0.12	0.12±0.01
Mean weight (g/fish)	8.5±0.5	8.5±0.0	8.41±0.1	8.3	8.2±0.7
Final					
Total weight (kg/tank)	13.1±0.38	14.5±0.16	14.3±0.41	0.79^{x}	$0.93±0.10^{y}$
Mean weight (g/fish)	101.5±2.7	113.6±2.0	107.1±2.1	52.5^{x}	$67.4±4.5^{y}$
Weight gain					
Total weight gain (kg/tank)	11.99±0.32	13.35±0.16	13.16±0.40	0.66^{x}	$0.81±0.11^{y}$
Mean weight gain (g/fish)	93.0±2.2	105.0±1.6	98.9±2.1	44.2^{x}	$59.2±4.7^{y}$
DWG (g/fish/day)	$1.03±0.02^{a}$	$1.17±0.02^{b}$	$1.10±0.02^{ab}$	0.49^{x}	$0.66±0.05^{y}$
Net yield (kg/m^2)	2.66±0.07	2.97±0.35	2.92±0.09	0.13^{x}	$0.16±0.02^{y}$
Gross yield (kg/m^2)	2.92±0.08	2.15±1.10	3.17±0.09	0.16^{x}	$0.19±0.02^{y}$
Extrapolated net yield (t/ha/yr)	97.2±2.6	108.3±15.4	106.6±3.2	5.4^{x}	$6.5±0.9^{y}$
Extrapolated gross yield (t/ha/yr)	106.5±3.1	117.6±15.4	115.6±3.3	6.4^{x}	$7.5±0.8^{y}$
Survival rate (%)	95.8±0.5	90.4±0.5	98.5±0.4	100.0	91.1±5.9
FCR	1.17±0.01	1.21±0.15	1.20±0.02	----	----

Pelleted feed was the dominant nutrient inputs in the integrated recycling culture system, which accounted for about 96% of both N and P inputs in all treatments. Hybrid catfish incorporated about 38% N and 45% P inputs from the feed in all treatments (Table 3). Nutrients released from hybrid catfish culture were 492.1, 552.7 and 548.9 g N, and Nile tilapia recovered 2.53% N and 3.68% P in the 3-day interval treatment, and 3.12% N and 4.47% P in the 7-day interval treatment from the nutrients contained in the hybrid catfish wastes (Table 3). Average loading of nutrients derived from hybrid catfish wastes fertilized tanks were 10.9, 12.3 and 12.2 kg N/ha/day, and 2.3, 2.6 and 2.6 kg P/ha/day in the control, 3- day interval treatment and 7-day interval treatment, respectively; giving a N:P ratio of about 4.7:1 during the experimental period. Based on the hybrid catfish production of 76,000 tons in 2000 (DOF, 2003), the hybrid catfish-Nile tilapia integrated recycling culture systems could reduce the nutrients released to the environment by 48-55 tons N and 18-20 tons P, compared to the common hybrid catfish monoculture practice (Table 4).

Table 2. Mean values of water quality parameters measured at the end of the 90-day experiment. Mean values with different superscript letters in the same row within each species tanks (a and b for hybrid catfish tanks, and x and y for Nile tilapia tanks) were significantly different ($P < 0.05$).

Parameters	Hybrid catfish tanks			Nile tilapia tanks	
	Control	3-day interval	7-day interval	3-day interval	7-day interval
DO at dawn (mg/L)	0.18±0.01	0.22±0.01	0.21±0.01	0.21±0.01	0.19±0.01
pH at dawn	6.95±0.04	7.03±0.01	6.92±0.03	6.96±0.08	6.90±0.13
Temperature (C)	31.4±0.0	31.6±0.2	31.5±0.1	31.3±0.1	31.4±0.1
Total alkalinity (mg/L as $CaCO_3$)	412±16	468±10	424±7	490±13[x]	416±6[y]
TAN (mg/L)	0.53±0.09[a]	3.44±0.02[b]	0.30±0.04[a]	0.60±0.01	0.60±0.02
Nitrite+Nitrate-N (mg/L)	0.23±0.02[a]	0.33±0.02[b]	0.32±0.02[b]	0.33±0.01	0.36±0.12
TKN (mg/L)	74.14±3.43	62.18±19.07	68.51±9.08	80.44±7.26	50.82±8.23
TP (mg/L)	15.01±1.13	12.37±1.65	11.43±0.17	12.44±0.28	9.75±0.92
Chlorophyll a (µg/L)	594±50[a]	330±25[b]	213±25[b]	361±59	224±37

Table 3. Nutrients (nitrogen and phosphorus) inputted from feed, incorporated by hybrid catfish, released to wastes, and recovered by Nile tilapia in the hybrid catfish-Nile tilapia integrated recycling culture system over the 90-day experimental period. Data in parentheses are percentages (%).

Nutrients	Total nitrogen (g)			Total phosphorus (g)		
	Control	3-day interval	7-day interval	Control	3-day interval	7-day interval
Inputs from feed	793.3 (100)	887.8 (100)	878.8 (100)	189.1 (100)	211.6 (100)	209.5 (100)
Incorporated by catfish	301.2 (37.97)	335.1 (37.74)	329.9 (37.54)	85.1 (45.00)	94.6 (44.71)	93.1 (44.44)
Released from catfish wastes	492.1 (62.03)	552.7 (62.26)	548.9 (62.46)	104.0 (55.00)	117.0 (55.29)	116.4 (55.56)
Recovered by tilapia from the wastes	----	14.0 (2.53)	17.1 (3.12)	----	4.3 (3.68)	5.2 (4.47)

Nile tilapia in the 3-day interval treatment recorded a mass mortality at the 10th week in one replicate and on the harvest day in another replicate. The mass mortality might be caused by sudden increases of TAN concentration (0.02 to 3.25 mg/L) coupled with the low DO, and probably by the prolonged exposure to the poor water quality. It was reported that unionized ammonia was more toxic when DO concentration was low (Merkens and Downing, 1957). Boyd (1990) observed that the ammonia concentration at 0.63 mg/L caused 95% reduction in catfish growth and no growth occurred at 1.17 mg/L. The toxic levels of ammonia for short-term exposure usually lie between 0.6 and 2.0 mg/L (The European Inland Fisheries Advisory Commission, 1973, cited by Boyd, 1988). However, Nile tilapia in the 7-day interval treatment had high average survival rate (91%) due to less water recirculation frequency compared to the 3-day interval treatment. The average extrapolated net and gross yields of Nile tilapia in the 7-day interval treatment were 6.5 and 7.5 tons/ha/year, respectively, which are similar to those achieved in the conventional integrated fish-livestock system (AIT, 1986), the systems optimally fertilized with chicken manure (Diana *et al*., 1988) or chemical fertilizers (Diana *et al*., 1991), and the integrated cage-cum-

Table 4. Comparisons of extrapolated nutrients inputted from feed, incorporated by hybrid catfish, recovered by Nile tilapia, and released to the environment between hybrid catfish monoculture (control) and the hybrid catfish-Nile tilapia integrated recycling culture systems, based on the estimated hybrid catfish production of 76,000 tons in 2000 (DOF, 2003).

Nutrients	Total nitrogen (tons)			Total phosphorus (tons)		
	Control	3-day interval	7-day interval	Control	3-day interval	7-day interval
Input from feed	5,028	5,054	5,075	1,198	1,204	1,210
Incorporated by catfish	1,909	1,908	1,905	538	538	538
Recovered by tilapia	----	82	99	----	26	30
Total incorporated by fish	1,909	1,990	2,004	538	564	568
Released to the environments	3,119	3,064	3,071	660	640	642
Reduction of released nutrients	----	55	48	----	20	18

pond systems (Lin, 1990; Ye, 1991; Lin and Diana,1995; Yi *et al*., 1996; Yi, 1997; Yi and Lin, 2001), but lower than those achieved in the integrated pen-cum-pond systems (Yi *et al*., 2003). The fertilization rates by hybrid catfish wastes were much higher in the present experiment than those reported by the above authors, due to the high hybrid catfish to Nile tilapia ratio (9:1). Ye (1991) and Yi *et al*. (2003) reported that the optimal hybrid catfish to Nile tilapia ratio was 2.5:1 and 6.3:1 in the cage-cum-pond and pen-cum-pond integrated systems, respectively. The high loading of hybrid catfish wastes caused depletion of water quality after the midway of the culture period, and did not result in higher yields of Nile tilapia, compared to those with lower loading rates reported by the above authors.

Nutrients released from the hybrid catfish culture component were about 62% N and 55% P in the present experiment, which were less than the values reported by Boyd (1985) in channel catfish culture and by Ye (1991) in a catfish-tilapia cage-cum-pond integrated culture, which were 73.2% N and 69.9% P, 65-70% N and 56-63% P, respectively. The released phosphorus in the present experiment were also less than those (79-84%) calculated by Beveridge (1984) for total P released into the environment from intensive cage culture of trout. The released nitrogen from producing 1 kg of live catfish in the present experiment was about 41 g, which was less than 48-73 g N reported by Ye (1991) and 51 g N reported by Boyd (1985).

In the present experiment, nutrient recovery by Nile tilapia were quite low (2.53%-3.12% N, and 3.68%-4.47% P) compared with those (4-13% N and 5-17% P) reported by Ye (1991) and Lin and Diana (1995). The main reasons for the low nutrient recovery were the high hybrid catfish to Nile tilapia ratio (9:1), which resulted in high waste loading and, in turn, might have affected Nile tilapia growth, adversely. Nile tilapia and hybrid catfish are the most commonly culture freshwater species in Thailand, with similar annual production

(82,363 and 76,000 tons, respectively, in year 2000) (DOF, 2003). If these two species could be cultured in the integrated systems with appropriate stocking ratio, nutrients released to the environments could be reduced while production cost also largely reduced as no additional inputs of feed and fertilizers is required for Nile tilapia culture.

The present experiment demonstrated that Nile tilapia can be cultured in an integrated recycling system to recover nutrients from wastewater, and suggested that the ratio of hybrid catfish to Nile tilapia can be lowered through either reducing the stocking density of hybrid catfish or increasing culture area for Nile tilapia in order to allow Nile tilapia to reuse more nutrients contained in hybrid catfish wastewater. The integrated recycling system is technically feasible, environmentally friendly and economically profitable.

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