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Co-culture of catfish (*Clarias macrocephalus* × *C. gariepinus*) and tilapia (*Oreochromis niloticus*) in ponds

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Abstract

The experiment was conducted for 122 days in central Thailand to test rearing of hybrid catfish in cages in earthen ponds, where tipalia (*Oreochromis niloticus*) was stocked to utilize the waste products derived from intensively reared catfish. Catfish fingerlings (13-17 g size) was stocked in plastic net cages at a density of 275 fish/m^3. Six earthen ponds (250 m^2-110 m^3 each) were used to suspend the cages in two loading densities as experimental treatments: 880 and 1 760 catfish/pond. Each loading density was replicated in 3 ponds. Each pond was stocked with 440 sex-reversed male tilapia of 6-7 g size in open water, giving the catfish and tilapia stocking ratios of 2:1 and 4:1, respectively. Catfish was fed twice daily at 3-10% body weight per day with commercial floating pellets containing 25-30% crude protein. Water quality was analyzed bi-weekly for concentration of dissolved oxygen, ammonia and chlorphyll *a*.

Results showed that there was no significant difference ($p<0.05$) in catfish growth rate and survival between the two loading densities. The mean weight gain of harvested catfish was 259.5 ± 34.5 g and 255.2 ± 8.4 g/fish, giving the total net yield of 218.0 ± 26.8 kg and 391.5 ± 88.0 kg per pond in low and high loading density, respectively. Tilapia was harvested with mean weight of 172.3 ± 37.8 g and 297.5 ± 32.0 g/fish, and the net yield of 68.1 ± 13.6 and 86.0 ± 27.2 kg/pond for low and high loading catfish density treatment, respectively. Chlorophyll *a* and total ammonia concentrations differed greatly between the two treatments. Early morning dissolved oxygen (DO) declined steadily both treatments over the culture period.

Keywords: Hybrid *Clarias*, tilapia, integrated culture.

Culture associée de l'hybride Clarias macrocephalus × C. gariepinus *et du tilapia* Oreochromis niloticus.

Résumé

L'expérience a été conduite pendant 122 jours en Thaïlande pour étudier l'élevage de poissons-chats hybrides en cages, en bassins en terre, où des tilapias *Oreochromis* étaient stockés afin d'utiliser les déchets dérivés de l'élevage intensif des poissons-chats. Les juvéniles de poissons-chats (13 à 17 g) étaient stockés en cage plastique à une densité de 275 individus par m^3. Six bassins en terre (250 m^2-220 m^3) ont été utilisés, où sont placées les cages à 2 densités expérimentales d'élevage: 880 et 1 760 poissons-chats par bassin. Chaque densité d'élevage a été répliquée dans 3 bassins. Dans chaque bassin ont été stockés 440 tilapias mâles de 6-7 g en circuit ouvert, c'est-à-dire un stockage en poissons-chats et en tilapias de 2 : 1 et 4 : 1 respectivement. Les poissons-chats ont été nourris deux fois par jour à raison de 3-10 % de poids vif par jour, avec des granulés contenant 25 à 30 % de protéines. La qualité de l'eau a été analysée toutes les 2 semaines pour la concentration en oxygène dissous, en ammoniaque et en chlorophylle *a*. Les résultats ne montrent pas de différence significative pour les taux de croissance et la survie entre les 2 densités de mise en charge de poissons-chats. Le gain de poids moyen de poissons-chats est de 259,5 ± 34,5 g et 255,2 ± 8,4 g/poisson, donnant un rendement net de 218,0 ± 26,8 kg et 391,5 ± 88,0 kg par bassin, respectivement pour la faible et pour la haute densité d'élevage. Les tilapias ont un poids moyen de 172,3 ± 37,8 g et 297,5 ± 32,0 g/poisson et le rendement net est de 68,1 ± 13,6 et 86,0 ± 27,2 kg/bassin pour la faible et la haute densité d'élevage de poisson-chats. Les concentrations en chlorophylle *a* et en ammoniaque diffèrent de façon importante entre les 2 expériences. Le matin, l'oxygène dissous diminue de façon significative dans les 2 expériences d'élevage.

Mots-clés : Hybride de *Clarias*, tilapia, culture intégrée.

INTRODUCTION

Walking catfish (*Clarias macrocephalus* × *C. gariepinus*) and Nile tilapia (*Oreochromis niloticus*) are commonly cultured freshwater fish in Thailand with an annual production of 29,000 and 28,000 tonnes, respectively (DOF, 1993). While the major production system for tilapia is semi-intensive with inorganic or organic fertilizer inputs, the catfish is monospecific intensive culture of hybrid (*Clarias macrocephalus* × *C. gariepinus*) in earthen ponds. Traditionally, the catfish are cultured intensively at extremely high density (30-60 fish/m^2) with production of 12.5-100 tonnes/ha/crop (3-5 months). Most common diets for catfish are chicken offal, trash fish or pelleted feed. Wastes as uneaten feed and metabolic products from intensive catfish rearing ponds often result in excessive phyto- and zooplankton blooms. To maintain favorable water quality, the pond water with rich nutrients and organic matter is periodically exchanged with new source water, causing pollution in natural waters. Meanwhile, pond culture of tilapia in Thailand is primarily semi-intensive based on fertilizer or on integrated systems with live stocks (Edwards, 1986, 1991). The fish-livestock integrated system for fish production has been practiced widely for centuries (Pillay, 1990).

The waste effluents from intensive fish culture have been a major concern as a source of pollutants to natural waters and various mitigative measures have been considered (Cowey and Cho, 1991; Pillay, 1992). Those wastes can be reused as a valuable resource in a integrated aquaculture system to generate natural food for culture of filter feeder species, e.g., tilapia (Lin *et al.*, 1989, 1993).

The present experiment is to determine the productivity and practical stocking ratio of catfish and tilapia to be co-cultured in ponds.

MATERIALS AND METHODS

Experimental design

The experiment was conducted at a Royal Thai Department of Fisheries station located at 14°11'N and 100°30'W in the tropical lowland of central Thailand during May-September 1991. The experimental treatments (A and B) were based on 2:1 and 4:1 of catfish and tilapia stocking ratios, giving 880 or 1 760 catfish with 440 tilapia in each pond. Each stocking combination was replicated in three ponds, which were randomly assigned to a block of 6 ponds. The 6 earthen ponds were 250 m^2 with 220 m^3 water per pond. Hybrid *Clarias* (*C. macrocephalus* × *C. gariepinus*) of 13-17 g size were stocked in cage of 4 m^3 (2 m × 2 m × 1 m) at a density of 220 fish/m^2, which equaled to 275 fish/m^3 as each cage was submerged only 0.8 m in 1-m deep ponds. The cages were made of metal frame and rigid PVC nets with 0.5-cm meshes. To maximize the water exchange those cages were suspended 0.2 m above the pond bottom near the center of each pond. Cages were brushed monthly to remove attached algal growth. Tilapia fingerlings with average weight of 6-7 g were stocked at a density of 2 fish/m^3 in the open ponds, or 220 fish/pond. To prevent reproduction problem, tilapia were sex-reversed with methyl-testosterone.

Feed and feeding

Catfish were fed in two equal rations daily at 0800 and 1700 hr with floating commercial pellets (CP Feed Mill Co.) at the following rates (% body weight/day): 10%, 8%, 5% and 3% for fish of 5-20 g, 20-50 g, 50-100 g and >100 g, respectively. The juvenile fish (<50 g) were fed with smaller size pellets (3 mm diam.) with 30% crude protein and adult fish (>50 g) 5-mm pellets with 25% protein. Both sizes of pellet contain approximately 12% moisture, 4% fat, 8% ash and 1.2% phosphorus. Pellets were kept in cages by shrouding the upper perimeter of each cage with 10-cm wide fine-meshed mosquito netting. As catfish in cages became easy prey and frightened by predatory birds, the cages were covered with 1-cm mesh net, which was sufficiently large to allow feed input.

Measurement of fish growth

Fish growth was determined monthly by sampling 5% of fish population from each cage and pond, and their individual body weight was determined with a field weighing scale to 0.1 g accuracy. Catfish were sampled from cages with a dip net and tilapia were seined from the entire pond. At the end of 4-month experimental period, ponds were drained and all fish in each pond were collected, counted and weighed in batches as well as individually weighing 5% of fish samples. The fish growth performance was expressed in the following parameters:

Net fish yield (NFY) = total final weight-total initial weight;

Mean weight gain = mean final weight-mean initial weight;

Daily weight gain = mean weight gain/number of culture days;

Feed conversion ratio (FCR) = feed consumed/NFY;

Survival (%) = (no. fish stocked-no. harvested)/no. fish stocked × 100.

Analysis of water quality

Pond water depth was maintained at 1 m, which was recorded weekly and water loss through seepage and evaporation was refilled weekly. Water samples for quality analysis were taken from a platform at the center part of each pond with a 1.5-m long PVC tube column sampler for integrated full depth samples. Concentrations of dissolved oxygen (DO) and water temperature were measured *in situ* bi- weekly with a portable meter (YSI Model 57) at 25 cm below the surface at 0600 (dawn) and 1500 hr, approximately representing low and peak level during a diel cycle. Phytoplankton production was measured bi-weekly as chlorophyll *a*, which was extracted with 90% acetone from samples concentrated with GF/C filters and determined spectrophotometrically following the Standard Methods (APHA *et al.*, 1989). Total ammonia concentration was also analyzed bi-weekly by phenate method (APHA *et al.*, 1989).

Data were analyzed for treatment difference using *t*-test ($p<0.05$).

RESULTS

Water quality. Pond water temperature measured in the mid-morning ranged from 30 to 32°C and pH 7 to 9 (one exceptional low value of 6.2) for both treatments throughout the experimental period (*fig.* 1). The dissolved oxygen, DO, concentration for both treatments measured in early morning decreased steadily from initial level of 3-5 to less than 1 mg/l

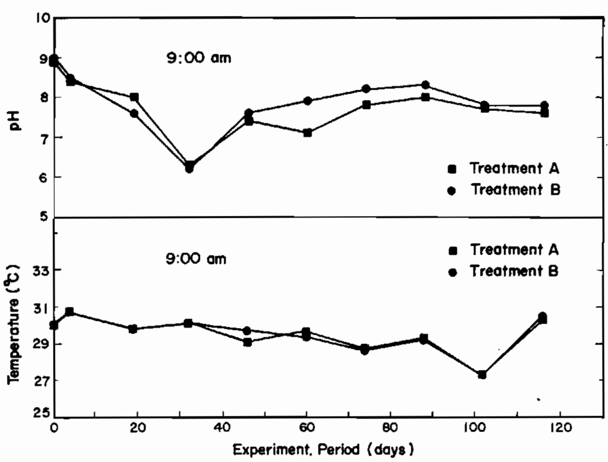

Figure 1. – Water temperature and pH recorded weekly throughout the experimental period.

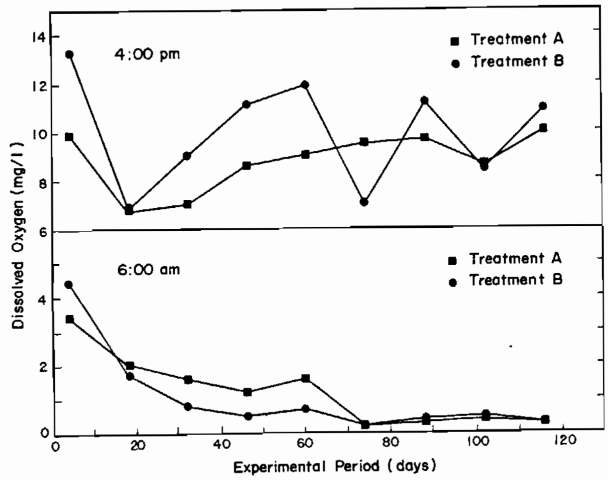

Figure 2. – Comparison of bi-weekly mean dissolved oxygen concentration in pond water between 2:1 (treatment A) and 4:1 (treatment B) catfish: tilapia stocking ratios, measured during early morning and mid-afternoon throughout the experimental period.

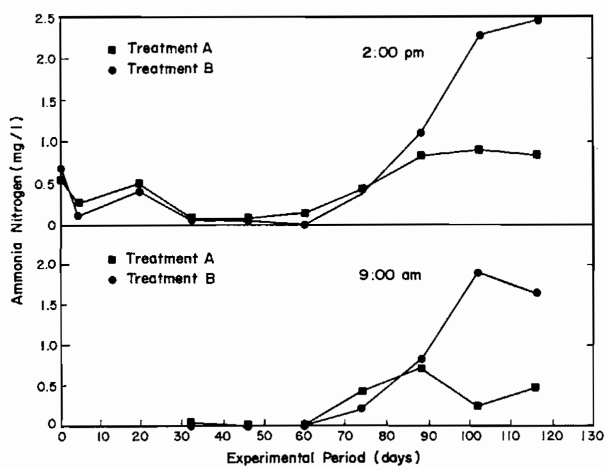

Figure 3. – Comparison of bi-weekly mean total ammonia concentration of pond water between low and high stocking ratios during mid-morning and mid-afternoon throughout the experimental period.

after halfway through the culture period. In contrast, the DO level in mid-afternoon was persistently supersaturated, with greater fluctuation in treatment of higher catfish stocking density (*fig.* 2). With almost a pattern reverse to that of early morning DO, the total NH_3-N concentration was low (<0.5 mg/l) during the first half of the culture period and increased steadily thereafter, and its concentration was markedly higher in ponds of greater catfish density (*fig.* 3). In response to treatment, the phytoplankton production as expressed in chlorophyll *a* concentration increased dramatically in high catfish density ponds, while it was relatively stable in ponds with low stocking density (*fig.* 4).

Fish growth performance, including caged catfish and open-pond tilapia is summarized in *table* 1.

Table 1. – Summary of growth performance of Nile tilapia and walking catfish over a 4-month grow-out period at Ayuthaya Fisheries Station (10 May-9 September 1991).*

Descriptors	*Catfish in cages*		*Tilapia in ponds*	
	A	B	A	B
Water volume (m^3)	3.2	3.2	220	220
Cage no./pond	1	2		
Initial stocking	275	275	2	2
Density (fish/m^3)	880	1 760	440	440
Total no. of fish	12.6 ± 0.9	26.4 ± 3.7	3.1 ± 0.1	3.0 ± 0.3
Total wt. (kg)	14.3 ± 1.0	15.0 ± 2.1	7.0 ± 0.1	6.7 ± 0.7
Mean wt. (kg)				
Harvest				
Total no. of fish	843 ± 30	1 539 ± 288	398 ± 17	307 ± 117
Total wt. (kg)	230.6 ± 27.4	417.8 ± 91.3	71.1 ± 13.7	88.9 ± 27.5
Mean wt. (kg)	273.8 ± 35.4	270.2 ± 10.1	179.2 ± 37.9 ^{a}	297.2 ± 32.0 ^{b}
Weight gain				
Net yield (kg/pond)	218.0 ± 26.8 ^{a}	391.5 ± 88.0 ^{b}	68.1 ± 13.6	86.0 ± 27.2
Mean wt. gain (g/fish)	259.5 ± 34.5	255.2 ± 8.43	172.3 ± 37.8 ^{a}	297.5 ± 32.0 ^{b}
Daily wt. gain (g/fish/day)	2.18 ± 0.29	2.14 ± 0.07	1.41 ± 0.31 ^{a}	2.38 ± 0.27 ^{b}
Survival (%)	95.8 ± 3.4	87.5 ± 16.3	90.5 ± 3.8	69.8 ± 26.6
Total feed input (kg)	417.8 ± 2.7	857.7 ± 83.5	–	–
Feed conversion ratio (FCR)	1.94 ± 0.30	2.24 ± 0.37	–	–

* Mean values with different alphabets in the same row were significantly different ($p < 0.05$).

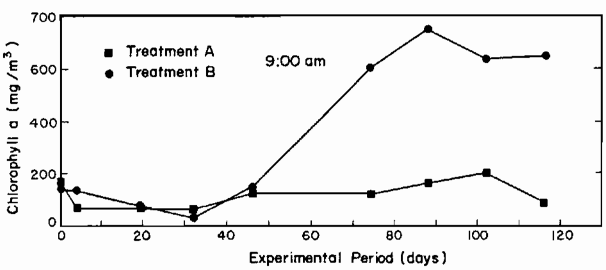

Figure 4. – Comparison of bi-weekly mean chlorophyll *a* concentration in pond water between low and high stocking ratios throughout the experimental period.

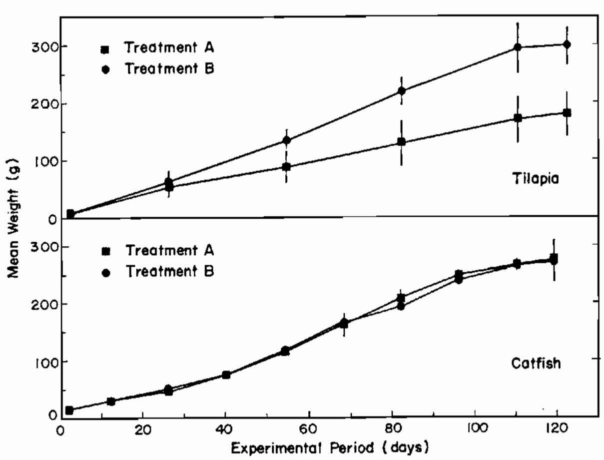

Figure 5. – Growth curve of catfish and tilapia under low and high stocking density treatments, each data point represents mean weight and standard deviation (vertical line).

While the catfish growth showed little difference throughout the culture period, the difference in tilapia growth between the two treatments increased markedly over time (*fig.* 5). The two catfish:tipalia stocking ratios did not significantly ($p<0.05$) affect catfish growth with a mean weight gain of 2.18 ± 0.29 g and 2.14 ± 0.07 g/day, giving NFY of 130-144 kg/m^3. But those two treatments in stocking ratio affected tilapia growth significantly ($p<0.05$) with mean weight gain of 1.41 ± 0.31 g and 2.38 ± 0.27 g/fish/day, and mean size of 172.3 ± 37.8 g and 297.5 ± 32.0 g/fish, respectively. The survival rate in treatment of higher stocking ratio was 69.8%, compared to 90.5% in the lower ratio. We observed that most mortality in former treatment occurred during the last two weeks of the experiment.

DISCUSSION

One of the most unique features of clarid catfish is their airbreathing ability, which enable them to live in extremely high population density and give great yields in various culture systems. The present cage culture experiment produced 71 kg/m^3 in 4 months, equivalent to approximately 30 m^2 of the traditional pond culture in Thailand, *i.e.*, 80 tonnes/ha/yr of *C. batracus* (Panayotou *et al.*, 1982). Still a greater yield of *C. gariepinus* at 400 kg/m^3/61 days has been achieved in recirculated flow-through tank culture in the Netherlands (Huisman and Richter, 1987). In the present cage culture experiment, there was no significant difference ($p>0.05$) in catfish growth between the two densities, which was perhaps due to their air-breathing ability to survive in low DO environment. However, the intensive pond culture of clarid catfish in Thailand often suffered from high mortality, which was suspected as a result of poor water quality, *i.e.*, high ammonia concentration. The tilapia production in open ponds was remarkably greater in the treatment of higher catfish:tilapia ratio. This was undoubtedly resulted from a greater amount of food material, *i.e.*, phytoplankton, generated from catfish wastes. However, the higher catfish stocking density resulted in lower tilapia survival, which was probably caused by deterioration of water quality due to excessive amount of wastes, particularly the relatively high NH_3-N (>2 mg/l) and extremely low morning DO (<0.5 mg/l) during the latter part of experiment.

Like many other intensive fish culture, catfish culture requires artificial feed input, most of which eventually enter surrounding water as uneaten feed and metabolic wastes. In recirculated clear water culture system those wastes could be removed by a sophisticated treatment process (Bovendeur *et al.*, 1987). In outdoor pond culture, those wastes containing high nutrient load stimulate phytoplankton growth, making pond water highly eutrophic. The waste material from caged catfish in the present experiment contained 14.9 and 30.9 kg N, and 5.6 and 11.6 kg P in low and high stocking density treatment, respectively. Those nutrient outputs fertilized the ponds at a rate of 2.48 kg N and 0.94 kg P $ha^{-1}.d^{-1}$ in low density pond, and 5.14 kg N and 1.94 kg P/ha/day in high density ponds. Both treatments gave a N:P ratio of 2.6:1. In terms of optimal rate of pond fertilization, those wastes provided nutrients in a range similar to that recommended for semi-intensive pond culture of tilapia in the tropics (Knut-Hansen *et al.*, 1991). The resultant tilapia production in the present experiment was equivalent to 4260 and 5334 $kg/ha^{-1}.yr^{-1}$, which was comparable to ponds fertilize with conventional chicken manure (Green, 1992) or chemical fertilizers (Diana *et al.*, 1991).

This catfish-tilapia integrated culture system is particularly appropriate for small-scale farmers in Thailand, where catfish fetches higher market value than tilapia does. Catfish reared in cages are easy and convenient for harvesting without needing to drain the ponds.

Tipalia production is basically free of charge because it requires no additional feed nor fertilizer input. The experiment demonstrated that the practicality of integrated fish/fish production system based on intensive culture of catfish in cages and semi-intensive tilapia in surrounding open pond. This approach is not only to augment the total aquaculture production, but also environmental friendly.

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