BANGLADESH RESEARCH PUBLICATIONS JOURNAL
ISSN: 1998-2003, Volume: 4, Issue: 1, Page: 15-23, May-June, 2010

A PRELIMINARY INVESTIGATION INTO THE PRODUCTION OF THAI KOI (*Anabas testudineus*) REARED IN NYLON HAPAS IN BANGLADESH

Mahmudul Hasan[1*], A. K. Shakur Ahammad[2] and Md. Mukhlesur Rahman Khan[3]

Mahmudul Hasan, A. K. Shakur Ahammad and Md. Mukhlesur Rahman Khan. (2010). A Preliminary Investigation into the Production of Thai Koi (*Anabas testudineus*) Reared in Nylon Hapas in Bangladesh. Bangladesh Res. Pub. J. 4(1): 15-23. Retrieve from http://www.bdresearchpublications.com/admin/journal/upload/09145/09145.pdf

Abstract

Feeding experiment was conducted for 90 days to elucidate the effect of three supplemental feeds on the growth, survival and production of 15 days old Thai koi (*Anabas testudineus*) fry in nylon hapa. Here, Suny, Mixed (prepared) and Saudi-Bangla fish feed were considered T_1, T_2 and T_3 respectively. Seventy fries (average length 3.63 ± 0.015 cm and weight 0.90 ± 0.18 g) were cultured under three treatments each having three replications. The net weight gain of fish in T_3 (37.20 ± 0.17g) and T_2 (36.80 ± 0.25 g) were significantly higher (p<0.05) than that of T_1 (32.60 ± 0.28g). Average food conversion ratios (FCR) were 3.99 ± 0.15, 3.11± 0.06 and 3.31 ± 0.02 in T_1, T_2 and T_3 respectively. The survival rates of fish were 73, 76 and 83% in T_1, T_2 and T_3 respectively. It was observed that growth of fry varied significantly (p<0.05) with different feeds. The best growth was found from the prepared and Saudi-Bangla fish feed while the poorest growth was found from the Suny feed. There was no significant difference in survival rates. Economic analysis reported that Mixed feed provided maximum profit compared with other feeds. The present study revealed that prepared feed might be used for mass production of Thai koi in hapa in Bangladesh.

Key words: *Anabas*, hapa, Supplemental feed

Introduction

The present rate of increase of fish production in Bangladesh is lesser than that of population boom. So, it is strongly felt that all sorts of efforts need to be employed to increase the fish production in all available inland water bodies to fulfill the protein demand of the people. Among the live fish (Jeoul), Thai koi can play a significant role to meet the protein requirement of these mushrooming populations. *A. testudineus* is an important climbing perch in Bangladesh (Hasan *et al.*, 2007). On the contrary, it is also becoming a highly demanded fish day by day due to its high nutrition, taste, faster growth and having ability to withstand harsh environmental condition (Alam *et al.*, 2006). In 2002, it was introduced into Bangladesh from Thailand. The high growth rate and bigger size of Thai koi pursue the fish farmers enthusiastic for its artificial breeding and culture in Bangladesh.

***Corrosponding Author**

[1] Mahmudul Hasan, PhD Fellow, Institute for Amphibian Biology, Graduate School of Science, Hiroshima University, Japan

[2] A. K. S. Ahammad, Lecturer, Department of Fisheries Biology and Genetics, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.

[3] Md. Mukhlesur Rahman Khan, Professor, Department of Fisheries Biology and Genetics, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.

Marginal farmers are very much interested to culture it due to its higher growth rate and better return compared to other species.

But, it is true that the vast water bodies have yet not been properly utilized for fish culture due to lack of adequate knowledge and proper technology. Therefore, culture system development is one of the most important factors in Bangladesh to increase the fish production. Among the various culture systems, hapa-cum-pond fish culture is more suitable at present context of Bangladesh. This is a system in which high-valued fish species are fed with artificial diets. However, comparatively it is a new method of aquaculture, which has gained much popularity throughout the world due to a number of advantages over the conventional method of fish farming. By integrating the cage culture system into the aquatic ecosystem the carrying capacity per unit area is optimized because the free flow of current brings in freshwater and removes the metabolic wastes, excess feed and fecal matter (Beveridge, 1983). Rural pond aquaculture in Bangladesh is mainly the semi-intensive carp polyculture of both Indian major and Chinese carps with low production (for example, 2.8 t/ha. DoF, 2001). Pond production systems in many countries are becoming increasingly reliant on external resources (feed and/or fertilizer) to supplement or autochthonous food production for fish. Such a system often discourages small-scale poor farmers because of low on investment. On the other hand, such poor farmers have limited financial resources to turn their whole ponds to culture high-valued species using expensive artificial feeds. However, the hapa-cum-pond fish culture system may provide an opportunity for small-scale farmers to use their limited resources, to include small amount of high-valued species in their ponds, to generate more income and improve their livelihood. This is achieved through improved nutrient utilization efficiency, marketing high-valued species and saving fertilizer cost, because fish in open pond can efficiently utilize hapa wastes and almost no fertilization required. Also this hapa-cum-pond system is eco-friendly due to less waste nutrients released to the environment.

In addition, experience with fish culture in hapa indicates that the device has the versatility for use in solving most of the problems encountered in farming fish in Bangladesh. For example, the problem commonly faced in pond culture in Bangladesh is multiple ownerships of ponds. This can be easily solved by farming fish in the above described hapa structure, kept confined to one's own area of the pond demarcated by mutual arrangement with co-shares.

Hapa-cum-pond culture system has been developed and practiced using combinations of catfish-tilapia in Tilapia (Lin 1990, Lin and Diana, 1995) and tilapia-tilapia (Yi *et al.*, 1996; Yi 1997; Yi and Lin, 2000 & 2001) at AIT, Thailand. Yi (1997) reported that the nutrient utilization efficiency could reach more than 50% in hapa-cum-pond system, resulting in the release of much less nutrients to the surrounding environment. In view of the above, the present study was undertaken to establish Thai koi production in hapa-cum-pond systems and to determine appropriate technology of climbing perch (*A. testudineus*) in Bangladesh.

Materials and Methods

Location and duration of the study

To find out the performance of Thai koi (*A. testudineus*) in hapa, the experiment was carried out in Fisheries Faculty Field Complex, Faculty of Fisheries, Bangladesh Agriculture University, Mymensingh-2202. Fifteen days old fry were released into the hapa for 90 days culture.

Description of the research hapa

All the hapas were situated in the same big pond. The hapa were rain-fed and of rectangle shape with an area of 2.23 m^2 each. The hapa were newly constructed before the start of the experiment. There was inlet or outlet facilities in the ponds in which hapa were set up.

Design of experiment

The experiment was carried out for a period of 90 days from 21st April to 19th July, 2006 with three treatments each having three replications. Hapas were randomly selected for three sets of trials. For convenience, the hapas were arbitrarily numbered was 1 to 9. The hapas were divided into three treatments each having three replications. The treatments were; T_1 where Suny feed was given, T_2 where Mixed (prepared) feed was given and T_3 where Saudi Bangla feed was given.

Hapa preparation

Nine hapas each measuring 1.52m × 1.21m × 1.21m were constructed for this experiment. The hapas were rectangular of synthetic netting of mesh size 5.0 mm closed from all sides except the top. The synthetic net were fitted with bamboo by using rope and metallic wire. The trough shaped enclosures of synthetic netting materials were fixed on the inner side of the frame. The hapas were kept afloat in such a way that 0.61m of structure remains below in water and the remaining 0.61 m were kept above water, so that fishes can get free access of sunlight and air.

Sources of fry

Fry of *A. testudineus* was collected from "Brahmaputra Fish Seed Complex", Shambhuganj, Mymensingh. Details of source, number of specimen and date of collection are shown in Table 1.

Table 1. Layout of the experiment for hapa

Treatment	Replication	Stocking density/treatment	Feed type	Feeding frequency (Twice a day)
T_1	R1	70	Suny feed	Morning (9.00am) & Afternoon (5.00 pm)
	R2	70		
	R3	70		
T_2	R1	70	Mixed feed	Morning (9.00am) & Afternoon (5.00 pm)
	R2	70		
	R3	70		
T_3	R1	70	Saudi-Bangla feed	Morning (9.00am) & Afternoon (5.00 pm)
	R2	70		
	R3	70		

Stocking of fry

Fry were kept in cistern for about 10 hours for conditioning prior to releasing in pond. Seventy fries were stocked in each hapa after proper conditioning at afternoon.

Rearing of fry

The stocked fry were reared separately for 90 days. As we know this fish species is omnivorous and required high amount of protein, three supplemental feeds i.e. Suny feed (trade name), Mixed (prepared) and Saudi-Bangla feed (trade name) containing 24%, 28.45% and 35% protein were applied for the culture of fish respectively.

Analysis of proximate composition of the feed ingredients

Proximate composition of the feed ingredients were determined following the standard methods given by Association of Official Analytical Chemists (AOAC, 1980) in the Nutrition Laboratory of the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh. Proximate composition of the different feed ingredients is shown in Table 2.

Table 2. Proximate composition of the feed ingredient

Components	Suny feed	Mixed feed	Saudi-Bangla feed
Protein	24%	28.45%	35%
Fat	4.5%	11.15%	5%
Ash	18%	15.15%	16%
Crude protein	6%	5.48%	6.5%
Moisture	11%	13.42%	12%

*NFE=Nitrogen free extract calculated as 100 - % (moisture + protein + lipid + ash)

Method of feed preparation

The required quantities of all ingredients mixed with hand (prepared feed) and spread it to the pond surface. The other feeds i.e. Suny feed and Saudi Bangla feed were purchased from Swadeshi Bazar, Mymynsingh town.

Feeding strategy

The experimental fish were fed in two times a day at 09.00 am and 5.00 pm. The quantity of feed was adjusted every 15 days on the basis of increase in the average body weight of the stocked biomass. Feeds were given twice daily (9.00 am and 5.00 pm) at the rate of 100%, 80%, 40%, 20%, 10% and 5% of their body weight respectively.

Sampling procedure

The culture potentiality on the growth under the different feeding strategy was assessed by recording the rate of growth in terms of gain in length (cm) and in weight (g) of fish every fifteen days. The length and weight were recorded by random sampling of 10 fishes from each hapa by using a small seine net. Weight was taken with a spring balance (DONGIL-15 kg x 50 g) and length with a measuring scale. All the data recorded in a note book and spread sheet and then finally calculated the average length and weight of fishes according to treatment on each sampling day.

Water quality parameters

Physico-chemical parameters like temperature, pH, dissolved oxygen (DO) and transparency of the water of ponds were measured at 15 days interval. Temperature was recorded by using a Celsius thermometer. D.O., pH and transparency were measured directly by a portable digital D.O. meter (Lutron, DO-5509), a digital pH meter (CORNING Model 445) and a Secchi disc respectively. Before taking a measurement pH meter was properly adjusted with buffer solution pH-7. On the spot, recording of water temperature (°C), dissolved oxygen (DO), pH and transparency (cm) were done between 9.00 and 10.00 a.m.

Economic analysis

An economic analysis was performed to estimate the net profit from different treatments. The net return/profit was measured by deducting the gross income from the gross cost per hapa. The benefit cost ratio was also measured as a ratio of gross income to gross cost. A simple economic analysis performed to estimate the net profit. The cost of inputs based on the Mymensingh whole sale

market price (2006). The cost of Suny feed was Tk19/ kg, mixed feed Tk 20 / kg and Saudi Bangla feed Tk 23 / kg. The selling price for Thai koi (*A. testudineus*) was estimated as Tk 300/kg.

Statistical analysis

One way analysis of variance (ANOVA) was used for statistical of the experimental data followed by Duncan's Multiple Range Test (Duncan, 1955) to determine the significance of variation among the treatments mean. Standard (±error) of treatments means were calculated from the residual mean square in the analysis of variance.

Results and Discussion

The water quality parameters were recorded from the three different treatments during the experimental period which are shown in Table 3. Dissolve oxygen (mg/L) of T_2 and T_3 are significantly higher than T_1. Transparencies (cm) were different from each other whereas plankton (cells/L) of T_2 was significantly higher than that of T_1 and T_3.

Table 3. Water quality parameters at 15 days interval of 90 days experimentation

Water quality parameters	Treatment 1 (M± SE)	Treatment 2 (M± SE)	Treatment 3 (M± SE)
Temperature (°c)	28.53 ± 0.13^a	28.50 ± 0.16^a	28.86 ± 0.22^a
Dissolved oxygen (mg/L)	6.07 ± 0.04^b	6.20 ± 0.00^a	6.17 ± 0.00^a
pH	8.04 ± 0.02^a	8.01 ± 0.01^a	8.03 ± 0.01^a
Transparency (cm)	26.58 ± 0.43^a	20.16 ± 0.82^c	24.04 ± 0.32^b
Plankton (cells/l)	$20\times10^4 \pm 8.50^c$	$22.50\times10^4 \pm 9.20^a$	$20.50\times10^4 \pm 7.50^b$

Values of the parameter in each rows with different superscripts (a, b & c) differs significantly (p<0.05).

In the present study, the final weight gain (g) was obtained 32.60 ± 0.28, 36.80 ± 0.25 and 37.20 ± 0.17 g in T_1, T_2 and T_3 respectively. The final length gain (cm) was obtained 8.77 ± 0.05, 9.54 ± 0.01 and 9.77 ± 0.05 cm in T_1, T_2 and T_3 respectively for 90 days experimental period with applying Suny feed, Prepared feed and Saudi-Bangla feed in those treatments respectively (Table 4).

Table 4. Growth and survival rate of Thai koi in hapa after 90 days experimentation

Treatment	Parameters						
	Weight gain (g) (M ± SE)	Length gain (cm) (M ± SE)	Percent Weight gain (M ± SE	Percent Length gain (M ± SE)	SGR (M ± SE)	FCR (M ± SE)	Survival rate (%) (M ± SE)
T_1	32.60 ± 0.28^b	8.77 ± 0.05^c	3622.22 ± 32.07^b	241.59 ± 1.59^c	3.69 ± 0.00^b	3.99 ± 0.15^a	73 ± 3.33^a
T_2	36.80 ± 0.25^a	9.54 ± 0.01^b	4088.88 ± 28.86^a	262.99 ± 0.40^b	3.81 ± 0.00^a	3.11 ± 0.06^b	76 ± 3.33^a
T_3	37.20 ± 0.17^a	9.77 ± 0.05^a	4233.33 ± 19.24^a	269.14 ± 1.59^a	3.82 ± 0.00^a	3.31 ± 0.02^b	83 ± 3.33^a

Values of the parameters in each column with different superscripts (a, b & c) differs significantly (p<0.05)

Soriano *et al.* (1995) reported that *Siganus gutatus* showed the mean weight and length increment of 108.07 g and 9.78 cm, respectively in a floating cage in a Manat river. The result of the present study was lower than those of above mentioned research. It might be occurred due to feed and environment differences, because here used only commercial and handmade feed but Soriano *et al.* (1995) used combination of commercial feed and natural feed. However, here the experiment was conducted in hapa in a pond but Soriano *et al.* (1995) performed his experiment in a river which was better living place for fish. Noor (2005) in her thesis reported that Thai koi (*A. testudineus*) obtained length 14.66 cm and weight 57.22 g for 50 days experimental period with supplemental feeding. From the present study it was observed that the growth of Thai koi (*A. testudineus*) in hapa was lower than the previous study. The reasons behind this less production might be restricted movement of fish and feed waste by leaching through the pore of net under water.

The SGR as recorded in the present study were 3.69%, 3.81% and 3.82% in T_1, T_2 and T_3 respectively (Table 4) with feeding 24%, 28.45% and 35% protein containing feed respectively which was approximately near to 8.09-9.21% obtained by the Samad *et al.* (2004) for Shing (*Heteropneustes fossilis)* with similar protein level (27.75-32.24%). Otubusin (2000) announced that in hapa system, SGR of *Clarias gariepinus* was 5.72% in 42 days experimental period when fish was fed frozen maggot. The result of the present study was lower than the above mentioned study. It might be due to the differences of the source of feed, because frozen maggot was animal source feed but here useable feed was dominantly plant sources.

The food conversion ratio (FCR) value was 3.99 ± 0.00, 3.11 ± 0.06 and 3.31 ± 0.02 in T_1, T_2 and T_3 respectively (Table 4). Christensen (1994) reported that FCR of Tinfold barb (*Puntius schwanenfeldii*) was 2.8 when fish were fed pellet feed in floating cages. The result of the present study was higher than the Christensen performed experiment. It might be due to low quality pellet feed than the useable commercial feed. Hossain *et al.* (1994) reported that the FCR of 1.74 to 2.29 for *P. gonionotus* fed diets containing different levels of mustard oilcake, seasame meals. Azad (2006) in his thesis announced that the FCR was 2.40, 2.22 and 2.07 in T_1, T_2 & T_3 respectively with the feeding of pelleted feed (Quality Fish Feed Ltd.) polyculture in nine earthen ponds of 135 days experimental period. In the present study the result is agreed by Azad (2006). But this result is slightly higher than those of Hossain *et al.* (1994) due to different environmental factors. Otubusin (2000) announced that in hapa culture system of *Clarias gariepinus*, frozen maggot showed best FCR 0.32 in 42 days experimental period. This result is not adjusted with our performed experiment. It might be due to age of *Clarias gariepinus* was lower than the Thai koi and also the variation of sources of feed.

The survivable rate of Thai koi (*A. testudineus*) during the period of experiment were 73%, 76% and 83% in T_1, T_2 and T_3 respectively (Table 4) although similar stocking density was maintained in all treatments. Soriano *et al.* (1995) showed that the survival rate of *Siganus gutatus* was100% in floating cages in Manat river. This result was higher than the present study. It might be due to feed and environmental differences, here in hapa fish might be not feel comfortable due to rough surface of net and restricted movement in a confined area. On the other hand, *Siganus* sp. were cultured in a cage which was placed in a river. Noor (2005) found that survivable rate of Thai koi (*A. testudineus*) was 81.67% in her 50 days experimental period with a hand made feed. Azad (2006) reported that the survivable rate of Pangasiid catfish (*Pangasius hypophthalmus*) was 95.2%, 96.0% and 96.8% and the survivable rate of Silver carp (*Hypophthalmichthys molitrix*) was 83.2%,85.2% & 86.0% in T_1, T_2 & T_3 respectively in polyculture system in ponds of 135

days experimental period. The result of present study was similar with the findings of Noor (2005). But, the present study finding was lower than of Pangasiid catfish (*Pangasius hypophthalmus*) and higher in (*Hypophthalmichthys molitrix*) which was reported by Azad (2006). It might be due to the different culture systems and species variation.

The total average cost of fingerling was Tk. 70/treatment. Here price of each fingerling was considered Tk. 1.00. The price of Suny feed was Tk.19/kg, mixed feed Tk. 20/kg and Saudi Bangla fish feed Tk. 23/kg. In addition, hapa preparation, feed and gross cost were Tk. 380, 155 and 605/treatment respectively. On the other hand, total production was 2.19kg/treatment. However, gross income/hapa/net profit and benefit cost ratio (BCR) were 657, 52 and 1.08 respectively (Table 5).

Table 5. Economic analysis of Thai koi (*A. testudineus*) production in a hapa at the end of study period

Parameters	Input cost (Tk.)	Parameters	Output (Tk.)
Price of fingerlings	70	Total production (Kg)	2.19
Hapa preparation	380	Gross income/hapa	657
Feed cost	155	Net profit	52
Gross cost	605	BCR	1.08

* One hapa (2.23m^2) would give profit TK. 52. Hence, 1 hectare would provide Tk. 1,11,020

** I US Dollar= Tk. 68

Although the cost of hapa preparation, maintenance and fingerlings were the same for each treatment but there were some variation in relation to production and profit. The net profits obtained were Tk. 52/hapa. In relation to this point, presumably one hectare contain 2135 hapa considering some space will be unused between and among each hapa for easy taking care the fish; and as well as good aeration and sun lighting from the nature which roughly provide Tk.1,11,020. Akter (2001) recorded the benefit of Tk. 1050/dec from pangas farming after 10 to 12 months culture. This result is higher than the present findings due to different culture system, technique and culture period. In integrated cage-pond aquaculture systems, waste derived from cages can effectively support growth of filter feeding species and the growth of open-pond fish increases with increasing nutrient loading from cages (Lin 1990; Lin *et al.*, 1989; Lin and Diana, 1995; Yi *et al.*, 1996; Yi, 1997; Yi and Lin, 2000, 2001). However, waste released from hapas to ponds in the present experiment was mainly in the form of feed materials instead of metabolic wastes of climbing perch, which may additional support for the better growth of fishes in the pond.

Although, fish culture in hapa is a new technology in our country, but it is a potential door which should be opened immediately for betterment of the nation. The concerned authority should give more attention in this technology just for meet the protein requirement of this mass population of Bangladesh. In conclusion, it was recommended that prepared feed would be used for mass culture of Thai koi in hapa since within very short period of time it yields more profit compared to other fish farming.

Acknowledgement

Authors acknowledge the Bangladesh Agricultural University Research Systems (BAURES), for research financial support for conducting the present

studies and also gratefully thanks to Dr. Niamul Naser, Professor, Department of zoology, Dhaka University for his constructive suggestion and criticism for improving the text of the paper.

References

Akter, N. (2001). An economic analysis of pangas fish production in a selected area of Trisal Upazilla in Mymensingh District. M.S. Thesis, Department of Agricultural Economics, BAU, Mymensingh, 74 pp.

Alam, M. A., Rahman, L., Khan, M. M. R. & Rahman S. M. Z. (2006). Allozyme marker for the analysis of genetic variation of cross koi (♀ local × ♂ Thai) Anabas testudineus with their parents. *Mol. Biol. & Biotech. J. 4*: 9-12.

AOAC (1980). Association of Official Analytical Chemists. 13rd ed., Washington DC, 1018 pp.

Azad, A. K. (2006). Effects of feeding schedule on growth, production and economics of pangasid catfish (*Pangasius hypophthalmus*) and silver carp (*Hypophthalmichthys molitrix*) polyculture in ponds. M.S.Thesis, Department of Fisheries Management, BAU, Mymensingh, 77 pp.

Beveridge, C. M., & Malcolm. (1983). Cage and pen fish farming: Carrying capacity models and environmental impacts. FAO Fisheries Technical paper 255.

Christensen, M. S. (1994). Growth of Tinfoil barb, *Puntius schwanenfeldii*, fed various feeds, including fresh chicken manure, in floating cages. *Asian Fish. Sci*. *7*(1): 29-34.

DoF (Department of Fisheries) (2001). Fish Week Compendium. Department of Fisheries, Ramna, Dhaka, Bangladesh.

Duncan, D. B. (1955). Multiple Range and Multiple F-test. *Biometrics*. *11*: 1-42.

Hasan, M., Khan, M.M.R. & Rahman, A. (2007). Some biological aspects of Thai koi, *Anabas testudineus* (Bloch). *J. of Bangla. Agril. Univ*. *5*(2):385-392.

Hossain, M. A., Toyub, M. A., Islam, M. N., & Islam, M. R. (1994). Effects of species combination on the major and Chinese carps in demonstration ponds under Feni district. *Bangla. J. Agril. Sci*. *21* (2): 257-266.

Lin, C. K., & Diana, J. S. (1995). Co-culture of catfish (*Clarias macrocephalus* × *C. gariepinus*) and tilapia (*Oreochromis niloticus*) in ponds. *Aquatic Living Res*. *8*: 449-454.

Lin, C. K. (1990). Integrated culture of walking catfish (*Clarias macrocephalus*) and tilapia (*Oreochromis niloticus*). In: Hirano, R. and I. Hanyu, Editors. The Second Asian Fisheries Forum. Asian Fish. Soc., Manila, Philippines. pp. 209-212.

Lin, C. K., JAIYEN, K., & Muthuan, V. (1989). Integration of intensive and semi-intensive Aquaculture concept and example. Thai Fisheries Gazette. 43: 425-430.

Noor, A. M. (2005). Growth and morphological comparison between local and Thai koi (*A. testudineus*) in Bangladesh. M.S. Thesis, Department of Fisheries Biology and Genetics., pp. 25-42.

Otubusin, S. O., & Ifili, N. N. (2000). Growth performance of *Clarias gariepinus* fed on plankton; frozen maggot; and pelleted feed in a floating hapa system. *J. Fish. Technol. 2*: 117-123.

Samad, M. A., Islam, M. A., Khalleque, M. A., Amin, M. R., & Alam, M. S. (2004). Fry rearing and culture of indigenous catfish, Shingi (*Heteropneustes fossilis* Bloch, 1794) BAU, Mymensingh, *Prog. Agric. 15* (1): 121-131.

Soriano, W. O., Bautista, A., & Doria, F. C. (1995). PhD Thesis, University of Miami, Coral Gables, Florida.

Yi, Y., & Lin, C. K. (2000). Integrated cage culture in ponds: concepts, practices and perspectives. In: The proceedings of the First Symposium on Cage Culture in Asia (eds. I.C. Liao and C. K. Lin). Asian Fisheries Society, Manila, Philippines and World Aquaculture Society-Southeast Asian Chapter, Bangkok, Thailand. pp. 233-240.

Yi, Y., & Lin, C. K. (2001). Effects of biomass of caged Nile Tilapia (*Oreochromis nilotcus*) and aeration on the growth and yields in an integrated cage-cum-pond system. *Aquaculture. 195* (3-4): 253-267.

Yi, Y. (1997). An Integrated Rotation Culture System for Fattening Large Nile Tilapia (*Oreochromis niloticus*) in Cages and Nursing Small Nile Tilapia in Open Ponds. PhD Thesis. Asian Institute of Technology, Bangkok, Thailand. 169 pp.

Yi, Y., Lin, C. K., & Diana, J. S. (1996). Effects of stocking densities on growth of caged adult Nile tilapia (*Oreochromis nilotcus*) and on yield of small Nile tilapia in open water in earthen ponds. *Aquaculture. 146*: 205-215.