JOURNAL OF THE
WORLD AQUACULTURE SOCIETY

Vol. 33, No. 3
September, 2002

Appropriate Timing of Supplemental Feeding for Production of Nile Tilapia, Silver Carp, and Common Carp in Fertilized Polyculture Ponds

ALI E. ABDELGHANY[1,3], MOHAMED-SALAH AYYAT[2] AND MOHAMMED H. AHMAD[1]

[1]*Central Laboratory of Aquaculture Research, Abbassa, Abohamad, Sharkia, Egypt*
[2]*Animal Production Dept., Faculty of Agriculture, Zagazig University, Zagazig, Egypt*

Abstract

In an attempt to identify appropriate times for initial application of supplemental feed in polyculture fertilized fish production earthen ponds, a study was conducted for 19 wk to establish the growth performance, yield, survival, and body composition of Nile tilapia, common carp, and silver carp as influenced by four different feeding regimens (treatments). The four treatments were: 1) supplemental feeding beginning at onset of the experiment (T-I) (control treatment); 2) 6-wk delay of feeding after fish stocking (T-II); 3) 13-wk delay of feeding after fish stocking (T-III), and 4) no supplemental feed application (T-IV). Two ponds were assigned to each treatment and each pond was stocked with a similar number and weight of each fish species. A commercial pelleted fish feed (25% protein) was used to feed fish in T-I, T-II, and T-III at 3% of their body weight, twice a day. At the end of the experiment, fish species (except for silver carp) in T-II showed weight gain, growth rates, and yields significantly higher than fish in T-III or T-IV. Also, the total fish production and net profit in T-II were significantly higher than in T-III or T-IV. Fish species in T-II showed weight gain, growth rates, survival rates, and yields similar to those of T-I (control treatment) with no significant differences. The amount of feed consumed by fish in T-II was reduced by approximately 7.3% compared to that consumed by fish at T-I. Moreover, there was increase in th net profit in T-II by 4.8% over that achieved in T-I. Therefore, T-II appears to be the most appropriate among the tested feeding treatments and recommended for use in order to achieve the best growth, production, and net profit.

Polyculture of Nile tilapia *Oreochromis niloticus* L., common carp *Cyprinus carpio* L., and silver carp *Hypophthalmichthys molitrix* Val. is the major aquaculture practice in Egypt and other countries in the world. The combination of the three species may ensure maximum utilization of available natural food in ponds because of their different feeding habits. Silver carp, Nile tilapia, and common carp could be considered as surface, column, and substratum feeders, respectively (Cremer and Smitherman 1980; Spataru et al. 1983). The three species are commonly cultured in semi-intensive systems with fertilization and supplemental feeding. Supplemental feeding in fertilized ponds resulted in significantly higher growth rates and greater yields than fertilization alone (Green 1992; Diana et al. 1994). Artificial feed costs in aquaculture operations account for approximately 50% of total operational costs (Keenum and Waldrop 1988; Ratafia 1994) and is considered a major constraint for both small fish farms and commercial fish aquaculture ventures. Reducing amount of feed is a means of lowering costs if production is not reduced. It is worth noting that reducing the feed amount by even a few kilograms/acre in fish farms might provide economic benefits. In attempts to reduce feed costs, fish farmers provide supplemental feed for part instead of all of the grow-out operation. An on-farm trial, carried out in the Philippines, demonstrated that initiation of feeding of Nile tilapia after 75 d of stocking in ponds produced the same yield as initiation of feeding at 45 d (Brown et al. 2000). However, the timing of the start of supplemental

[3] Corresponding author's present address: 12 Sakr-Korish, Apt. #23, Maadi El-Gadeda, Cairo, Egypt.

feeding is variable and should be evaluated. The objective of the present study was to evaluate the effects of different periods of delay before initial application of supplemental feed on growth, yield, and survival of Nile tilapia, silver carp, and common carp raised in polyculture fertilized earthen ponds. The results of this study might contribute to reducing feed costs without jeopardizing fish production and improve aquaculture management practices.

Materials and Methods

This production and nutritional study consisted of four feeding treatments to determine the appropriate timing of first feed application for Nile tilapia, silver carp, and common carp raised in fertilized polyculture ponds system. The system consisted of eight 0.1-ha earthen ponds (mean water depth 1.0 m) located at the experimental station of the Central Laboratory of Aquaculture Research (CLAR), Sharkia, Egypt. All the experimental ponds were drained and sun-dried for 10 d. Nylon screen enclosures were installed on the water inlets and outlet pipes of each pond to prevent escape and entry of unwanted fishes. All ponds were fertilized using a standard fertilization program (Hepher 1963) to initiate and promote natural organisms to grow.

The fish were collected from nursery ponds in the CLAR. Each species was separately held in four 5-m^3 fiberglass tanks that were placed near the experimental ponds and filled with fresh pond water. Each species of fish was graded, counted, weighed, and immediately distributed into the ponds on May 1 and cultured over a 19-wk summer growing season. Each pond was stocked with 1,000 Nile tilapia, 1,000 silver carp, and 200 common carp fingerlings having average initial weights of 13.65 g, 1.87 g, and 10.85 g, respectively. Thus, all ponds were stocked with equal number and weight of each species. The relative stocking rates among the three species were approximately 45%, 45%, and 10% for Nile tilapia, silver carp, and common carp, respectively. The low stocking density of common carp relative to Nile tilapia or silver carp is a common practice on fish farms in Egypt and was adopted according to the low preference of the consumers, the low price of the species in the market, and its vigorousness of feed consumption. The four treatments were similar in all aspects except for the timing of the onset of supplemental feeding applications, which were as follows: (T-I) onset of feeding started on the first day of fish stocking: (T-II) 6-wk delay in feeding after fish stocking; (T-III) 13-wk delay in feeding after fish stocking; and (T-IV) no supplemental feed application. Two ponds were assigned to each treatment (two replicates/treatment).

The fertilization program consisted of organic (chicken litter) and inorganic fertilizers (triple-superphosphate and urea). The chicken litter was applied by broadcast method on the pond bottoms at the rate of 750 kg/ha then, ponds were filled to 20-cm deep with water via a supply canal that had taken its water from the Ismailia irrigation canal. After 2 wk the water level in all ponds was raised to 1-m deep, and fish were then stocked. Eight additional applications with 150 kg/ha of chicken litter were applied biweekly. Additionally, eight applications with 100-kg triple-superphosphate/ha and 20-kg urea/ha were alternatively made at 2-wk intervals together with the chicken litter.

Fish in T-I, T-II, and T-III were fed a commercial pelleted type fish feed (approximately 25% crude protein) at 3% of their body weight twice a day, 6 d a week. The feed ingredients consisted of soybean meal, fish meal, corn, binders, and a mixture of vitamins and minerals. Proximate chemical analysis of the feed for protein, lipid, ash, and moisture was conducted according to standard methods (AOAC 1990; Table 1). Nitrogen content was measured by the microkjeldahl method, and crude protein was estimated (N $\times$ 6.25). Lipid content was established by ether extraction method, and ash value was determined by igniting the

TABLE 1. *Diet composition and guaranteed analysis provided by the supplier (A) and proximate analyses of the diet by the nutritional laboratory at CLAR (B). Diet composition is presented as a % dry matter.*

Component	A	B
Moisture	NR[a]	10.24
Protein	25.97	25.51
Lipid	4.75	6.08
Fiber	5.22	5.59
Ash	NR[a]	13.13
Gross energy (kcal/g diet)	NR[a]	4.28

[a] NR = not reported.

samples in a muffle furnace at 550 C for 6 h. Moisture content was estimated by heating samples in a forced air oven at 105 C for 24 h and computing the weight losses. Gross energy was calculated using values of 4.0 kcal/g carbohydrate, 9.5 kcal/g lipid, and 5.7 kcal/g protein as reported by NRC (1993).

Samples of at least 40 fish from each species in each pond were periodically collected with a seine net (0.4-cm stretched mesh) to determine weight (to the nearest 0.01 g) and to adjust the amount of feed. Fish were returned to their ponds after weighing. In the present study, tilapia reproduction occurred in all ponds, and the fry and juveniles were removed weekly from the pond surfaces by scoop nets and discarded to avoid overpopulation. Fry and juvenile weights were not included in tilapia growth or yield calculations. At the end of the experimental period, five fish from each species in each pond were separately homogenized in a blender and analyzed for crude protein, lipid, ash, and moisture following the procedures described by Lovell (1981). At harvest, all fish were removed from the ponds, and the total number and weight of fish species in each pond were determined. Survival rates were estimated from yield data at the end of the study.

Water quality variables in each pond were measured following Boyd (1990). Temperature and dissolved oxygen concentrations were measured weekly in the morning at a depth of 20 cm, with an YSI model 58 oxygen meter (Yellow Springs Instruments, Yellow Springs, Ohio, USA). Simultaneously, Secchi-disk visibility was measured. Total ammonia-N and pH were periodically recorded using a Hach color comparator DREL/5 and model Corning-345 electronic pH meter, respectively. Bicarbonate alkalinity was determined by sulfuric acid titration method (APHA et al. 1989). Total dissolved orthophosphate concentrations were determined by methods described by Greeson et al. (1977). Water samples were collected monthly from each pond for plankton and chlorophyll-a determination. The phytoplankton was concentrated and preserved with 50 ml of 4% buffered formalin solution for microscopic identification and counting in a Sedgewick-Rafter cell in combination with a Whipple ocular grid following the methods of Boyd (1979). Chlorophyll-a was extracted in 90% acetone and was spectrophotometrically determined as reported by Boyd (1990). For zooplankton determination, water samples of 10 L each were collected at 0.75-m depth using a water sampler. The samples were strained using a plankton net with 70-μm mesh. Zooplankton were preserved, identified, and enumerated following the methods of (APHA 1989).

One-way analysis of variance was used to test the effects of the treatments on various growth and feed utilization parameters. Duncan's Multiple Range Test (Duncan 1955) was applied to compare the significance of means of the various parameters among the tested treatments. Differences were considered significant at $P \leq 0.05$. All data were analyzed using the SPSS software program.

The income of the different treatments was estimated by a simple economic analysis. Facility costs were not included in the analysis, because the intent was only to compare relative differences in efficiency among treatments, and we assumed those costs would be similar for all treatments. The estimation was based on local market retail prices (at the current time) of feed,

TABLE 2. *Growth performance of Nile tilapia, common carp, and silver carp reared in polyculture fertilized ponds for 19 wk at different timing in onset feeding after stocking. Means with common letters in the same row are not significantly different (P > 0.05). NT = Nile tilapia, CC = common carp, SC = silver carp.*

		Feeding Treatments			
Items	Species	(I) No delay[1] (Control)	(II) 6 wk delay[2]	(III) 13 wk delay[2]	(IV) Total delay[3]
Initial weight	NT	13.81	13.62	13.64	13.60
	CC	10.66	10.72	10.69	10.76
	SC	1.85	1.83	1.73	1.81
Weight gain-2	NT	148.19 a	148.50 a	94.37 b	46.02 c
	CC	576.92 a	587.78 a	287.67 b	200.36 c
	SC	232.53 c	241.65 bc	269.93 a	250.44 b
% Weight gain	NT	1,073	1,090	692	471
	CC	5,412	5,483	2692	1,862
	SC	12,569	13,205	1,5603	13,836
Growth rate, g/d	NT	1.11 a	1.12 a	0.71 b	0.48 c
	CC	4.34 a	4.42 a	2.16 b	1.51 c
	SC	1.75 c	1.82 bc	2.03 a	1.88 b
% Survival	NT	98.8 a	98.9 a	97.9 a	80.9 b
	CC	95.5 a	96.0 a	95.5 a	88.0 b
	SC	84.9 a	82.1 a	82.2 a	70.2 b
Yield (kg/ha)	NT	1,601.2 a	1,603.8 a	1,057.8 b	627.9 c
	CC	1,122.3 a	1,150.7 a	569.9 b	371.2 c
	SC	1,975.1 b	1,996.7 b	2,230.3 a	1,771.4 c
Total yield, kg/ha		4,698.6 a	4,751.2 a	3,858.0 b	2,770.5 c

[1] No delay = onset feeding started on the stocking day and continued for all grow-out period.
[2] Delay = delay in onset feeding after fish stocking.
[3] Total delay = feeding was totally delayed or deleted (no exogenous feeding).

fertilizers, and fishes, which were all converted to US dollars. These prices were set at \$0.31/kg of feed, \$0.097/kg of triple-superphosphate, \$0.156/kg of urea, and \$0.049/kg of chicken litter. The values of the stocked fingerlings per 1,000 of Nile tilapia, common carp, and silver carp were set at \$30.56, \$22.22, and \$11.11, respectively. Means of market sale values of harvested fish were set at \$2.22/kg for Nile tilapia, \$1.25/kg for silver carp, and \$0.97/kg for common carp.

Results and Discussion

Growth and Production Performance

The growth responses of fish species in all the treatments were generally satisfactory, and they all reached the marketable sizes at the end of the experiment. Fish grown on fertilizer alone achieved a reasonable growth and production, while supplemental feeding of fish resulted in more rapid growth and higher production (Table 2) than fertilization alone, and the timing of onset feeding affected overall growth rates and production. In the three species, yields (kg/ha) were significantly ($P < 0.05$) higher in the two earliest fed treatments (T-I and T-II) than in the latest fed treatment (T-III) or the treatment without supplemental feed (T-IV). Fish species (except silver carp) at T-IV (no exogenous feed) showed significantly ($P < 0.05$) lower growth rates (g/d), percent weight gain, survival rate and total production (kg/ha) compared to all other treatments (Table 2, 3). There were increases by 1.70, 1.72, and 1.39 fold of total fish production in T-I, T-II, and T-III, respec-

TABLE 3. *Feeding efficiency parameters of Nile tilapia, common carp, and silver carp raised in fertilized ponds for 19 wk at different timing in onset feeding after fish stocking. Means with common letters in the same row are not significantly different* (P > *0.05).*

Items	Feeding treatments (I) No delay[1] (Control)	(II) 6 wk delay[2]	(III) 13 wk delay[2]	(IV) Total delay[3]
Yield (kg/ha)	4,698.6 a	4,751.2 a	3,858.0 b	2,770.5 c
Fish weight stocked	177.9	175.9	175.1	175.6
Net yield (kg/ha)	4,520.7 a	4,575.3 a	3,682.9 b	2,594.9 c
Feed intake (kg/ha)	6,716.3 a	6,228.4 b	3,671.3 c	—
Apparent-pond-FCR[4]	1.49 a	1.36 b	1.00 c	—

[1] No delay = onset feeding started one day after stocking and continued for all grow-out period.
[2] Delay = delay of onset feeding after fish stocking.
[3] Total delay = feeding was totally delayed or deleted (no exogenous feeding).
[4] Apparent-Pond-FCR = Feed intake/Net production (Boyd et al. 1979).

tively, compared to the production in T-IV. Pond fertilization only without feed supplementation supported approximately 58%, 59%, and 72% of the total fish production achieved by fish groups in T-II, T-I (control group), and T-III, respectively. In other words, supplemental feed supported approximately 42%, 41%, and 28% of the total fish production achieved by fish groups in T-II, T-I (control group), and T-III, respectively. These results demonstrate the effect of delays of the onset feeding on fish production, and quantify the effect of supplemental feed in promoting fish production. Growth performance parameters (growth rate, weight gain, and yield) in T-II were higher than in T-I, but the differences were not significant ($P > 0.05$). Fish in T-Ii consumed approximately 7% less feed than the fish in T-I (Table 3). Therefore, T-Ii appears to be the most appropriate feeding regimen to maximize growth and production. This means that fish do not need to be fed immediately after stocking but can be supported by the natural food in the pond ecosystem. These results also indicate that ample feed (e.g., at the control group), possibly represents overfeeding.

Silver carp showed different and irregular responses to feed than Nile tilapia and common carp. Silver carp in T-IV (no exogenous feed) had significantly ($P < 0.05$) higher weight gain (g/fish), percent weight gain, and growth rate (g/d) compared to those of silver carp in T-I (Table 2). Silver carp in T-III showed significantly higher weight gain ($P < 0.05$) g/fish), percent weight gain, growth rate (g/d), and yield (kg/ha) compared to the silver carp in the other treatments. These results suggest that supplemental feed may be undesirable, may affect growth of small sizes of silver carp, and is not needed or accepted by fish until they grow to large sizes (approximately 150 g/fish). However, it is documented in literature that silver carp do not consume artificial feeds (Cremer and Smitherman 1980; Oposzynski 1981) and that supplemental feed had no significant effect on the growth of silver carp (Muller 1979).

Comparison of growth parameters among fish species in the present experiment was not possible due to differences in their initial sizes at stocking. Differences in growth performance and production (Table 2) are likely due to the feeding regimen because all other factors that influence growth parameters were similar. Therefore, these results could provide technical guidance to farmers about feeding practices that optimize fish growth and pond production.

The total amount of feed applied differed

TABLE 4. *Chemical analysis (as % dry matter) of body composition of Nile tilapia, common carp, and silver carp raised in polyculture fertilized ponds for 19 wk at different timing in onset feeding fish stocking. Means with common letters in the same row are not significantly different* (P > *0.05).*

Items	Species	Feeding treatments (I) No delay[1] (Control)	(II) 6 wk delay[2]	(III) 13 wk delay[2]	(IV) Total delay[3]
Moisture	NT	74.00 a	68.44 b	74.29 a	72.79 a
	CC	63.85 b	68.82 ab	70.28 ab	73.33 a
	SC	75.54 a	72.31 b	74.45 a	72.61 b
Crude protein	NT	53.84 b	50.32 b	62.10 a	63.83 a
	CC	50.79 b	50.49 b	50.71 b	64.09 a
	SC	67.82 a	63.48 b	63.42 b	67.91 a
Crude lipid	NT	36.97 a	29.73 b	20.39 c	17.61 d
	CC	40.17 a	41.29 a	39.02 a	20.07 b
	SC	17.26 d	20.66 c	22.89 b	29.46 a
Ash	NT	16.71 b	13.01 c	17.33 b	23.78 a
	CC	9.01 b	8.33 b	10.02 b	11.99 a
	SC	15.04 a	16.09 a	13.95 b	13.83 b

[1] No delay = onset feeding started one day after stocking and continued for all grow-out period.
[2] Delay = delay of onset feeding after fish stocking.
[3] Total delay = feeding was totally delayed or deleted (no exogenous feeding).

significantly (*P* < 0.05) among treatments (Table 3). The average values of feed conversion ratios (FCR) (Table 3) were calculated for the whole fish community in polyculture system as described by Siddiqui et al. (1993). Ignoring the natural food consumed by the fish, the resulting FCR is, therefore, an apparent rather than true value and is called the Apparent-Pond-Food Conversion Ratio (AP-FCR) (Boyd et al. 1979). In the present study, feed conversion values were significantly (*P* < 0.05) improved with greater delay in the onset of feeding. The values of AP-FCR were 1.49, 1.36, and 1.00 for T-I, T-II, and T-III (Table 3). Feed conversion values reflect feed consumption rather than feed quality since the feed was the same in all treatments. Feed conversion decreases as the amount of feed fed decreases, and increases with the increase in the amount of feed fed (Halver 1989). The increase in AP-FCR with similar fish production in T-I compared to that of T-II further suggests that the T-I feed regimen represents overfeeding. The low AP-FCR yield in T-III compared to those parameters in T-I or T-II suggests that fish in T-III were underfed (Tables 2, 3).

Fish survival in all treatments exceeded 80% except for the silver carp in T-IV where survival was 70% (Table 2). The survival rates of the three fish species in the three fed treatments (T-I, T-II, and T-III) were not significantly (*P* > 0.05) affected by the delay in onset of feeding. The survival of the three fish species in T-IV was significantly (*P* < 0.05) lower than all the other treatments. These results suggest that supplemental feed provided necessary nutritional components and energy for better fish growth.

Proximate Chemical Analysis

The timing of the onset of feeding showed either irregular pattern or no effects on proximate analysis of whole body composition of Nile tilapia, common carp, or silver carp (Table 4). Lipid percent in Nile tilapia decreased significantly (*P* < 0.05) as onset of feeding was delayed, while a reverse trend was observed with silver carp, where lipid percent increased significantly

TABLE 5. *Cost benefit analysis per hectare of Nile tilapia, common carp, and silver carp raised in polyculture fertilized ponds for 19 wk at different timing in onset feeding fish stocking. Means with common letters in the same row are not significantly different* ($P > 0.05$).

	Feeding treatments			
Items (costs as US $/ha)	(I) No delay[1] (Control)	(II) 6 wk delay[2]	(III) 13 wk delay[2]	(IV) Total delay[3]
Cost of fish stock	461.1	461.1	461.1	461.1
Cost of fertilizers	198.11	198.11	198.11	198.11
Feed consumed (k)	6,716.3 a	6,228.4 b	3,671.3 c	—
Cost of feed	2,082.1 a	1,930.8 b	1,138.1 c	—
Total cost of production	2,741.31	2,590.01	1,797.31	655.4
Income (fish sale)	7,112.2 a	7,172.5 a	5,689.0 b	3,968.3 c
Net benefit	4,370.9 b	4,582.5 a	3,891.7 c	3,309.1 d
Net benefit of fed treatments over not fed treatment	1,061.8	1,273.4	582.6	—
Net benefit of fed treatments relative to not fed treatment	1.32	1.38	1.18	—

[1] No delay = onset feeding started one day after stocking and continued for all grow-out period.
[2] Delay = delay of onset feeding after stocking.
[3] Total delay = feeding was totally delayed or deleted (no exogenous feeding).

($P < 0.05$). Ash percent in silver carp decreased significantly ($P < 0.05$) as feeding was delayed (T-III) or with no exogenous feeding (T-IV) compared to those of T-I or T-II. Ash percent of Nile tilapia or common carp in T-IV was significantly ($P < 0.05$) higher than fish in all other treatments. Protein percentages in Nile tilapia increased significantly ($P < 0.05$) with excessive delay in the onset of feeding (T-III) or with no exogenous feeding (T-IV). Protein content of common carp in T-IV as significantly ($P < 0.05$) higher, and lipid percentage was significantly ($P < 0.05$) lower than in other treatments. Hepher (1988) stated that natural food organisms contain low energy, while protein is in excess, therefore, fish consuming only natural food have minimal fat and maximum protein accumulation in their body. These results are also in agreement with findings reported by Weatherley and Gill (1987), Jobling (1994), and Shearer (1994).

Water Quality

Water quality parameters ranged as follows: temperature, 26.6–26.8 C; DO, 5.1–6.6 mg/L; pH, 8.1–8.3; alkalinity, 320–580 mg/L; ammonia-N, 0.59–0.65 mg/L; phosphate, 1.05–1.26 mg/L, and Secchi disk reading, 13.0–14.6 cm. All values were within the acceptable limits for fish culture in ponds as reported by Boyd (1982) and were not significantly different ($P > 0.05$) among treatments. Phytoplankton were mainly comprised of Chlorophyceae, Bacillariophyceae, unicellular Cyanophyceae, and Euglenophyceae. Zooplankton populations were represented by cladocerans, copepods and rotifers. Plankton (phytoplankton or zooplankton) counts and chlorophyll-a were significantly ($P < 0.05$) higher in treatments with the earlier onset of feeding. The mean monthly abundance values for T-I, T-II, T-II, and T-IV were 7.96×10, 6.80×10, 4.92×10, and 3.36×10 cell/mL, respectively, for phytoplankton; 18.7, 16.1, 12.9, and 10.8 organism/mL, respectively, for zooplankton; and 158.4, 139.1, 107.9, and 90.1 μg/mL, respectively, for chlorophyll-a.

Economics

All of the treatments in this experiment generated a profit (Table 5). T-II produced the highest income among all treatments with a slightly higher income value ($7,172.50/ha) compared with the T-I $7,112.20/ha (Table 5). Because the 6-wk delay in the onset of feeding (T-II) resulted in a reduced amount of feed used, the net profit ($4,582.50) generated by T-Ii was significantly ($P < 0.05$) higher than that of T-I ($4,370.90). Net profits were reduced when feeding was delayed more than 6 wk after stocking (e.g., in T-III) or when supplemental feeding was completely eliminated (T-IV). It is clear that the lower fish production and net profit in T-I (control) compared to T-Ii did not justify the extra cost of using more feed. At current feed prices, the amount of feed used in T-I costs 7.8% more than the amount used in T-II (Table 5). Net profit in T-I, T-II, and T-III, exceded that of T-IV by 1,061.80, 1,273.40, and 582.60 US$/ha, respectively. Therefore, among the feeding regimens tested, T-II appears to be the most appropriate to maximize fish growth, overall production, and net profit.

Acknowledgments

The authors wish to thank Dr. M. Abdul-Tawwab, Department of Fish Ecology at CLAR, for his assistance in phytoplankton identification and quantification.

Literature Cited

APHA (American Public Health Association), American Water Works Association, and Water Pollution Control Federation. 1989. Standard methods for the examination of water and wastewater, 17th edition. New York, New York, USA.

AOAC. 1990. Official methods of analysis. 15th edition. Association of Official Analytical Chemists, Inc., Arlington, Virginia, USA.

Boyd, C. E. 1979. Water quality in warm water fish ponds. Auburn University, Agricultural Experiment Station, Auburn, Alabama, USA.

Boyd, C. E. 1982. Water quality management for pond fish culture. Elsevier Scientific Publishing Company, Inc., New York, New York, USA.

Boyd, C. E. 1990. Water quality in ponds for aquaculture. Alabama Agricultural Experiment Station, Auburn University, Alabama, USA.

Boyd, C. E., R. P. Romaire, and E. Johnson. 1979. Water quality in channel catfish production ponds. Journal of Environmental Quality 8:424–429.

Brown, C. L., R. B. Bolivar, E. T. Jimenez, and J. Szyper. 2000. Timing of the onset of supplemental feeding of Nile tilapia 'Oreochromis niloticus' in ponds Page 237 *in* K. Fitzsimmons, editor. Proceedings of the Fifth International Symposium on Tilapia Aquaculture. 3–7 September, Rio De Janeiro, Brazil.

Cremer, M. C. and R. O. Smitherman. 1980. Food habits and growth of silver and bighead carp in cages and ponds. Aquaculture 20:57–64.

Diana, J. S., C. K. Lin, and K. Jaiyen. 1994. Supplemental feeding of tilapia in fertilized ponds. Journal of the World Aquaculture Society 25:497–506.

Duncan, D. B. 1955. Multiple range and multiple *F* tests. Biometrics 11:1–46.

Green B. W. 1992. Substitution of organic manure for pelleted feed in tilapia production. Aquaculture 101:213–222.

Greeson, P. E., T. A. Ehlke, G. A. Irwin, B. W. Lium, and K. V. Slack. 1977. Techniques of water-resources investigations of the United States Geological Survey. U.S. Department of the Interior. U.S. Government Printing Office, Washington, D.C., USA.

Halver, J. E. 1989. Fish nutrition. Academic Press, Inc., San Diego, California, USA.

Hepher, B. 1963. Ten years of research in fishponds fertilization in Israel. 1. The effect of fertilization on fish yields. Bamidgeh 14:29–38.

Hepher, B. 1988. Nutrition of pond fishes. Formerly of fish and aquaculture station, Dor, Israel. The Press Syndicate of the University of Cambridge. Cambridge, England.

Jobling, M. 1994. Fish bioenergetics. Chapman and Hall: London, England.

Keenum, M. E. and J. E. Waldrop. 1988. Economic analysis of farm-raised catfish production in Mississippi. Bulletin 155. Mississippi Agriculture & Forestry Experiment Station, Mississippi State, Mississippi, USA.

Lovell, R. T. 1981. A laboratory manual for fish feed analysis and fish nutrition studies. Department of fisheries and allied aquaculture. Auburn University, Alabama, USA.

Muller, F. 1979. The European and Hungarian results of cage culture of fish. Pages 30–40 *in* SEAFDEC/IDRC International Workshop on Cage and Pen Culture. February 11–22, 1979, Tigbauan, Iloilo, Philippines.

NRC. 1993. Nutrient requirement of fish. National Research Council. National Academy Press, Washington, D.C., USA.

Opuszynski, K. 1981. Comparison of the usefulness of the silver and bighead carp as additional fish in carp ponds. Aquaculture 25:223–233.

Ratafia, M. 1994. Feed suppliers should consider aquaculture market. Feedstuffs 66:10–12.

Shearer, K. D. 1994. Factor affecting the proximate composition of cultured fishes with emphasis on salmonids. Aquaculture 119:63–88.

Siddiqui, A. Q., A. R. Alnajda, and H. M. Alhinty. 1993. Growth, survival and production of hybrid tilapia, common carp, and sharptooth catfish in mono- and polyculture systems during winter in central Saudi Arabia. The Progressive Fish-Culturist 55:57–59.

Spataru, P., G. W. Wohlfarth, and G. Hulata. 1983. Studies on the natural food of different fish species in intensively manured polyculture ponds. Aquaculture 35:283–298.

Weatherley, A. H., and H. S. Gill. 1987. The biology of fish growth. Academic Press, London, England.