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The Development of Small-Scale Hapa Culture of Tilapia (*Oreochromis niloticus*) in Northeastern Thailand. I. Fish Density and Stocking Weight

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Abstract

The growth rate, feed conversion and net production of tilapia cultured in nylon hapas of 8 m^3, was studied in Srisaket, northeastern Thailand. If fish densities were kept sufficiently low to maintain standing crops below the carrying capacity of the hapa, estimated at 25 kg, growth was significantly correlated to initial fish weight. Observed specific growth rates ranged from 2.60% at an initial weight (W_0) of 18 g, to 0.55% at an initial weight of 264 g. The mean feed conversion ratio was 2.13, corresponding to a mean daily feeding level of 2.5% of fish body weight. A power function was fitted to the relation of the specific growth rate and the stocking weights and used to estimate net production for a hypothetical rearing period of 100 days. The recommended fish density is 32 fish·m^{-3} for a stocking weight of 25 g, reaching a harvest weight of about 100 g after 100 days. A second rearing cycle of 100 days at a stocking density of 13 fish·m^{-3} would be required to reach a market size of 234 g. For the hypothetical rearing period of 100 days, depending upon fish density, net hapa production would vary from 20.8 kg (W_0 = 10 g) to 12.2 kg (W_0 = 200 g).

Introduction

Fish production from communal village ponds in northeastern Thailand has been disappointing (Bruns 1987). Total standing crop was as low as 50 $kg \cdot ha^{-1}$ (Middendorp and Verreth, in press) and consisted mainly of wild fish populations, i.e., snakehead (*Channa striata*), walking catfish (*Clarias batrachus*), *Rasbora* and *Danio* sp.

A rational fishery management for these village ponds is virtually impossible because of their large surface and the poor organization of the large number of people involved. By privatizing parts of the common

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water resource, farmers may respond to economic incentives and increase fish production accordingly. The introduction of small-scale hapa culture could be a useful means to reach that goal.

Generally, in northeastern Thailand, farmers are unaware of more intensive fish farming techniques. Cage and hapa culture are not yet popular. Important prerequisites for their widespread introduction are low capital requirements and simple management techniques. Because of the low initial investments, fish culture in artisanally made hapas is preferred above culture in commercially available cages, even when this implies lower productivity. For a successful introduction of small-scale hapa culture in village ponds, guidelines need to be developed for the appropriate technology and management. To support this introduction, the Srisaket Agricultural College set up the Tilapia Hapa Culture Project to work on the following: (a) development of guidelines on stocking density and stocking weight (the present study); (b) development of guidelines on the formulation and use of home-made feeds (Middendorp and Verreth, this vol.); and (c) introduction and economic evaluation of hapa culture among local farmers (Middendorp and Verreth, in press). The Project recommended the use of nylon mosquito net to construct the hapas because it is widely available and cheap, easier to rig and repair than fish nets and is not damaged by crabs or puffer fish (*Tetraodon leiurus*).

The present study sought to develop practical stocking guidelines for hapa culture of tilapia (*Oreochromis niloticus*) by investigating its growth and net production in relation to fish weight at stocking and fish density. The subject was approached by assessing the relationship between initial stocking weight of the tilapia and specific growth rate (SGR). In preliminary trials, the carrying capacity of the hapas used in this study (volume: 8 m^3) appeared to be 25 kg·$hapa^{-1}$. Given this figure and the mentioned relationship between stocking weight and SGR, the optimal fish density can be assessed for each possible combination of stocking weight (available fingerling size), culture period (available labor time) and harvest weight (preferable market size) of the fish.

Materials and Methods

From October 1986 to March 1987, 16 hapas were stocked with tilapia (*O. niloticus*) in two large ponds (> 2 ha) at Srisaket Agricultural College. Fingerlings of both sexes and varying sizes were obtained from the college ponds. Water temperature in the afternoon varied between 25 and 28°C, and pH fluctuated daily between 6.0 and 7.5.

Table 1. Feed composition in percentage of wet weight (commercial floating pellet: Charoen Pokphand Co.). Proximate analysis by the National Inland Fisheries Institute.

moisture	10.1
crude protein	35.4
crude fat	1.9
ash	12.6
NFE	39.9
gross energy ($kJ \cdot g^{-1}$)*	15.9

*Gross energy: 23.8 $kJ \cdot g^{-1}$ protein; 39.7 $kJ \cdot g^{-1}$ fat; 16.7 $kJ \cdot g^{-1}$ NFE.

Hapas were constructed of blue nylon mosquito netting (6 strings/cm, mesh opening 1.5 x 1.5 mm) and measured 3.7 x 1.8 x 1.8 m. They were submerged to a depth of 1.2 m (water volume: 8 m^3). About 2 kg of bricks were tied to each bottom corner. Two hapas were suspended in tandem from one bamboo float (4 x 4 m).

Experimental hapas were stocked as fingerlings were available. For this reason, average stocking size of the fingerlings changed from 18 to 264 g, enabling the assessment of the relation between stocking weight and SGR.

A commercial floating pellet (Charoen Pokphand Co.) for catfish (Table 1) was fed twice a day, *ad libitum*. Feeding commenced 3-6 days after stocking. Rearing time (t) was defined as the number of feeding days and, due to various practical constraints, varied from 34 to 75 days. Fish densities at harvest (N) ranged from 52 to 160 fish per hapa (6.5 to 20 fish/m^3). Since mortalities were rare (overall survival rate was 96%) and occurred only during the first days of the trials, they were assumed to be due to handling, not having influenced the culture densities. Therefore, the final densities (N) were considered to be the experimental fish densities.

Fish were batch-weighed and counted at stocking and at harvest. Average initial (W_0) and final fish weight (W_t) were calculated. The total stocking weight (TW_0) was adjusted for the incurred mortality loss by multiplying W_0 with the (a posteriori determined) experimental fish density N. SGR in % of the body weight per day was calculated as: $((\ln W_t - \ln W_0)/t) \cdot 100$. Total feed consumption could be monitored only per set of two hapas reared simultaneously. For each pair of hapas, feed was given from a separate feed bag weighed at the start and at the end of the experiment. Consequently, also the feed conversion ratio (FCR) was calculated per hapa pair, and was defined as the total amount of feed administered divided by the total weight at harvest (TW_t) minus the (adjusted) total weight at stocking. The average daily feeding rate (R) was calculated as FCR·SGR (% body weight·day^{-1}).

A power relation between SGR and stocking weight was assessed by fitting the linear regression: $\ln(SGR) = a \cdot \ln(W_0) + b$. This relation was further used to calculate several hypothetical production parameters. Because of the wide range of experimental rearing periods, all these production parameters were calculated for a standardized hypothetical rearing period of 100 days. This period was assumed to reflect a realistic rearing period considering the local conditions regarding fingerling supply, preferred fish sizes on the market and local labor availability. For a wide range of stocking weights (between 10 and 200 g), the harvest weight after 100 days (W_{100}) of rearing was estimated by splitting the rearing period into intervals of 10 days for each of which the final weight was calculated from the corresponding initial weight and SGR (as assessed through the mentioned regression analysis). This final weight was subsequently used as the initial weight of the next interval. The corresponding fish density (N_{100}) was calculated from W_{100} and the hapa carrying capacity as: $N_{100} = 25/W_{100}$. The estimated net hapa production (HP) was defined as total yield (25 kg) minus total weight at stocking ($N_{100} \cdot W_0$).

Results

Mean initial weight (W_0) ranged from 17.9 to 264.2 g (Table 2). SGR ranged from 2.60 to 0.55% of body weight·day^{-1} (Table 2). SGR was significantly correlated with W_0. After double logarithmic transformation, the regression analysis yielded a slope of a = -0.4055 and an intercept b = 1.868. The coefficient of determination R^2 explained 59.7% ($P<0.01$) of the total variance (Fig. 1).

FCR varied between 1.05 and 4.23. The mean FCR and feeding rate was 2.13 and 2.5% of the body weight·day^{-1}, respectively. Both averages were strongly influenced by the deviating result of hapa pair no. 2 (Table 3).

Table 2. Total fish weight at stocking (TW_0) and at harvest (TW_t), mean fish weight at stocking (W_0) and at harvest (W_t), stocking density (SD) and fish density at harvest (N), rearing time (t) and specific growth rate (SGR) in tilapia (*O. niloticus*) growout trials in hapas at Srisaket Agricultural College, Thailand. Results refer to hapa means.

	Stocking			Harvest				
Hapa (no.)	TW_0 (kg)	SD (no.)	W_0 (g)	TW_t (kg)	N (no.)	W_t (g)	t (days)	SGR (%)
1	4.8	265	17.9	7.6	118*	64.0	49	2.60
2	3.5	167	21.0	5.9	157	37.6	42	1.39
3	2.2	105	21.0	4.1	98	41.8	42	1.64
4	4.8	143	33.6	9.2	143	64.3	39	1.66
5	5.2	147	35.0	10.0	147	68.0	39	1.70
6	4.0	110	36.4	6.6	96	68.4	34	1.86
7	5.7	152	37.6	14.4	151	95.5	70	1.33
8	5.0	110	45.0	9.6	110	87.3	42	1.58
9	6.9	107	64.5	8.5	106	80.2	34	0.64
10	6.6	88	75.0	17.0	87	195.4	78	1.23
11	7.1	88	80.7	15.5	85	182.4	78	1.05
12	8.9	102	87.3	16.2	89	181.5	70	1.05
13	4.8	164	90.2	23.4	160	146.3	44	1.10
14	10.2	82	124.4	19.7	77	255.8	44	1.64
15	12.2	60	203.3	19.3	56	344.6	75	0.70
16	14.0	53	264.2	20.8	52	400.0	75	0.55

*estimated from a sample.

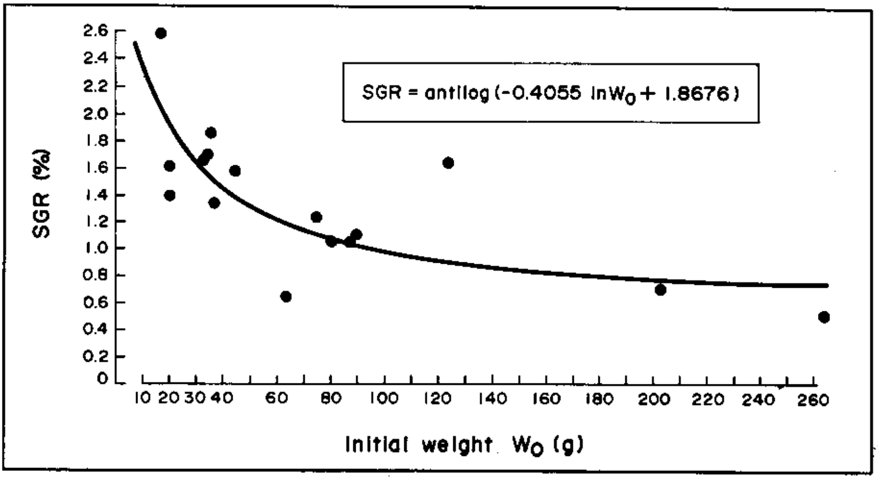

Fig. 1. The specific growth rate (% body weight·day^{-1}) of tilapia (*Oreochromis niloticus*) reared in small-scale hapas in communal village ponds of northeastern Thailand, in relation to the initial stocking weight of the fish.

Table 3. Growth, feed conversion and feeding ratio in experimental hapa culture of tilapia (*Oreochromis niloticus*). Data refer to means per pair of hapas reared simultaneously.

Data pair no.	1	2	3	4
Hapa no.	(4;5)	(6;9)	(13;14)	(15;16)
W_0 (g)	34.3	50.2	101.6	231.9
SGR (% body weight·day^{-1})	1.69	1.17	1.32	0.63
FCR	1.51	4.23	1.05	1.72
R (% body weight·day^{-1})	2.56	4.95	1.38	1.09

In the hypothetical rearing model, final fish weight after 100 days of rearing (W_{100}) was proportional to fish weight at stocking (Fig. 2). Concomitantly, maximum fish density decreased with increasing stocking weight. Net hapa production estimations decreased from 20.8 kg·hapa^{-1} when fingerlings of 10 g were stocked at maximum density of 417 fish·hapa^{-1} to 12.2 kg·hapa^{-1} for a stocking weight of 200 g and a stocking density of 64 fish·hapa^{-1} (Fig. 2).

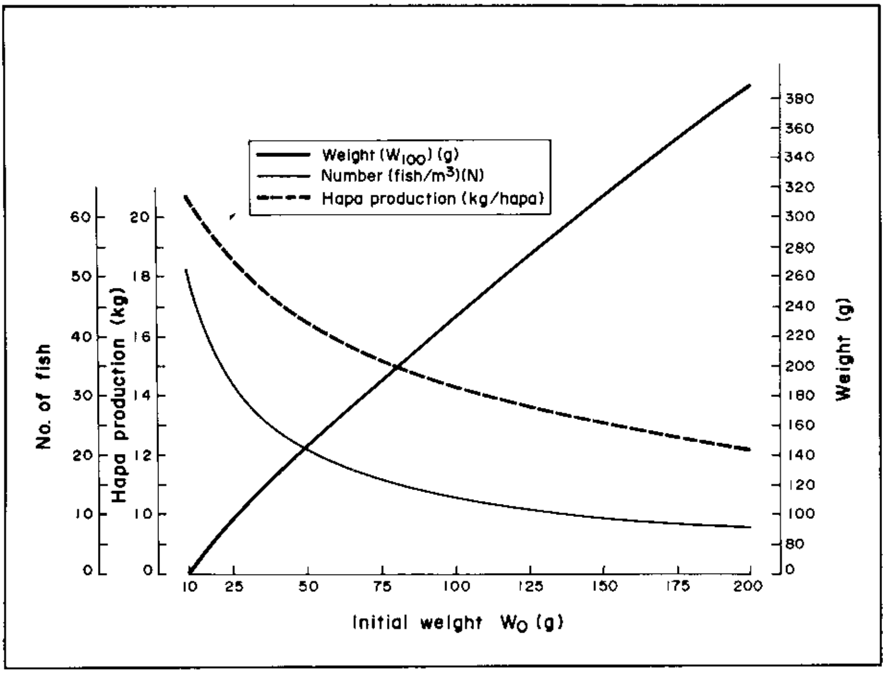

Fig. 2. Optimal fish density (N/hapa), the final fish weight (g), yield and net production (kg/hapa) of tilapia (*Oreochromis niloticus*) reared during 100 days in small-scale hapas in communal village ponds of northeastern Thailand. Data are estimated from the combination of (a) the fish growth rate in relation to the stocking weight as assessed experimentally (see Fig. 1) and (b) a preliminary measured hapa carrying capacity of 25 kg.

Discussion and Conclusions

In preliminary trials, growth slowed down at higher biomass, apparently reaching a carrying capacity at about 25 kg per hapa, i.e., about 3 kg fish·m^{-3}. In these preliminary trials, a total loss of appetite was observed, and especially among the larger fish, mortalities occurred. Also, at dawn, fish in the hapas were gulping air, whereas the fish in the pond did not. It is therefore hypothesized that the low carrying capacity of the hapas was related to limiting oxygen conditions or other adverse water quality conditions caused by clogging of the mosquito nets. The projected hapa production parameters were indirectly based on this carrying capacity through the estimation of "safe" and therefore recommendable maximum fish densities. To prevent the fish biomass to bypass at any time the carrying capacity of the hapas, for the different stocking weights, the corresponding fish densities (N_{100}) were calculated by dividing the carrying capacity by the estimated final weights (W_{100}).

In the present study, the relation between SGR and stocking weight was used to calculate different production parameters for a hypothetical fixed rearing period of 100 days. The same relation can be used to evaluate the effect of rearing time at a fixed stocking weight. For whatever stocking weight used, the estimated final weights increased almost linearly with increasing rearing time (Fig. 3). This corroborates well with literature data, where such a constant increase in mean weight with time ($W_t < 200$ g) is commonly observed for tilapia fingerlings (Edwards et al. 1985; Papoutsoglou and Voutsinos 1988; Siddiqui et al. 1988).

In the experimental trials, the average FCR was 2.13. This is in the same range as reported in other studies. Siddiqui et al. (1988) reported FCR values between 1.70 and 2.82 for *O. niloticus* juveniles of about 40 g reared in tanks and fed diets with a protein content ranging from 20 to 50% at a feeding level of 3% of body weight·day^{-1}. Also in tank cultures, the FCR for *Tilapia aureus* (initial weight about 65 g) increased from 1.42 to 1.52 and from 2.35 to 2.99, for feeding levels of 1-2% and 3-4%, respectively, of body weight·day^{-1}, with a diet containing 47.5% protein (Papoutsoglou and Voutsinos 1988). However, the average FCR obtained in this study was strongly influenced by the result of hapa pair no. 2 (4.23 against 1.05, 1.51 and 1.72 for the other three pairs) (Table 3). This deviating result can only be explained by the procedure with which the amount of administered feed was measured. It did not allow separation between feed losses due to theft or any other cause and the amount

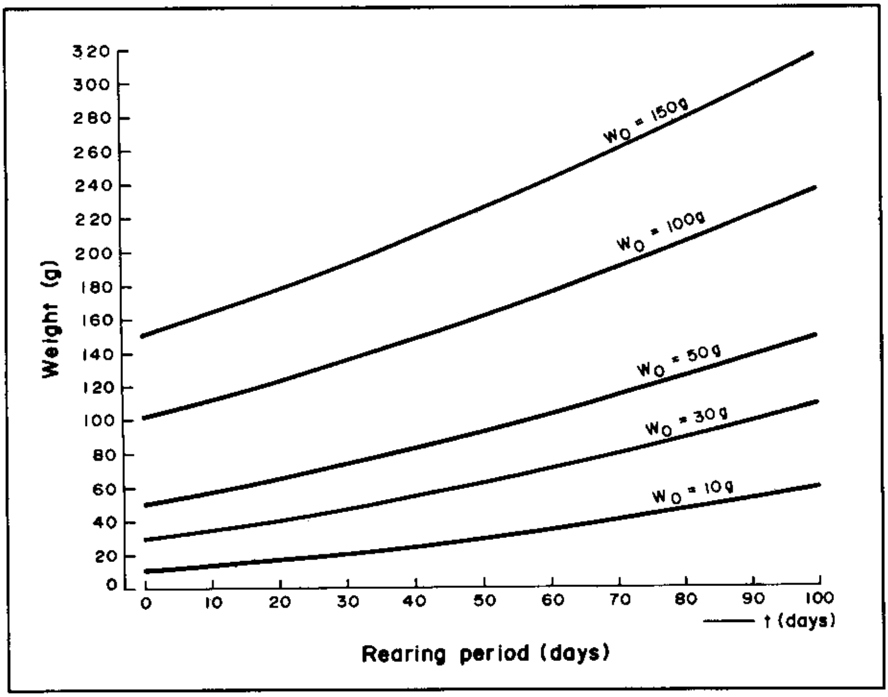

Fig. 3. The effect of rearing time on the final weight of tilapia (*Oreochromis niloticus*) reared in hapas, in relation to the initial stocking weights. Data are estimated from the empirically assessed relation between SGR and initial stocking weight (see also Fig. 1).

actually fed to the fish. Three of the four hapa pairs showed a very favorable FCR compared to literature data. Also, in village trials under circumstances similar to the present study, an average FCR of 1.42 was obtained in hapa cultures of tilapia (Middendorp and Verreth, in press). It is hypothesized that these low FCR values are partially due to the low daily feeding rates. The tilapia were seen nibbling all day on periphyton growing on the sides of the hapas. The phytoplankton, blooming due to the fertilization effect of fish feces and uneaten feed, may also have contributed to the tilapia growth (Edwards 1980, quoted in Schroeder 1983a; Schroeder 1983b; Spataru et al. 1983; Edwards et al. 1985).

The present study is the first step in the development of an appropriate technology for semi-intensive cage rearing of tilapia in northeastern Thailand. Small hapas (8 m^3) made of mosquito net were used because they correspond to the prerequisites of low capital and management requirements set by the target group. The small hapas are easily handled by one or two persons. The bamboo sticks needed to construct the float can be collected in communal bamboo stands. A major disadvantage of using mosquito net in hapas of this size, is the limited water exchange leading to relatively low productivities. In the present study, the net hapa production varied between 4 and 7 $kg{\cdot}m^{-3}{\cdot}month^{-1}$, whereas in cages with larger mesh sizes, production of 10-25 $kg{\cdot}m^{-3}{\cdot}month^{-1}$ can be obtained with the same species (*O. niloticus*) (Balarin and Haller 1982). Extension workers of the Tilapia Hapa Culture Project learned however, that in northeastern Thailand, small-scale farmers were not prepared to invest the capital required to construct cages made of fish nets with a larger mesh size.

The final recommendations are based on a standardized hypothetical rearing period of 100 days. This period was chosen because of local socioeconomic conditions. In northeastern Thailand, rice farmers prefer short rearing cycles (85 days, Middendorp and Verreth, in press) to limit their risks. On the other hand, fish need sufficient growout time to reach market size (200-250 g).

Fish production and the appropriate fish density are calculated from the theoretical production model (Fig. 2). Fingerlings of 25 g need two rearing cycles of 100 days to reach a size which is well accepted in the market (Table 4). In the first rearing cycle and at a density of 32 $fish{\cdot}m^{-3}$, they would attain a final weight of nearly 100 g. At the end of the second rearing cycle and at a density of 13 $fish{\cdot}m^{-3}$, they would reach 234 g. Fingerlings of 50 g would attain 150 g in the first cycle (density = 21 $fish{\cdot}m^{-3}$) and 314 g in the second cycle (density = 10 $fish{\cdot}m^{-3}$). The net production per hapa decreases from 18.5 kg at an initial fish weight of 25 g to 14.3 kg for an initial fingerling size of 100 g (Fig. 2). Therefore, stocking fingerlings above 50 g is not recommended.

Table 4. Production parameters of tilapia culture in hapas, as estimated from the regression correlation $\ln(SGR) = -0.4055 * \ln(W_0) + 1.868$ (see Fig. 2) and the empirically observed hapa carrying capacity of 25 kg per hapa. The hapa volume was 8 m^3.

W_0 (g)	10	20	25	30	40	50	100	150	200
W_{100} (g)	60	85	97	108	128	147	234	314	390
N ($fish{\cdot}hapa^{-1}$)	417	294	258	231	195	170	107	80	64
N ($fish{\cdot}m^{-3}$)	52	37	32	29	24	21	13	10	8
Y_{100} ($kg{\cdot}hapa^{-1}$)	25	25	25	25	25	25	25	25	25
HP ($kg{\cdot}hapa^{-1}$)	20.8	19.1	18.6	18.1	17.2	16.5	14.3	13.1	12.2

In Thailand, usually government hatcheries supply fingerlings at a size of about 1 g. Under local circumstances in northeastern Thailand, often fingerlings of 20-50 g may be available from backyard ponds and/ or ricefields. Hapa culture would make efficient use of these fingerlings.

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References

Balarin, J.D. and R.D. Haller. 1982. The intensive culture of tilapia in tanks, raceways and cages, p. 265-355. *In* J.F. Muir and R.J. Roberts (eds.) Recent advances in aquaculture. Croom Helm, London.

Bruns, B. 1987. Performance and potential: a survey of small-scale weirs and reservoirs in Khon Kaen. Small-Scale Irrigation Systems Project, Water Resources and Environment Institute, Khon Kaen University, Khon Kaen, Thailand. 35 p.

Edwards, P., M. Kamal and K.L. Wee. 1985. Incorporation of composted and dried water hyacinth in pelleted feed for tilapia *Oreochromis niloticus* (Peters). Aquacult. Fish. Manage. 1:223-248.

Middendorp, J. and J. Verreth. The feasibility of small-scale hapa culture of tilapia (*Oreochromis niloticus*) as a side activity for rice farmers in Northeast Thailand. Asian Fish. Sci. (In press).

Papoutsoglou, S.E. and G.A. Voutsinos. 1988. Influence of feeding level on growth rate of *Tilapia aureus* (Steindachner) reared in a closed circulated system. Aquacult. Fish. Manage. 19:291-298.

Schroeder, G.L. 1983a. The role of natural foods in tilapia growth: a study based on stable isotope analyses, p. 313-322. *In* L. Fishelson and Z. Yaron (eds.) International Symposium on Tilapia in Aquaculture. Tel Aviv University, Tel Aviv, 624 p.

Schroeder, G.L. 1983b. Sources of fish and prawn growth in polyculture ponds as indicated by δ C analysis. Aquaculture 35:29-42.

Siddiqui, A.Q., M.S. Howlader and A.A. Adam. 1988. Effects of dietary protein levels on growth, feed conversion and protein utilization in fry and young nile tilapia, *Oreochromis niloticus*. Aquaculture 70:63-73.

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

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