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# Effect of Protein Level in Supplemental Diets on the Growth of Cage-Cultured Nile Tilapia in the East Lake, P.R. China

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## Abstract

Five diets containing different protein levels from 15.8% to 35.6% were fed to Nile tilapia *(Oreochromis niloticus)* reared in net cages in the eutrophic East Lake in Wuhan, Hubei, P.R. China, to investigate the protein requirement in the supplemental diet. After the 87- day feeding trial, the results shows that specific growth rate of tilapia fed the diets containing 15.8-25.5% and 25.5-36.5% protein were not significantly different. It was suggested that 15.8-25.5% dietary protein in the supplemental diet was sufficient for the optimum growth of cage-cultured tilapia in a eutrophic water body like the East Lake. This requirement is much lower than the level determined from laboratory studies. Fish body dry matter decreased with increased dietary protein levels while crude protein, crude fat, ash or energy content was not significantly affected.

## Introduction

Nile tilapia (*Oreochromis niloticus*) is a widely-cultured species all over the world. The nutrient requirements have been reported by several authors (Santiago et al. 1982; Wang et al. 1985; Santiago and Lovell 1988; Northcote et al. 1991; El-Sayed and Teshima 1992; Getachew 1993). But most of these experiments were carried out under controlled conditions, with artificial diet as the only source of nutrients. In developing countries, intensive culture of tilapia, with artificial diets as the major source of nutrients, is not always economical because the price of fish is low relative to that of feed ingredients, and semi-intensive culture is more widely practiced. Few studies, however, have been made on the scientific formulations of supplemental diets in semi-intensive culture of tilapia and, in many situations, either nutrient-complete diets or a mixture of cheap raw materials are used. It can be assumed that tilapia require less dietary protein under semi-intensive culture than under intensive culture because they can obtain a substantial amount of nutrients from natural foods. Though there have been some reports on supplemental feeds for tilapia (Santiago et al. 1985; Chiayvareesajja et al. 1988; Hargreaves et al. 1988; Diana et al. 1994), information on the protein requirement for cage cultured Nile tilapia, especially in eutrophic water bodies, is not available. This experiment was designed to investigate the effect of protein level in supplemental diets on Nile tilapia (*Oreochromis niloticus*) cultured in cages in a eutrophic lake - the East Lake, P.R. China.

## Materials and Methods

An on-farm experiment was conducted in net-cages in the East Lake in Wuhan Hubei, P.R. China. The lake has an area of 28 $km^2$ (Cai 1990) and mean water depth of 2.21m. Mean limnological parameters at the study site were: total dissolved nitrogen 11.9 mg/L, ammonia nitrogen 1.24 mg/L, total dissolved phosphorus 0.176 ug/L, phytoplankton biomass 11.52 mg/L, and zooplankton biomass 1.99 mg/L (Shei et al. 1992 ). During the study period (July to September 1995), mean plankton biomass was 0.457 mg/L for Cladocera and Copepoda (Yang, personal communication). Mean density of phytoplankton was $0.98 x 10^5$ ind/mL (Lei, personal communication). Such eutrophic lakes are common along the middle and lower reaches of the Yangtze River and have been widely used for aquaculture.

Fifteen net-cages (5×2.5×3 m) were used. The bottom of the cage almost reached the bottom of the lake (2.3 m deep in the water) and the upper rim is 0.7 m above the water surface. A food platform (2×1 m) was fixed at the middle of each cage.

Five isoenergetic practical diets were formulated to contain protein levels of 35, 30, 25, 20 and 15%, respectively (Table 1). Due to the incorrect evaluation of protein content of ingredients, the determined protein level were somewhat different from the designed. The diets were made into different sizes

Table 1. Nutrient formulation and chemical composition of experimental diets (% or J/mg of wet weight)

| Diets | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Fish meal[1] | 11.5 | 10.0 | 8.4 | 6.6 | 5.0 |
| Soybean meal | 37.0 | 30.0 | 19.2 | 11.1 | 0.4 |
| Rapeseed meal | 35.0 | 25.0 | 20.0 | 12.9 | 5.6 |
| Wheat | 8.5 | 27.0 | 44.4 | 61.4 | 81.0 |
| Vitamin premix[2] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Mineral premix[3] | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Vegetable oil | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Protein | 36.5 | 31.6 | 28.1 | 25.5 | 15.8 |
| Lipid | 11.7 | 9.7 | 6.8 | 6.8 | 5.6 |
| Ash | 12.7 | 12.3 | 9.0 | 7.1 | 4.8 |
| Fibre | 6..9 | 7.2 | 5.0 | 3.7 | 2.7 |
| Gross energy (J/mg) | 14.54 | 14.39 | 13.85 | 14.88 | 14.08 |
| Moisture | 9.9 | 13.1 | 13.8 | 10.4 | 10.9 |

1 The fishmeal used in the experiment was from Peru; soybean meal and rapeseed meal was solvent extracted.

[2] Vitamin premix (g): B1, 10; B2,20; B6, 10; B12, 2; A, 4; D3, 0.4; K3, 80; folic acid, 5; calcium patotheniate, 40; inositol, 400; niacin, 150; E,60; choline, 6000; C, 500; wheat powder, 218.6.

[3] Mineral premix (g): NaCl, 0.25; $MgSO_4$, 3.75; $KH_2PO_4$, 8; $Ca(H_2PO_4)$, 5; $FeSO_4$, 0.72, $(CH_2CHCOO)_2Ca.5H_2O$, 0.88; $ZnSO_4.7H_2O$, 0.088; $MnSO_4.4H_2O$, 0.040; $CuSO_4.5H_2O$, 0.008; $CoCl_2.6H_2O$, 0.00025; $KIO_3.6H_2O$, 0.00075; Wheat powder, 0.112.

( 0.1-2 mm diameter) using a pellet presser. Three cages were randomly assigned to each diet.

Nile tilapia used for the experiment were collected from Puqi Fish Hatchery Farm in Hubei Province, P.R. China, and reared in three large cages for two months prior to the experiment. At the start of the experiment, about 50 fish from each of the three cages were measured for initial body weight and composition. Initial weight of the fish was 4.2±0.5 g (mean ± s.e). One thousand and five hundred fish were then stocked into each experimental cage.

The feeding trial lasted for 87 days from 28 June to 26 September 1995. During the experimental period, fish were fed twice a day at 3% of body weight in July and 2.5% in August and September. Once a month, about 3 kg (10 to 100 individuals) of fish were randomly sampled from each cage, weighed and counted. The feed amount was adjusted according to total biomass, assuming there was no mortality. During each month, the feed amount was held constant. Water temperature was recorded daily. Dissolved oxygen and water pH were measured every two weeks. Water temperature ranged from 23-36 °C, dissolved oxygen was 3-10 mg/L (mostly greater than 4 mg/L), and pH was 6.8.

At the end of the trial, all fish from each cage were weighed. About 300 fish were sampled from each cage, weighed and counted to estimate mean body weight. Number of fish surviving to the end of the experiment was estimated from the total biomass and mean body weight of fish from the cage. More than 300 g of fish (2-4 individuals) were sampled from each cage and frozen for chemical analysis.

Proximate chemical composition and energy content were measured for the feed and fish samples. Crude protein content was analyzed by Kjeldahl method and crude fat content by ether extraction. Fiber (measured for feeds only) was determined for the diets by drying and ashing after the extraction with 0.5M $H_2SO_4$ and 0.5M NaOH. Ash content was determined after 12h at 550 °C in the muffle furnace (AOAC 1984). Gross energy was measured by bomb calorimetry (Gentry, Philipson Instruments Inc., USA).

The following parameters were measured or calculated.

Specific growth rate (SGR: %/day) = 100 ×·(Ln(final body weight)-Ln(initial body weight)) / feeding days.

Feed efficiency (FE: %) = 100 × weight gain / feed intake.

Protein retention rate (PR: %) = ((crude protein in final fish body × final biomass)-(crude protein in initial fish body × initial biomass)) × 100 / (crude protein in the diet × total feed intake).

Energy retention rate (ER: %) = energy increase in fish body × 100 / energy intake in food

The average differences between groups were subjected to the multiple range test (LSD) after ANOVA. Differences were regarded significant if p values were less than 0.05.

## Results

### *Growth and feed utilization*

The change of average body weight throughout the experimental period is shown in Fig. 1. Dietary protein level significantly affected specific growth rate and protein retention rate, but not feed efficiency or energy retention rate

(Table 2). The specific growth rate of the fish fed the diet containing 15.8% protein was significantly lower than that of the fish fed the diet of 31.6% protein ($p<0.05$), while no significant differences existed between other groups ($p>0.05$). Protein retention rate of the fish fed the diet containing 15.8% dietary protein was significantly higher than other groups ($p<0.05$). The survival rate of the fish fed the diet containing 15.8% dietary protein was significantly higher than that of the fish fed the diets containing 25.5% and 31.6% ($p<0.05$). There are no significant differences in the energy retention rate between the fish fed the diets containing different protein levels ($p>0.05$).

***Body composition***

Final dry matter content of fish tissues was significantly affected by dietary protein ($p<0.05$) (Table 3). Fish fed diet with 36.5% protein had higher dry matter content than those fed diets with 15.8-25.5% protein. Dietary protein had no significant effect on body protein, lipid or ash content ($p>0.05$).

## Discussion

In the present study, survival rates were variable among dietary groups and were low in some groups. It is not clear whether survival rate was related to diet or some other unknown factors. The East Lake has poor water quality (Zhang et al. 1984 ), and outbreaks of fish kills occur often in the open

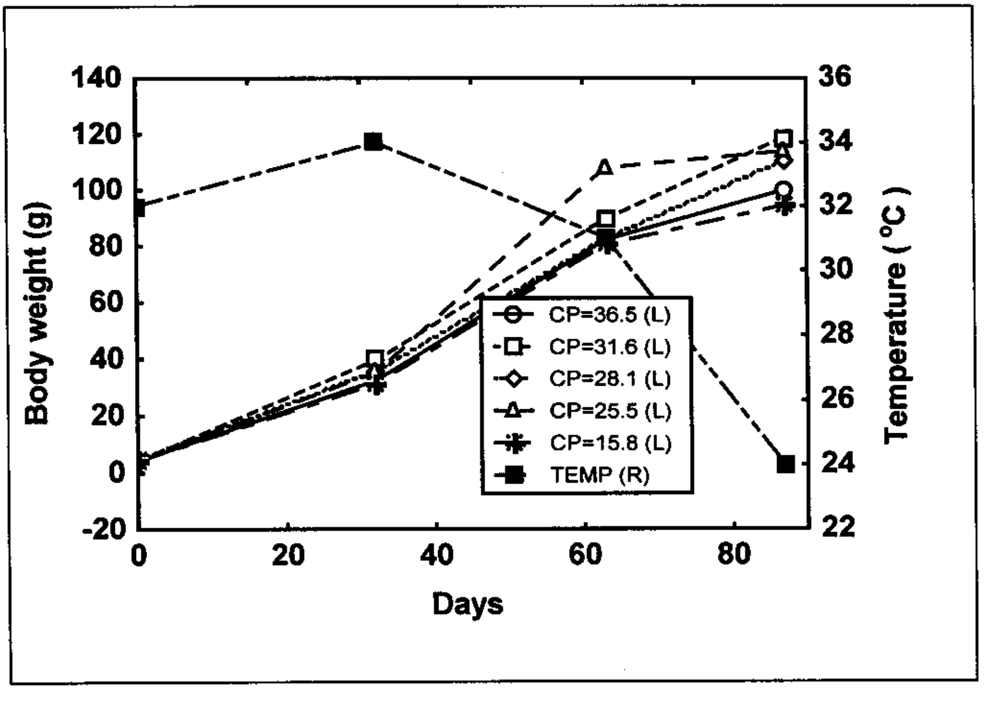


Fig. 1 Effects of dietary protein level on weight changes of Nile tilapia cage-cultured in a eutrophic lake over the experimental period. Also shown are changes in water temperature.

Table 2. Effects of dietary protein levels on growth and feed utilization of cage-cultured tilipia[1,2]

| Protein level (%) | 15.8 | 25.5 | 28.1 | 31.6 | 36.5 |
|---|---|---|---|---|---|
| FBW | 94.58a | 113.89ab | 110.17ab | 114.54b | 99.94ab |
| s.e. | 8.49 | 7.10 | 6.89 | 6.57 | 8.27 |
| SGR | 3.58a | 3.80ab | 3.76ab | 3.84b | 3.64ab |
| s.e. | 0.10 | 0.07 | 0.07 | 0.05 | 0.09 |
| SURVIVAL | 94.96b | 56.08a | 76.21ab | 62.99a | 93.24ab |
| s.e. | 11.91 | 16.18 | 9.77 | 5.35 | 2.48 |
| FE | 154.64 | 106.44 | 122.52 | 83.98 | 114.95 |
| s.e. | 18.43 | 33.06 | 9.23 | 32.38 | 26.57 |
| PR | 133.3a | 64.7b | 58.2b | 54.6b | 51.4b |
| s.e. | 14.84 | 24.25 | 5.50 | 1.39 | 13.65 |
| ER | 66.2 | 44.4 | 54.1 | 48.6 | 53.3 |
| s.e. | 8.35 | 17.37 | 2.62 | 0.62 | 13.01 |

[1] Initial body weight was 4.18±0.50g.
[2] Means followed by different letters show significant difference ($p<0.05$).
3 FBW: final body weight (g)
SGR: specific growth rate in wet weight (%/day)
SURVIVAL: survival rate (%)
FE: feed efficiency (%)
PR: protein retention rate (%)
ER: energy retention rate (%)

Table 3. Effects of dietary protein levels on fish body composition (% or J/mg of wet weight)[1,2]

| Protein levels (%) | 36.5 | 31.6 | 28.1 | 25.5 | 15.8 |
|---|---|---|---|---|---|
| Dry matter (%) | 32.51ab | 30.23a | 29.40ab | 29.64ab | 29.01b |
| s.e. | 2.07 | 0.27 | 0.42 | 0.10 | 0.82 |
| Crude protein (%) | 16.84 | 15.85 | 15.54 | 15.71 | 15.44 |
| s.e. | 1.27 | 0.24 | 0.17 | 0.34 | 0.31 |
| Crude fat (%) | 9.01 | 8.22 | 8.35 | 8.60 | 7.89 |
| s.e. | 0.27 | 0.50 | 0.25 | 0.04 | 0.94 |
| Ash (%) | 5.00 | 4.74 | 4.58 | 4.73 | 5.05 |
| s.e. | 0.51 | 0.24 | 0.09 | 0.13 | 0.21 |
| Energy (J/mg) | 6.91 | 6.40 | 6.27 | 6.44 | 6.19 |
| s.e. | 0.43 | 0.12 | 0.19 | 0.02 | 0.15 |

[1]Initial fish body composition was: 19.69% dry matter, 10.51% crude protein, 3.84% fat, 3.24% ash and 3.76 J/mg gross energy.
[2] Means followed by different letters show significant difference ($p<0.05$).

(Xu, personal communication). Because of the variable survival, no analysis was made on the fish yield.

There was no significant difference in specific growth rate between fish fed diets containing 25.5-36.5% dietary protein and those fed 15.8-25.5% dietary protein, suggesting that 15.8-25.5% protein in supplemental diets was sufficient for optimum growth of Nile tilapia under semi-intensive culture conditions in the eutrophic East Lake. This protein level was much lower than the protein requirements (30-35%) of Nile tilapia fry or fingerlings under laboratory conditions (Santiago et al. 1982; Wang et al. 1985). Our present result was similar to that reported by Wannigama et al. (1985) (optimum dietary protein: 19-29%) for Nile tilapia juveniles in outdoor cages in Udawalawe reservoir. The results support our hypothesis that tilapia under semi-intensive culture conditions require less protein from artificial diets than fish under intensive culture. The cost of feed can be greatly reduced by using a low-protein diet. The hypothesis was also supported by results in catfish. The protein requirement for pond-cultured catfish (25%, Deyoe et al. 1968) was also much lower than that in catfish cultured in the laboratory (35%, Page and Andrews 1973).

The lack of differences in feed efficiency and energy retention among different dietary groups is probably because the diets were made iso-energetic and the fish may be able to obtain substantial amounts of protein from protein-rich natural diets, i.e. zooplankton, which has a high biomass in the lake. Protein retention rate in fish fed diet with 15.8% protein was much higher than in those fed diets with higher proteins. Most laboratory studies also suggested that protein retention decreased with increased dietary protein level (Dabrowski 1977; Mazid et al. 1979; Papaparaskeva-Papoutsoglon and Alexis 1986; De la Higuera et al. 1989 ). Protein retention rates determined in this study (51-133%) were much higher than the values of 49-75% determined for Nile tilapia under laboratory conditions (Wang et al. 1985), and were also higher than those determined for several other fish species, i.e. 9.6-29.0% for eel (Degani and Viola 1987), 12.1-34.3% for carp and 11-23% for rainbow trout (Steffens 1981), 28-77% for Tilapia zillii (Mazid et al. 1979), 21-46% for *Tilapia mossambica* (Jauncey 1982) and 16-28% for grey mullet (Papaparaskeva-Papoutsoglou and Alexis 1986), suggesting that tilapia under semi-intensive culture obtains substantial amounts of protein from natural food.

In the present study, the dry matter of fish tended to decrease with decreasing dietary protein. Although this is similar to results in striped bass (Millikin 1982), some authors have reported increased dry matter content with an increase in dietary protein (Satia 1974; Austreng and Refstie 1979; Mazid et al. 1979; Jauncey 1982; Wee and Tacon 1982). Still, others have concluded that the dry matter of fish body was not affected by dietary protein (Anderson et al. 1981; Wang et al. 1985; Papaparaskeva-Papoutsglou and Alexis 1986).

Crude protein, fat and energy contents of tilapia in the present study were not significantly different among the fish fed the diets containing different protein levels. This is different from some other reports which showed increased protein content and decreased fat content in fish body when the dietary protein increased (Satia 1974; Austreng and Refstie 1979; Mazid et al. 1979; Jauncey 1982; Wee and Tacon 1982). Wang et al. (1985) reported that both crude protein and lipid in fish body increased with dietary protein levels and Millikin (1982) reported both fish body protein and fat decreased with increased dietary protein.

A major limitation of the present study is that the results may change with variations in the limnological conditions of the study site. This is also a common problem with on-farm studies of semi-intensive fish farming. Though the major limnological parameters were measured, for the results to be comparable to other semi-intensive culture conditions, it will be desirable to quantify the contribution of natural food to the nutrition of cage-cultured fish. Analysis of consumption of natural food by cage-cultured tilapia is under way, using approaches of bioenergetics modeling and periodic sampling of stomach contents over a diel cycle.

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