EFFECT OF DIETARY PROTEIN LEVELS ON GROWTH PERFORMANCE AND PROTEIN UTILIZATION IN NILE TILAPIA *(Oreochromis niloticus* L.) WITH DIFFERENT INITIAL BODY WEIGHTS

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Abstract

The effect of dietary protein levels (25%, 35% and 45%) on growth, survival, feed utilization and body composition of Nile tilapia; *Oreochromis niloticus* L. were investigated for three sizes. The different sizes were fry size (0.4 to 0.5 g/fish), fingerlings size (17 to 22 g/fish) and adult size (37 to 43 g/fish). Fish were fed frequently to satiation for 5 days a week for 70 days.

Results showed that fish growth was significantly affected by protein level and fish size, however, the interaction among the two studied factors was insignificant. The highest growth performance of fry were obtained with 45% protein diets and the poorest one was obtained with 25% protein diet ($P<0.05$). Fingerlings and adults showed the optimum growth performance with 35% and 45% protein diets with insignificant difference ($P>0.05$). The survival rate of each fish group at dietary protein levels or among different Nile tilapia sizes was unaffected.

Also, results mentioned that feed intake and feed conversion ratio (FCR) were significantly affected by protein level, fish size and their interaction. FCR ranged from 1.49-1.81 for fry, from 1.92 to 2.22 for fingerlings and from 2.29 to 2.79 for adult fish ($P<0.05$). Protein utilization parameters i.e. protein efficiency ratio (PER), protein productive value (PPV) and protein growth rate (PGR) were significantly affected by protein level and fish size, but not affected by their interaction. The lowest PER were obtained with 45% protein diets for fry, fingerlings and adult tilapia with significant difference among fish sizes ($P<0.05$). PPV exhibited the same trend of PER for fry and fingerlings where the lowest values of PPV were obtained at using the 45% protein diet, while the lowest PPV of adult tilapia w as obtained with 35% and 45% levels with insignificant difference. Similarly, PGR was inversely affected by increasing fish size. It was insignificantly increased with increasing dietary protein level for fingerlings and adult fish and ranged from 1.00% to 1.24% for fingerlings and 0.69% to 0.89% for adult fish. In case of fry, the highest PGR was obtained with 45% protein diet (4.32%), while it has approximately similar values with 25% and 35% protein diets (3.98% and 3.94%, respectively; $P>0.05$).

Results of body composition showed that protein and lipids contents were significantly affected by protein level and fish size, but not affected by their interaction. Ash was only affected by fish size. Protein content was significantly increased ($P<0.05$) with increasing protein levels in the diets for fry, fingerlings and adult fish. In contrast, lipid content was inversely affected by increasing the dietary protein level at each size. Ash content in whole fish body was unaffected by dietary protein levels at all fish sizes. Moreover, differences in ash contents among fingerlings and adult fish were insignificant and both were significantly higher than that of fish fry.

Introduction

Tilapias are considered as the best species for culture because of their high tolerance to adverse environmental conditions, their relatively fast growth and they could be easily breed (El-Sayed, 1999). Tilapia intensive culture would require the formulation of efficient food with optimum potency to meet the protein requirements in fish culture during grow-out period (Kenawy, 1993).

Protein is the main constituent of the fish body thus sufficient dietary supply is needed for optimum growth. Protein is the most expensive macronutrient in fish diet (Pillay, 1990). So, the amount of protein in the diet should be just enough for fish growth where the excess protein in fish diets may be wasteful and cause diets to be unnecessarily expensive (Ahmad, 2000). Reducing feeding costs could be a key factor for successful development of aquaculture.

Protein requirements for optimum growth of the fish seem to be affected by numerous factors such as temperature, salinity, fish age and size, etc. (Cowey, 1976). Most studies are confined to fry and young tilapia, although the supplementary feed is used during grow-out phase. Furthermore, understanding the protein requirement during the grow-out period is an important thing in fish culture management. Realization of the optimum protein level for cultured fish would help reduce the costs and maximize the feed conversion efficiency (Charles *et al.*, 1984; Sampath, 1984; Chiu *et al.*, 1987). Therefore, the objective of this study was to assess the optimum protein level leading to optimum growth and feed utilization of different weights of Nile tilapia, *Oreochromis niloticus* L.

Materials and methods

The experimental design

Three groups of healthy fish of Nile tilapia, *Oreochromis niloticus* L. with different sizes were obtained from Abbassa fish hatchery, General Authority for Fish Resources Development, Abbassa, Abo-Hammad, Sharkia, Egypt. Fry size ranged from 0.4 to 0.5 g/fish, fingerlings size ranged from 17 to 22 g/fish and adult size ranged from 37 to 43 g/fish. Fish were acclimated in indoor tanks for 2 weeks where they were fed a commercial diet containing 25% CP. Weight of 200 gm of each size was frozen at -20 ^{o}C for chemical analyses. The fish of mixed sex of each size were distributed randomly in glass aquaria

(75x60x50 cm) containing 100 liter aerated water at a rate of 10 fish/aquarium. Each aquarium was supplied with compressed air via air-stones from air pumps (Boss 9500, Germany). Well-aerated water supply was provided from a storage fiberglass tank. The temperature was adjusted at 27±1^{o}C by using thermostatically controlled heaters. Siphoning a portion of water from each aquarium was done every day for excreta removal and then replaced with an equal volume of water.

Fish diets and feeding regime

A semi-moist basal diet was prepared from purified ingredients and was used to formulate three identical diets in all the nutrient contents except for the protein levels (Table 1). The formulated diets contained 25%, 35% and 45% crude protein. Each of the three diets was fed to fry, fingerlings and adult fish. Three aquaria were randomly assigned for each treatment. Fish were fed frequently to satiation for 5 days a week for 70 days. The amount of consumed feed for each aquarium was subsequently calculated. Fish in each aquarium was biweekly weighed. Dead fish were removed and recorded daily.

Proximate analysis of diet and fish

The tested diets and fish from each treatment were chemically analyzed according to the standard methods of AOAC (1990) for moisture, protein, fat and ash. Moisture content was estimated by heating samples in an oven at 85^{o}C till constant weight and calculating weight loss. Nitrogen content was measured using a microkjeldahl apparatus and crude protein was estimated by multiplying nitrogen content by 6.25. Total lipids content was determined by ether extraction for 16 hr and ash was determined by combusting samples in a muffle furnace at 550 ^{o}C for 6 hr. Crude fiber was estimated according to Goering and Van Soest (1970).

Growth parameters

Growth performance was determined and feed utilization was calculated as described by Sveier *et al.* (2000) as follows:

$$\text{Weight gain} = W_2 - W_1$$
$$\text{Specific growth rate (SGR)} = 100 (\ln W_2 - \ln W_1) / T$$

where W_1 and W_2 are the initial and final fish weight, respectively, and T is the number of days in the feeding period.

$$\text{Feed conversion ratio (FCR)} = \text{Feed intake} / \text{Weight gain}$$
$$\text{Protein efficiency ratio (PER)} = \text{Weight gain} / \text{Protein intake}$$
$$\text{Protein productive value (PPV)} = \text{Protein gain} / \text{Protein intake}$$
$$\text{Protein growth rate (SGR)} = 100 (\ln P_2 - \ln P_1) / T$$

where P_1 and P_2 are the initial and final protein content in fish, respectively, and T is the number of in the feeding period.

Statistical analysis

Data on growth, feed utilization, survival rate and proximate and chemical composition of whole fish body were subjected to two-way ANOVA following Snedecor and Cochran (1982). To locate significant differences between fish size within protein levels, the data were analyzed with a one-way ANOVA to obtain the error mean square needed for Duncan' s multiple rang test (Duncan, 1955).

Results

Growth performance

As shown in Table 2 growth performance of Nile tilapia was significantly affected by protein level and its initial size, while the interaction of both factors does not affect the growth parameters except SGR. The highest growth (final weight, gain, gain % and SGR) of Nile tilapia fry were obtained with the 45% protein diet followed by those fed 35%, and the poorest growth performance of fish fry was obtained with the 25% protein diet ($P<0.05$).

Fingerlings of Nile tilapia with a starting average weight about 20.3 g/fish showed the optimum growth performance with 35% protein diet followed by 45% protein diet with insignificant difference ($P>0.05$), but both diets were significantly higher than that fed the 25% protein diets ($P<0.05$). Furthermore, adult fish exhibited the same trend as shown with fingerlings. The optimum growth performance of adult fish (40.5 g/fish) was obtained with 35% and 45% protein diet with insignificant difference ($P>0.05$), while the poorest growth was significantly obtained from fish fed the 25% protein diets ($P<0.05$).

Survival rate of fish groups at dietary protein levels or among different Nile tilapia sizes was almost similar (100%) except that of fish fry at 25% protein diets (96.7%; Table 2).

Feed utilization

Feed utilization of Nile tilapia was significantly affected by protein level and its initial size, while the interaction of both factors did not affect the feed intake and feed conversion ratio (FCR). Results of feed intake and FCR of different treatments are shown in Table 3. It is worth mentioning that FCR of each fish size was enhanced by optimization of dietary protein level. The best FCR for tilapia fry was obtained from 35% and 45% protein diets with insignificant difference (1.65 and 1.49, respectively; $P>0.05$), while the poorest FCR was obtained at 25% protein diets (1.81; $P<0.05$). In case of fingerlings, diets containing 35% and 45% protein gave better FCR with approximately similar values (1.92 and 1.98, respectively; $P>0.05$). The same results were obtained for adult tilapia where the optimum FCR was obtained at 35% and 45% protein diets (2.29 and 2.45, respectively; $P>0.05$), while the poorest FCR was obtained from 25% protein diets (2.79; $P<0.05$).

Protein utilization

Protein utilization was assessed through protein dependant parameters i.e. PER, PPV and PGR. It was noticed that PER was inversely affected by dietary protein levels ($P<0.05$) for different fish weights. The lowest values of PER were obtained with diets containing 45% protein for fry, fingerlings and adult tilapia with significant difference among fish sizes

(1.58, 1.19 and 0.99, respectively; $P<0.05$). Results of PPV exhibited the same trend of PER for fish fry and fingerlings where the lowest values of PPV were obtained at 45% protein diets for fry, fingerlings with significant difference among (25.18% and 19.73%, respectively; $P<0.05$). The lowest PPV of adult tilapia was obtained at 35% and 45% with insignificant difference (21.92% and 19.70%, respectively). PGR, decreased significantly with increasing fish size. It insignificantly increased with increasing dietary protein level for fingerlings and adult fish and ranged from 1.00% to 1.24% for fingerlings and 0.69% to 0.89% for adult fish. In case of fry fish, the highest protein growth rate was obtained with the 45% protein diet (4.32%), while it showed approximately similar values in the 25% and 35% protein diets (3.98% and 3.94%, respectively; $P>0.05$).

Body composition

Results of body composition of each fish size fed diets containing 25, 35 and 45% protein are summarized in Table (4). Protein and lipid contents in whole fish body were affected by fish size and dietary protein level, while ash content was only affected by fish size. The interaction of both factors did not affect body chemical analysis. The body protein content was direct proportionally affected by protein levels ($P<0.05$) in the tested diets for fry, fingerlings and adult fish. The highest protein content in whole fish body was obtained from the 45% protein diet for fry, fingerlings and adult fish (57.5%, 59.6% and 58.5%, respectively; $P<0.05$). The whole-body lipid contents decreased with increasing the dietary protein level within each fish size. The highest lipid content was recorded with 25% protein diet at all sizes, while the lowest lipid contents were obtained with 45% CP for fry fish (28.5%) and with 35% CP for fingerlings and adult fish with insignificant difference (20.4% and 20.9%, respectively; $P>0.05$). Ash content in whole fish body was unaffected by dietary protein levels at all fish sizes, and its content in fingerlings and adult fish did not significantly differ and both are significantly higher than that of fish fry.

Nutrient deposition

Nutrient deposition in fish body was significantly affected by fish size, protein level and their interaction ($P<0.05$). Results in Table 5 showed that protein deposition was positively affected by dietary protein level within all tested fish sizes. The maximum protein gain was obtained with 45% CP for fry, fingerlings and adult fish (1.552, 3.96 and 4.52 g/fish, respectively). Meanwhile, the lowest protein gain was obtained with 25% CP level (0.701, 2.90 and 3.26 g/fish for fry, fingerlings and adult fish, respectively). It was noticed that lipids gain was significantly increased by increasing dietary protein level only in fry fish, while in fingerlings and adult fish, lipids gain decreased with increasing protein level. The higher lipids gain was obtained at 45% CP for fry (0.777 g/fish) and 25% CP in fingerlings and adult fish (1.258 and 1.689 g/fish, respectively). Meanwhile the lowest lipids gain was obtained with 25% CP level in fry (0.454 g/fish), and 45% CP in fingerlings and adult fish (1.133 and 1.013 g/fish, respectively). Ash deposition was positively affected by protein level and fish size ($P<0.05$). The highest ash gain was obtained at 45% CP in fry (0.367 g/fish) and 35% CP in fingerlings and adult fish (1.217 and 1.555 g/fish, respectively) with insignificant difference with that of 45%CP.

Discussion

Dietary protein is always considered to be of primary importance in fish feeding (Jauncey and Ross, 1982), thus sufficient supply of dietary protein is needed for rapid growth (Lovell, 1989). In the present study, results revealed that the optimum dietary protein level is 45% for Nile tilapia fry (~0.5 g/fish), 35% for fingerlings (~20 g/fish) and adult (~40 g/fish). The high protein level (45% protein) did not significantly enhance the fish growth at fingerlings and adults. This result may be due to the fact that each fish size has a certain protein limit after which excess protein level could not be utilized efficiently. These results are in agreement with Tacon (1987) who reported that dietary protein level varies from 42% for fry to 35% for growing adult of omnivorous fish.

The dietary protein requirement for fish fry is high and ranges from 35% to 56% (Jauncy and Ross, 1982). Furthermore, Wilson (1989), Pillay (1990) and El-Sayed and Teshima (1991) found that dietary protein requirements decreased with increasing fish size and age. Based on various studies, Balarin and Halfer (1982) made a general conclusion that fry of tilapia <1 g requires diet with 35-50% protein, 1-5 g fish requires diet with 30-40% protein and 5-25 g fish requires diet with 25-35% protein. These results may be due to the fact that each fish size has a certain protein limit after which excess protein level could not be utilized efficiently.

Many authors obtained conflicting results from their studies on the effect of dietary protein level on the growth of Nile tilapia. The dietary protein requirements of several species of tilapia have been estimated to range between 20% and 56% (El-Sayed and Teshima, 1991). De Silva and Perera (1985), Siddiqui *et al.* (1988) and Abdelghany (2000) reported that the optimum dietary protein level for growth of Nile tilapia fry was 30% crude protein. Hamza and Kenawy (1997) found out that 40% protein was more potent than other levels for Nile tilapia growth. Al-Hafedh (1999) and Al-Hafedh *et al.* (1999) found out that the better growth of Nile tilapia was obtained at high dietary protein levels (40-45%) rather than 25-35%. Khattab *et al.* (2000) studied the optimum dietary protein level for Nile tilapia collected from Aswan, Abbassa, Manzalah and Maryut. They found out that the optimum dietary protein level is 37% for Abbassa strain, 27% for Aswan strain and 32% for Manzalah and Maryut strains.

Moreover, the growth characteristics of Nile tilapia were found to be significantly affected by initial stocking size ($P<0.05$). Similar result was obtained by Akbulut *et al*. (2003) who found that the growth rate and final biomass of rainbow trout were significantly affected by initial stocking size. Also, Duston *et al*. (2004) found that the final biomass of juvenile striped bass was significantly affected by initial stocking size.

The considerable variations in the results recorded previously for optimum dietary protein requirements for maximum growth might be due to the variations in fish size and age, stocking density, protein quality, hygiene and environmental conditions or other unknown factors, which mask the standardization of the parameters.

Feed conversion ratio (FCR) increased with increasing weight of fish and decreased with increasing dietary protein level and it ranged from 1.50-1.81 for fry (~0.5 g), from 1.98 to 2.21 for fingerlings (~20.4 g) and from 2.30 to 2.76 for adult fish (~40.5 g). These FCR trends are in agreement with that obtained by Al-Hafedh (1999) and Khattab *et al*. (2000). Similar result was obtained by Akbulut *et al*. (2003) who found that the feed conversion and daily feeding rate of rainbow trout were significantly affected by initial stocking size. Also, Duston *et al*. (2004) found that the FCR of juvenile striped bass was significantly affected by initial stocking size. FCRs found by Al-Hafedh (1999), that ranged from 1.6 to 2.5 for fry (0.51 g) and from3.13 to 4.86 for fingerlings fish (45 g), were higher because his experiment was conducted in winter (18-25^{o}C). In this study, water temperature was 27^{o}C, which represents the optimum range of temperature for Nile tilapia which is 26^{o}C to 29^{o}C (Chervinski, 1982).

PER, PPV and PGR are used as indicators of protein quantity and quality in the fish diet and amino acids balance. So, these parameters are used to assess protein utilization and turnover, where they are related to dietary protein intake and its conversion into fish gain and protein gain. In this study, PER, PPV and PGR were significantly affected by protein level and reflects that protein utilization decreased by increasing dietary protein levels. However, the maximum protein utilization was obtained at low protein level (25% CP) at all fish sizes. Furthermore, PGR was inversely affected by fish size indicating that protein utilization decreased by increasing fish size. These results may be due to that fact that the major part of weight gain is related to the deposition of protein, and the protein accretion is a balance between protein anabolism and catabolism. Furthermore, gastric emptying rate or solubility of the protein has been shown to affect the utilization of dietary protein (de la Higuera *et al.*, 1998; Epse *et al.*, 1999). Moreover, Boirie *et al.* (1997) demonstrated that the rate of absorption of amino acids from the gut from casein or whey protein-based diets affects the protein synthesis within the whole body protein catabolism and oxidation of amino acids.

In this study, PER ranged from 1.58-2.35 for fry (~0.5 g), from 1.19 to 1.92 for fingerlings (~20.4 g) and from 0.99 to 1.53 for adult fish (~40.5 g). On the other hand, PER reported by Al-Hafedh (1999) exhibited the same trend that found in this study. Also, PER in study of Khattab *et al*. (2000) ranged from 1.25 to1.98 for Nile tilapia collected from Abbassa fishponds (12 g). Dabrowski (1979) reported different patterns of changes in PER in relation to dietary protein level and found that the relationship between dietary protein and PER differs from species to species. Jauncey (1982) and De Silva *et al*. (1989) also reported that FCR and PER decreased with increasing dietary protein level.

The whole body composition of fry, fingerlings and adult (grow out) of Nile tilapia was influenced significantly by dietary protein level. Fish fed 25% protein diet had lower content of protein and higher content of lipid than fish fed 35% or 45% protein diets. These results are similar to that obtained by Wee and Tuan (1988) and Al-Hafedh (1999). Ash content was unaffected by dietary protein level but affected by fish size. Khattab *et al.* (2000) also reported that ash content was unaffected by protein level in Nile tilapia collected from Abbassa fishponds.

The results of the present study indicate that a diet containing 45% protein appears to be economical and suitable for fry of Nile tilapia (~0.5 g), and diets containing 35% protein is recommended for fingerlings and adult (grow out) fish (20-40 g).

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Table 1. Ingredients and chemical composition and the experimental diet (on dry matter basis).

Ingredients	Dietary protein levels		
	25%	35%	45%
Fish meal	15.6	20.3	31.0
Soybean meal	20.0	40.0	50.0
Wheat bran	5.0	5.0	5.0
Ground corn	52.63	28.42	9.44
Fish oil + Corn oil (1:1)	2.0	2.0	2.0
Vitamins & minerals premix (1)	1.5	1.5	1.5
Ascorbic acid	0.06	0.06	0.06
Starch	2.21	1.72	0.0
Carboxymethyl cellulose	1.0	1.0	1.0
Total	100	100	100
Chemical analysis (%)			
Dry matter	92.48 ± 0.7	92.69 ± 0.6	93.09 ± 0.6
Crude protein	25.32 ± 0.24	35.41 ± 0.33	45.56 ± 0.46
Crude fat	5.87 ± 0.15	5.67 ± 0.25	5.99 ± 0.20
Ash	5.51 ± 0.23	6.31 ± 0.36	7.31 ± 0.37
Fiber	6.68 ± 0.15	5.50 ± 0.12	5.76 ± 0.13
NFE (2)	56.62	47.11	35.38
GE (Kcal/100 g) (3)	439.14	446.85	458.92

(1) Vitamin & minerals premix: each 2.5 kg contain vitamin A 12 MIU, D_3 2 MIU, E 10 g; K 2 g, B_1 1 g,B_2 4 g, B_6 1.5 g, B_{12} 10 mg, Pantothenic acid 10 g, Nicotinic acid 20 g, Folic acid 1 g, Biotin 50 mg, Choline chloride 500 mg, copper 10 g, iodine 1 g, iron 30 g, manganese 55 g, zinc 55 g and selenium 0.1 g.

(2) NFE (nitrogen free extract) = 100 – (protein + lipid + ash + fiber)

(3) GE (gross energy): Calculated after NRC (1993) as 5.64, 9.44 and 4.11 Kcal/g for protein, lipid and NFE, respectively.

Table 2. Growth performance parameters of Nile tilapia (*O. niloticus*) as affected by dietary protein levels and different initial body weights.

Items	Treatments								
	Fry			Fingerlings			Adult		
	25%	35%	45%	25%	35%	45%	25%	35%	45%
Initial weight (g/fish)	0.51	0.50	0.51	20.3	20.3	20.4	40.6	40.4	40.3
Final weight (g/fish)	5.10 g ±0.03	7.67 f ±0.09	10.26 e ±0.15	41.1 d ±0.8	45.2 c ±1.3	44.3 c ±0.6	58.6 b ±0.8	64.7 a ±1.5	62.9 a ±0.7
Weight gain (g/fish)	4.59 f ±0.05	7.17 c ±0.09	9.75 d ±0.19	20.8 b ±0.64	24.9 a ±1.39	23.9 a ±0.64	18.0 c ±0.78	24.3 a ±1.47	22.6 ab ±0.67
Weight gain (%)	900	1434.0	1911.8	102.45	122.66	117.16	44.33	60.15	56.07
SGR (%)	3.289 c ±0.014	3.900 a ±0.028	4.287 b ±0.045	1.007 e ±0.018	1.143 d ±0.047	1.107 d ±0.021	0.524 g ±0.019	0.672 f ±0.039	0.635 f ±0.016
Survival (%)	96.7	100	100	100	100	100	100	100	100

Means having the same letter in the same row is not significantly different at P<0.05.

ANOVA

Sources	df	Mean squares		
		Final weight	Gain	SGR
PL	2	55.75**	57.35**	0.169**
FS	2	6867.00**	685.61**	22.94**
PL x FS	4	5.153	5.120	0.039**
Error	18	1.987	2.003	0.0026

PL= protein level; FS = fish size; **P<0.01.

Table 3. Feed intake, feed conversion ratio (FCR), protein efficiency ratio (PER), protein productive value (PPV) and protein growth rate (PGR) of Nile tilapia (*O. niloticus*) as affected by dietary protein levels and different initial body weights.

Items	Treatments								
	Fry			Fingerlings			Adult		
	25%	35%	45%	25%	35%	45%	25%	35%	45%
Feed Intake (g feed/g fish)	8.3 e ± 0.23	11.8 d ± 0.32	14.5 d ± 0.46	46.2 c ± 1.12	47.9 bc ± 1.33	47.3 bc ± 1.39	50.2 b ± 1.58	55.7 a ± 1.67	55.5 a ± 1.29
FCR	1.81 de ± 0.05	1.65 ef ± 0.04	1.49 f ± 0.05	2.22 bc ± 0.06	1.92 cd ± 0.10	1.98 cd ± 0.10	2.79 a ± 0.11	2.29 b ± 0.09	2.45 b ± 0.10
PER	2.35 a ± 0.06	1.85 b ± 0.05	1.58 c ± 0.06	1.92 b ± 0.10	1.58 c ± 0.10	1.19 d ± 0.06	1.53 c ± 0.06	1.33 d ± 0.05	0.99 e ± 0.06
PPV (%)	35.95 a ± 1.05	28.97 b ± 0.85	25.18 cd ± 0.72	26.80 cb ± 0.77	24.17 d ± 0.70	19.73 e ± 0.67	27.72 b ± 0.81	21.92 e ± 0.85	19.70 e ± 0.57
PGR (%)	3.98 b ± 0.17	3.94 b ± 0.13	4.32 a ± 0.13	1.00 cd ± 0.03	1.21 c ± 0.04	1.24 c ± 0.04	0.69 e ± 0.03	0.81 de ± 0.03	0.89 de ± 0.03

Means having the same letter in the same row is not significantly different at $P<0.05$.

ANOVA

Sources	df	Mean squares			
		FCR	PER	PPV	PGR
PL	2	0.256**	1.029**	170.88**	0.135*
FS	2	1.579**	0.884**	136.48**	29.654**
PL x FS	4	0.023*	0.020	5.167	0.031
Error	18	0.021	0.012	1.857	0.024

PL= protein level; FS = fish size; *$P<0.05$; **$P<0.01$.

Table 4. Proximate chemical analysis (%; on dry matter basis) of Nile tilapia (*O. niloticus*) fed different levels of dietary protein at different initial body weights.

Items	Treatments								
	Fry			Fingerlings			Adult		
	25%	35%	45%	25%	35%	45%	25%	35%	45%
Moisture	71.6 g ± 0.14	72.0 fg ± 0.56	72.46 ef ± 0.04	75.2 a ± 0.31	74.9 ab ± 0.10	74.2 bc ± 0.04	73.1 de ± 0.29	74.7 ab ± 0.18	73.5 cd ± 0.21
Crude protein	54.0 e ± 0.15	55.86 d ± 0.27	57.5 c ± 0.21	56.3 d ± 0.39	58.5 b ± 0.25	59.6 a ± 0.03	54.1 e ± 0.40	56.5 d ± 0.23	58.5 b ± 0.34
Total lipids	34.1 a ± 0.60	31.5 b ± 0.39	28.5 c ± 0.51	23.3 d ± 0.64	20.4 e ± 1.17	19.8 e ± 0.46	24.4 d ± 1.13	20.9 e ± 0.19	18.9 e ± 0.43
Ash	11.7 c ± 0.25	12.5 c ± 0.51	13.5 c ± 1.05	20.2 b ± 0.19	21.0 ab ± 0.83	20.5 ab ± 0.36	21.5 ab ± 0.50	22.6 a ± 0.40	22.4 ab ± 1.25

Means having the same letter in the same row is not significantly different at P<0.05 otherwise they do.

ANOVA

Sources	df	Mean squares			
		Moisture	Crude protein	Total lipids	Ash
PL	2	0.857*	32.263**	54.167**	2.460
FS	2	17.315**	13.089**	305.435**	238.49**
PL x FS	4	1.212**	0.313	1.519	0.571
Error	18	0.199	0.225	1.419	1.428

PL= protein level; FS = fish size; *P<0.05; **P<0.01.

Table 5. Nutrient gain in the body of Nile tilapia (*O. niloticus*) fed different levels of dietary protein at different initial body weights.

Items	Treatments								
	Fry			Fingerlings			Adult		
	25%	35%	45%	25%	35%	45%	25%	35%	45%
Dry matter	1.316 f 0.033	2.019 e 0.066	2.696 d 0.151	5.05 c 0.152	6.21 b 0.225	6.27 b 0.174	6.18 b 0.099	6.84 ab 0.197	7.16 a 0.207
Crude protein	0.701 g 0.020	1.124 f 0.026	1.552 e 0.056	2.90 d 0.066	3.80 b 0.104	3.96 b 0.116	3.26 c 0.11	4.01 b 0.095	4.52 a 0.116
Total lipids	0.454 g 0.007	0.639 f 0.027	0.777 e 0.033	1.258 b 0.038	1.189 bc 0.037	1.133 cd 0.032	1.689 a 0.049	1.277 b 0.038	1.013 d 0.059
Ash	0.161 e 0.004	0.256 e 0.005	0.367 d 0.010	0.892 c 0.023	1.217 b 0.036	1.172 b 0.050	1.243 b 0.042	1.555 a 0.060	1.625 a 0.056

Means having the same letter in the same row is not significantly different at P<0.05.

ANOVA

Sources	df	Mean squares				
		Dry matter	Crude protein	Total lipids	Ash	Gross energy
PL	2	56.78**	21.29**	1.277**	3.519**	1320.48**
FS	2	3.58**	2.59**	0.051**	0.226**	45.96**
PL x FS	4	0.094	0.072*	0.175**	0.0149*	10.697**
Error	18	0.068	0.0223	0.00436	0.00434	1.9186

PL= protein level; FS = fish size; *P<0.05; **P<0.01.