Effect of Dietary Protein Content and Sources, on Growth, Food Conversion and Body Composition of Tilapia *Oreochromis niloticus* Fingerlings

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Abstract

The effect of dietary protein content on selected nutritional parameters of *Oreochromis niloticus* fingerlings was studied. Eight diets with varied protein contents (7.30% - 44.24% dry matter) were tested. Specific growth rates and body protein content increased with higher dietary protein. Beyond 33.32%, a gradual decline was observed. The diet containing 33.32% crude protein with a protein : energy ratio of 16.26 mg Kj^{-1} appeared optimal for the protein requirement of this species. Food conversion ratio was lowest at this protein level resulting in highest growth rate. The fish body ash did not vary with dietary protein supplied.

Keywords: Tilapia, *Oreochromis niloticus*, Dietary protein

Introduction

Many studies have already been carried out on the nutritional requirements of tilapia. Some studies attempted to determine the exact dietary protein requirements of the different species to maximise growth (Hughes, 1977; Santiago et al., 1982; Wang et al., 1985; El-Sayed and Teshima, 1992; Kaushik et al., 1995). Others have been directed towards identifying low-cost, readily available raw materials as protein sources for tilapia diets (Goldstein, 1970; Jackson et al., 1982; Viola and Arieli, 1982; Ofojekwu and Ejike, 1984). In spite of all these studies the picture is not clear and our knowledge of the dietary requirements of tilapia still remains inadequate (Jauncey, 1982a).

According to Dabrowski (1977) studies on the determination of optimal protein diet for fish are complicated, because protein level is considerably affected by the components of the diets and by the experimental conditions. Effect of dietary protein contents on nutritional parameters is also influenced by these factors. This makes it difficult to compare results from different studies. It is therefore important to relate all reports about the dietary requirements and nutritional response studies of fish to the experimental conditions.

The objectives of this study are; (1) to determine the protein requirement of *Oreochromis niloticus* in relation to fish meal protein source under specified experimental conditions (2) to assess the effect of fish meal - potato starch diets on the growth, food conversion, and body composition of this species.

Materials and methods

Preparation of experimental diets.

Eight experimental diets with a range of 7.30 - 44.24% crude protein were prepared using graded quantity of fish meal and protein starch (Table 1). The dry diet components including vitamin and mineral mix were thoroughly mixed with sunflower oil. Water was added and the feed pressed into pellets of 1mm diameter.

Table 1: Formulation and proximate composition (% dry matter) of experimental diets

	Diets							
Ingredients (%)	1	2	3	4	5	6	7	8
Fish meal	0	25	30	35	40	45	55	60
Sunflower oil	10	10	10	10	10	10	10	10
Potato starch	35.3	60	55	50	45	40	30	25
Wheat starch	49.7	-	-	-	-	-	-	-
Vit.& Min.Mix[1]	5	5	5	5	5	5	5	5
TOTAL	100	100	100	100	100	100	100	100
Moisture (%)	13.2	11	9.82	9.27	10.27	8.53	12.10	10.25
Crude protein (%)	7.30	20.62	23.72	27.74	31.18	33.32	42.08	44.24
Crude fat (%)	12.36	14.16	14.13	14.77	15.14	16.02	16.03	16.14
NFE + Fiber (%)[2]	76.71	51.71	54.07	48.63	43.98	40.38	-	-
Ash (%)	3.63	6.34	8.08	8.86	9.70	10.28	-	-
Energy content (KJ/g)	19.89	20.33	20.59	20.63	20.83	20.49	21.61	21.67

[1]Vitamin and Mineral mix (Spezialfutter Neuruppin - VM BM 55/13 Nr. 7310) supplied per 100g of dry feed : Vitamin A 15000 IU; Vitamin D3 2500 IU; Vitamin E 500mg; Vitamin K3 23mg; Vitamin B1 42mg; Vitamin B2 18mg; Vitamin B6 21mg Vitamin B12 59µg; Nicotinic acid 100mg; Biotin 544.65µg; Folic acid 13mg; Pantothenic acid 123mg, Inositol 1230mg; Vitamin C 66.7mg; Antioxidants (BHT) 121.87mg; Calcium 20.2%;
[2]Nitrogen free extract, (NFE) = 100 - (% protein + % fat + % ash).

Experimental conditions

The experimental conditions are shown in Table 2. Tilapia fingerlings bred at the facilities of Institute of Freshwater Ecology and Inland Fisheries (Berlin), were reared in a re-circulation system. 15-20 fingerlings (initial weight, 4-5g) were introduced to each of the 9 experimental tanks. Each test diet was assigned to 3 tanks at random after an adaptation period of 2 weeks. The feeding experiment lasted for 8 weeks. The fish were fed at the rate of 5% (wet weight basis) of their total biomass per day in 3 portions. The fish were weighed every 2 weeks and quantity of food adjusted accordingly. Experimental tanks were cleaned regularly. Ph, conductivity, oxygen concentration and temperature of water were measured 3 times every week. The water was well aerated and oxygen saturation above 60%. Temperature was maintained at 27±1°C through out the experiment. Due to insufficient number of experimental tanks this study was carried out in 3 phases.

Table 2: Experimental conditions

Water temperature (°C)	27 ± 1
Tank size (Litre)	40.38
Water volume (Litre)	34.61
Initial size range of fish (g/fish)	4 - 5
Number of experimental diets	8
Size of pellets (mm, diameter)	1
Number of fish per tank	15 - 20
Number of replicates	3
Experimental time (weeks)	8
Feeding rate (% body weight)	5
Feeding frequency (per day)	3
Weighing intervals (weeks)	2

Analyses of feed and fish samples

At the end of each experimental phase the fish was measured. 20 from each feeding group were taken, their intestine removed and the carcass homogenised. Freeze dried samples of fish at the beginning and end of the experiments as well as the samples of the test diets were analysed for proximate composition. Protein (N × 6.25) was determined by the Kjeltec System (Tecator); crude fat by Soxtec System HT (Tecator) using petroleum ether, and ash by burning in a muffle furnace at 750°C for 4 hours. Oxygen bomb calorimeter (Framo- MK 200) was used for energy determination at two replications per sample.

Statistical analyses and calculation

All statistical analyses were carried out by the Duncan multiple range method using SPSS for windows. From the experimental data obtained, weight gain, specific growth rate (SGR) and food conversion ratio (FCR) were calculated.

Results

Growth and Food conversion

The increase in average fish weight throughout the experiments is shown in Figure 1. The average specific growth rate (SGR) and food conversion ratio (FCR) for each diet is presented in Table 3. At the dietary protein content of 33.32% dry matter (Diet 6), the fish gained 23.28g in weight after 8 weeks. At this protein content also the SGR of the fish (3.39) is higher than others. This SGR value is not statistically different from those of dietary protein content of 42.08% and 44.24%. However the food conversion ratio at 33.32% protein content was lowest (1.19) and significantly different at 95% probability. The worst SGR and FCR was obtained with the fish group fed Diet 1 (7.30% crude protein).

Figure 1. The relationship between average fish weight and time for each dietary protein content

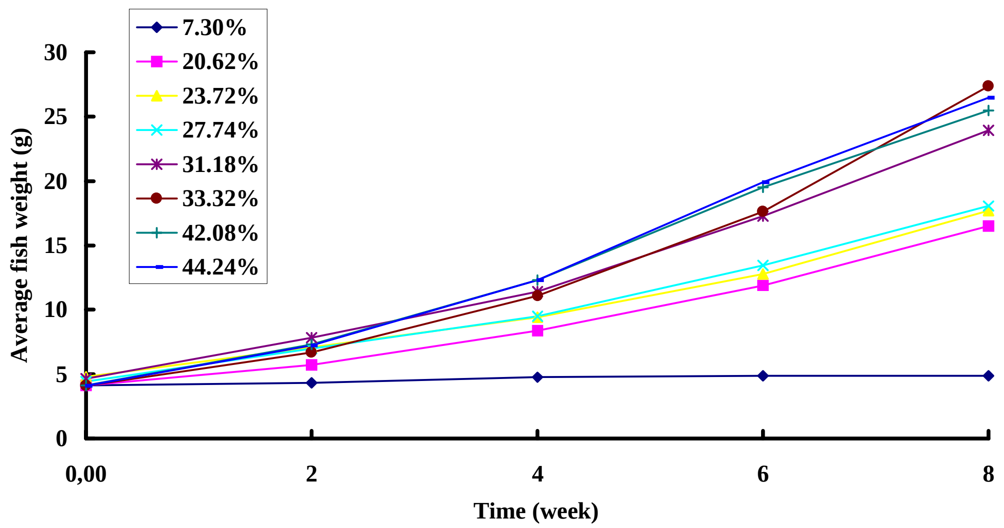


Table 3: Growth data, food conversion and protein / energy ratio of *O. niloticus* fingerlings*

Diets	% Protein	Initial wt. (g)	Final wt. (g)	Weight gain (g)	P / E ratio [1]	SGR[2]	FCR[3]
1	7.30	4.13	4.89[a]	0.76[a]	3.67	0.29[a]	-
2	20.62	4-13	16.53[b]	12.40[a]	10.33	2.47[b]	1.70[a]
3	23.72	4.82	17.68[b]	12.86[b]	11.52	2.32[b]	1.78[a]
4	27.74	4.43	18.07[b]	13.63[b]	13.45	2.51[b]	1.68[a]
5	31.18	4.67	23.93[c]	19.26[c]	14.97	2.91[c]	1.43[b]
6	33.32	4.10	27.38[c,d]	23.28[d]	16.26	3.39[d]	1.19[c]
7	42.08	4.13	25.48[c,d]	21.35[c,d]	19.47	3.25[d]	1.41[b]
8	44.24	4.09	26.50[c,d]	22.41[c,d]	20.42	3.33[d]	1.36[b]

*Figures in the same row with different subscript letters are significantly different ($P < 0.05$)from each other; [1]P/E = Protein to energy ratio in mg protein / KJ energy; [2]Specific growth rate = $(\ln W_2 - \ln W_1 / T_2 - T_1) \times 100$;
[3]Food conversion ratio = food fed(g)/live weight gain (g).

Body composition

The proximate body composition of the fish fed different experimental diets is presented in Table 4 and 5. At all experimental phases it is noticed that the body protein of the fish increased with increasing dietary protein content (Table 4). However, fish fed Diet 6 accumulated more body protein. Comparing the effect of different dietary protein on the fish, the body protein content decreased after 33.32% (Table 5). Increasing crude protein content in the diet, did not influence the body ash content. The body water and fat contents appeared to be related inversely. Energy content of the fish body was affected more by dietary fat content than the protein content. Higher energy content in the fish body was recorded when the body fat content was high. Both, however were inversely related to the body water content (Table 5).

Table 4: Proximate body composition of *O. niloticus* fingerlings (grouped according to the three experimental phases)

	Body composition (% dry matter)				
Diets	Moisture	Protein	Fat	Ash	Energy (KJ/g)
Initial - 1	**29.29**	**58.83**	**25.08**	**15.56**	**22.95**
3	26.47	61.24	20.60	17.32	22.09
4	26.32	62.15	18.62	18.47	21.97
5	27.07	61.26	22.30	15.68	22.88
Initial - 2	**25.70**	**58.40**	**27.28**	**15.72**	**23.67**
1	26.18	58.15	22.60	19.54	21.80
2	28.62	54.90	29.32	15.28	24.31
6	28.16	62.83	21.48	15.42	23.13
Initial - 3	**27.36**	**58.26**	**25.42**	**-**	**23.46**
7	27.78	60.10	21.24	-	23.31
8	26.88	60.84	18.11	-	22.48

Table 5: Proximate body composition of *O. niloticus* fingerlings (presented in relation to the dietary protein).

	Body composition (% dry matter)				
Diets	Moisture	Protein	Fat	Ash	Energy (KJ/g)
1	26.18	58.15	22.60	19.54	21.80
2	28.62	54.90	29.32	15.28	24.31
3	26.47	61.24	20.60	17.32	22.09
4	26.32	62.15	18.62	18.47	21.97
5	27.07	61.26	22.30	15.68	22.88
6	28.16	62.83	21.48	15.42	23.13
7	27.78	60.10	21.24	-	23.31
8	26.88	60.84	18.11	-	22.48

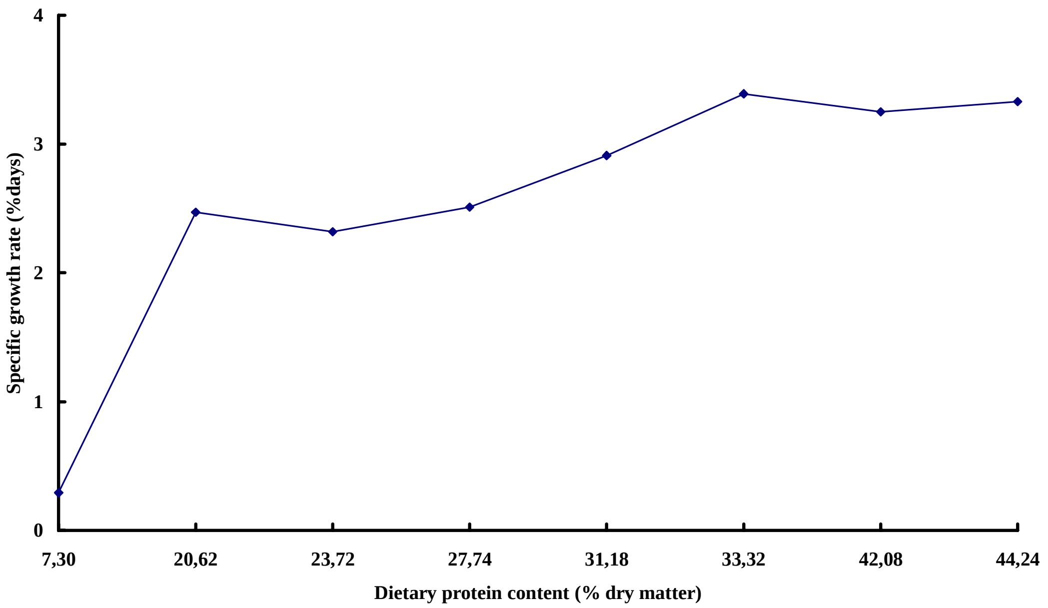
Discussion

In this study the highest growth rate of *O. niloticus* (initial weight, 4 -5g) was realised at the dietary protein content of 33.32% (dry matter) related to fish meal protein source. The protein to energy ratio (P:E) at this dietary protein content was 16.26 mg Kj^{-1}. This value is comparable to 17 mg Kj^{-1} reported by DE Silva et al., (1989) for tilapia. However it is lower than 19.43 mg Kj^{-1} reported by Mazid et al., (1979) at 35% protein level for *Tilapia zilli*. Jauncey (1982a) reported a higher ratio of 27.81 mg Kj^{-1} for tilapia *Sarotherodon mossambicus* at 40% protein level. (These P:E values were recalculated using the previously presented values). It should be noted that optimum protein - energy ratio varies significantly between species, and will also vary within species depending on the digestibility and amino acid composition of the protein source. Water temperature (Hidalgo and Alliot, 1988), and other environmental parameters which affect the partitioning of energy (DE Silva and Trevor, 1995) are also likely to affect this ratio.

From the plot of fish weight against time (Figure 1); SGR and FCR (Table 3), 33.32% appears to be the dietary protein content meeting the protein need of *O. niloticus*. Siddiqui et al., (1988) reported an optimum dietary requirement of 40% for *O. niloticus* fry (initial weight. 0.838g), and 30% for young fish (initial weight, 40g). Jauncey (1982a); El-Sayed and Teshima (1992) also reported 40% for fingerlings and frys respectively. Kaushik et al. (1995) observed the maximum growth rates and feed efficiencies at 35% dietary protein for the same species. The differences reported may be due to different protein sources used, varied components, formulation methods, different environmental conditions, level of dietary intake and experimental duration.

The SGR increased with higher dietary protein content up to 33.32%. It decreased slightly at 42.08% DP and raised gradually again (Table 3; Fig. 2). According to Jauncey (1982a), slight decrease in SGR at protein levels above the optimum may be due to a reduction in dietary energy available for growth since more energy is required to deaminate and excrete excess absorbed amino acids. FCR decreased with increasing dietary protein content though not linearly (Table 3). The lowest ratio of 1.19 was observed at the dietary protein content of 33.32% indicating the most efficient utilisation of food. All other test diets however showed an excellent food conversion by the fish. This result is comparable to those of Mazid et al., (1984) for *Tilapia zilli*.

Figure 2. Specific growth rate against dietary protein content.



In this study the body ash content did not vary in relation to the dietary protein supplied. This is similar to the observations of Siddiqui et al., (1988) for *O. niloticus*, Dabrowska and Wojno (1977) for *Salmon gairdneri*, Zeitler et al. (1984) and Jauncey (1982b) for *Cyprinus carpio*. However it contradicts the result of Shiau and Lan (1996) who reported a lower ash content at higher dietary protein levels for grouper (*Epinephelus malabaricus*). Kim and Kaushik (1992) observed an increase in ash levels in the whole body of rainbow trout (*Oncorhynchus mykiss*) from 0.8% to 2.5%. They did not attribute this increase to the effect of dietary protein treatment. The fish body protein increased with increasing dietary protein content at each phase of the experiment.

In spite of the initial body composition of fish at the beginning of each experimental phase (Table 4), the final body composition responded predictably to the effect of the different dietary protein contents (Table 5). It therefore appears that the dietary protein content (not the initial status of fish) determines the final body protein composition.

No relation between the dietary protein content and the body fat composition was observed. There was no defined trend identified in this study. This is in contrast with results reported by Dabrowska and Wojno (1977), Attack et al. (1979) and Chen and Tsai (1994), who observed either linear or inverse relationships respectively. The difference noted appears to be a result of the carbohydrate sources used in the experimental diets (in this study potato starch was used). A relationship between the fish body lipid and carbohydrate sources in fish diets has been reported (Shiau and Lan, 1996). A higher body lipid was observed in tilapia fed starch diets than those fed glucose diets (Shiau and Lin, 1993). More studies are needed to establish concrete relationship between dietary carbohydrate sources and the resultant fat composition of the fish body.

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References

Attack, T. H., Jauncey, K., Matty, A. J., (1979). The utilisation of some single cell proteins by fingerlings mirror carp (Cyprinus carpio). Aquaculture 18: 337 - 348.

Chen, H. Y., Tsai, J. C., (1994). Optimal dietary protein level for growth of juvenile grouper, Epinephelus malabricus, fed semipurified diets. Aquaculture 119: 265 - 271.

Dabrowski, K., (1977). Protein requirements of grass carp fry (Ctenopharyngodon idella Val.) Aquaculture 12: 63 - 73.

De Silva, S. S., Anderson, T. A., (1995). Fish Nutrition in Aquaculture. Chapman and Hall London, pp 31.

El-Sayed, A. M., Teshima, S., (1992). Protein and energy requirements of Nile tilapia, Oreochromis niloticus, fry. Aquaculture 103: 55 - 63.

Goldstein, R. J., (1970). Cichlids. TFH publications, Neptune City, NJ, 254pp.

Hadalgo, F., Alliot, E., (1988). Influence of water temperature on protein requirement and protein utilisation in juvenile sea bass Dicentrarchus labrax. Aquaculture 72, 115 - 129.

Hughes, D. G., (1977). Progress report on fisheries development in El Salvador. International centre of Aquaculture, Auburn University, Auburn, AL, 16pp.

Jackson, A. J., Capper, B. S., Matty, A. J., (1982). Evaluation of some plant proteins in complete diets for the tilapia (Sarotherodon mossambicus). Aquaculture 27: 97 -109.

Jauncey, K., (1982a). The effect of varying dietary protein levels on the growth, food conversion, protein utilisation and body composition of juvenile tilapias (Sarotherodon mossambicus). Aquaculture 27: 43 - 54.

Jauncey, K., (1982b). Carp (Cyprinus carpio L.) nutrition - a review. In: J.F. Muir and R. J. Roberts (editors), Recent Advances in Aquaculture. Croom Helm Ltd., London, pp 216 -263.

Kaushik, S. J., Doudet, T., Médole, F., Aguirre, P., Blank, D., (1995). Protein and energy needs for maintenance and growth of Nile tilapia (Oreochromis niloticus). J. Appl. Ichthyol. 11: 290 - 296.

Kim, J. D., Kaushik, S. J., (1992). Contribution of digestible energy from carbohydrates and estimation of protein/energy requirements for growth of rainbow trout (Oncorhynchus mykiss). Aquaculture 106: 161 - 169.

Mazid, M. A., Tanaka, Y., Katayama, T., Rahman, M. A., Simpson, K. L., Chichester, C. O., (1979). Growth response of Tilapia zilli fingerlings fed isocaloric diets with variable protein levels. Aquaculture 18: 115 -122.

Ofojekwu, P. C. and Ejike, C., (1984). Growth response and feed utilisation in the tropical cichlid Oreochromis niloticus (Linn.) fed on cotton seed - based artificial diets. Aquaculture 42: 27 - 36.

Santiago, C. B., Banes- Aldaba, M., Laron, M. A., (1982). Dietary crude protein requirement of Tilapia nilotica fry. Kalkasan Philipp. J. Biol., 11: 255 -265.

Shiau, S.- Y., Lin, S. F., (1993). Effect of supplementary dietary chromium and vanadium on the utilisation of different carbohydrates in tilapia Oreochromis niloticus × O. aureus. Aquaculture 110: 321 - 330.

Shiau, S.- Y., Lan, C.- W., (1996). Optimum dietary protein level and protein to energy ratio for growth of grouper (Epinephelus malabricus) Aquaculture 145: 259 - 266.

Siddiqui, A.Q., Howlader, M. S., Adam, A. A., (1988). Effect of dietary protein levels on growth, feed conversion utilisation in fry and young Nile tilapia, Oreochromis niloticus. Aquaculture 70: 63 - 73.

Wang, K., Takeuchi, T., Wantanabe, T., (1985). Effect of dietary protein levels on growth of Tilapia nilotica. Bull. Jpn. Soc. Fish., 51: 133 - 140 (English summary).

Viola, S., Arieli, Y., (1982). Nutritional studies with tilapia (Sarotherodon): Replacement of fish meal by soya meal in feeds for intensive tilapia culture. Bamidgeh, 35: 9 -17.

Zeitler, M. H., Kirchgessner, M., Schwarz, F. J., (1984). Effect of different protein and energy supplies on carcass composition of carp (Cyprinus carpio). Aquaculture 36: 37 - 48.