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Nutritional Requirements of *Tilapia*: Utilization of Dietary Protein by *Tilapia zillii*

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Abstract

Feeding experiments were carried out by using a purified diet varying levels of protein (casein) on the fish, *Tilapia zillii*. Also, the effects of dietary energy levels on growth of *T. zillii* were examined.

The optimum protein levels for *T. zillii* were determined to be 35–40 % when casein was used as a sole protein source. The body weight gain increased in proportion to the dietary protein levels within the range of 0 % to 35 %. The utilization of protein by this fish was also evaluated with respect to protein efficiency ratio (P. E. R.), net protein ratio (N. P. R.), net protein utilization (N. P. U.), and feed efficiency. P. E. R., N. P. R. and N. P. U. decreased with the increase of casein levels in the diets.

The body weight gain of *T. zillii* was improved with the increase of calorie of diets, with suggestion that lipids are effective as energy sources more than carbohydrates.

Introduction

A fish, *Tilapia zillii*, is an herbivorous species belonging to the family Cichlidae and originates from Africa[1]. The *Tilapia* has been cultured in Africa since 2500 years ago[2], because of easiness in culture, high growth rate, and rapid reproduction. Now, the fish has been distributed all over the tropical and subtropical countries and actually cultured in Southeast Asia, Japan, Asiatic Russia, India, East Europe, United States, and Latin American countries besides Africa.

For an economical and intensive fish culture, the knowledge on nutritional requirements is indispensable; especially in the economical view point it is necessary to rear fish by using a well balanced diet which is composed of cheap and abundant sources and enables to attain high growth rate. In spite of the wide distribution in the world, the information of nutritional requirements of *Tilapia* is a little[1~3]. Hence, the authors intend to clarify the nutritional requirements of *Tilapia*. To this approach, in the present study two experiments were carried out. In Experiment-1, the effects of dietary protein levels on body weight gain, protein efficiency ratio (P. E. R.), net protein utilization (N. P. U.), net

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protein ratio (N. P. R.), and feed efficiency were examined. On the basis of the optimum protein level estimated in Experiment-1 using casein as a sole protein source, Experiment-2 was conducted to investigate the effects of energy levels in the diets on the body weight gain, P. E. R. and feed efficiency. In Experiment-2, some evaluation was also performed on the nutritive values of casein and gelatin, the effects of carbohydrates and lipids as energy sources, and the levels of minerals in the diets.

This paper deals with these results and discussion.

Experimentals

Fingerlings of *T. zillii* were obtained in September, 1977, from the Ibusuki Branch of the Fisheries Experimental Station of Kagoshima Prefecture, transported to this laboratory, and maintained on a commercial diet for a carp until use. Prior to the feeding trials, *T. zillii* were acclimated in a purified diet (diet No. 4) for two weeks, divided into the experimental groups at random, and fed on the test diets. Plastic aquarium (30 liter-capacity) equipped with a sand bed at bottom was used for each experimental group. Dechlorinated tap water was exchanged every week and the sand bed was cleaned once at the 15th-day of feeding period. Water temperature was not controlled in both Experiment-1 and Experiment-2. The average water temperatures were 25°C and 20°C in Experiment-1 and Experiment-2, respectively. In each aquarium, twenty-five, 1.67 g in average weight, and twenty, 1.5 g in average weight, *Tilapia* were put in Experiment-1 and Experiment-2, respectively. The diets were given to *Tilapia* at the 4% level of their body weight daily, twice a day in week day and once in Sunday.

The compositions of the test diets used in present study are listed in Table 1. The diets used in Experiment-1 contain the same calorie (3500 kcal/kg diet) each other, and the calorie was adjusted by changing the amounts of dextrin and cellulose. Since there are no informations about the digestibility of nutrients with respect to *Tilapia*, the following caloric values were adopted for calculation of calorie; proteins (4.5 kcal/g)[4], carbohydrates (4.0 kcal/g), and lipids (9.0 kcal/g). After the feeding trials, the contents of proteins and lipids in the whole body of *Tilapia* were determined by Kjeldahl method and by Bligh and Dyer method[5], respectively.

Body weight gain, P. E. R., N. P. U., N. P. R., and feed efficiency are calculated on the following formulae:

$$\text{Body weight gain } (\%) = \frac{\text{Final body wt. (g)} - \text{Initial body wt. (g)}}{\text{Initial body wt. (g)}} \times 100$$

$$\text{P. E. R.} = \frac{\text{Body weight gain (g)}}{\text{Protein intake (g)}}$$

Table 1. Composion of the test diets

Ingredient (%)	Diet used in Experiment-1							
	1	2	3	4	5	6	7	8
Casein (milk)	0	15	25	35	40	45	55	65
Dextrin	76.25	59.37	48.12	36.87	31.25	25.62	14.37	3.12
Lipids*1	5	5	5	5	5	5	5	5
Minerals*2	4	4	4	4	4	4	4	4
Vitamins*2	1	1	1	1	1	1	1	1
Cellulose powder	10.75	12.62	13.87	15.12	15.75	16.37	17.62	18.87
Agar	3	3	3	3	3	3	3	3
L-Tryptophan	0	0	0	0	0	0	0	0
L-Methionine	0	0	0	0	0	0	0	0
Water (ml)	100	100	100	100	100	100	100	100
Calorie (kcal/kg)	3500	3500	3500	3500	3500	3500	3500	3500

Ingredient (%)	Diet used in Experiment-2								
	4	5	9	10	11	12	13	14	15
Casein (milk)	35	40	40	35	35	35	27.4	27.4	27.4
Gelatin	0	0	0	0	0	0	7.6	7.6	0
Dextrin	36.87	31.25	41.25	46.87	36.87	36.87	36.87	36.87	
Lipids	5	5	5	5	10	15	5	5	5
Minerals	4	4	4	4	4	4	4	4	8
Vitamins	1	1	1	1	1	1	1	1	1
Cellulose powder	15.12	15.75	5.75	5.12	10.12	5.12	18.75	17.25	11.12
Agar	3	3	3	3	3	3	0	0	3
L-Tryptophan	0	0	0	0	0	0	0	0.5	0
L-Methionine	0	0	0	0	0	0	0	1.5	0
Water (ml)	100	100	100	100	100	100	100	100	100
Calorie (kcal/kg)	3500	3500	3900	3900	3950	4400	3500	3500	3500

*1 A mixture of pollack liver oil and soybean oil (1 : 1)
*2 Minerals and vitamins according to HALVER (1957)[21]

$$\text{N.P.U.} = \frac{B_p - B_o}{I_p} \times 100$$

B_p: Final body protein (g) of the fish fed on a protein-containing diet
B_o: Final body protein (g) of the fish fed on a non-protein-containing diet
I_p: Protein (g) intaked by fish

$$\text{N.P.R.} = \frac{W_p - W_o}{I_p}$$

W_p: Final body weight (g) of the fish fed on a protein-containing diet
W_o: Final body weight (g) of the fish fed on a non-protein-containing diet

$$\text{Feed efficiency} = \frac{\text{Body weight gain (g)}}{\text{Feed intake (g)}}$$

Results and Discussion

The fish, *T. zillii*, showed a good appetite for the diets during the experimental period, except for the group receiving the protein-free diet (diet No.1). In the *Tilapia* fed the diet No. 1, movement activity and appetite gradually declined to be lost towards the end of experimental period. The results of Experiment-1 are given in Table 2 and Fig. 1. As shown in Table 2 and Fig. 1, the optimum growth in Experiment-1 was attained in the diets (diet No. 4 and diet No. 5) containing 35–40 % levels of casein. The body weight gain increased almost proportionally to the levels of casein in the diets within the range of 0 % to 40 %, but it slightly decreased in the range of 45 % or more levels of casein. The tendency observed in the relationship between the body weight gain of *Tilapia* and the dietary protein levels has been demonstrated in grass carp[6], eel[7], and plaice[8]. However, in the case of the common carp[9], gilthead bream[10], chinook salmon[11], and rainbow trout[12], further increase of protein levels in the

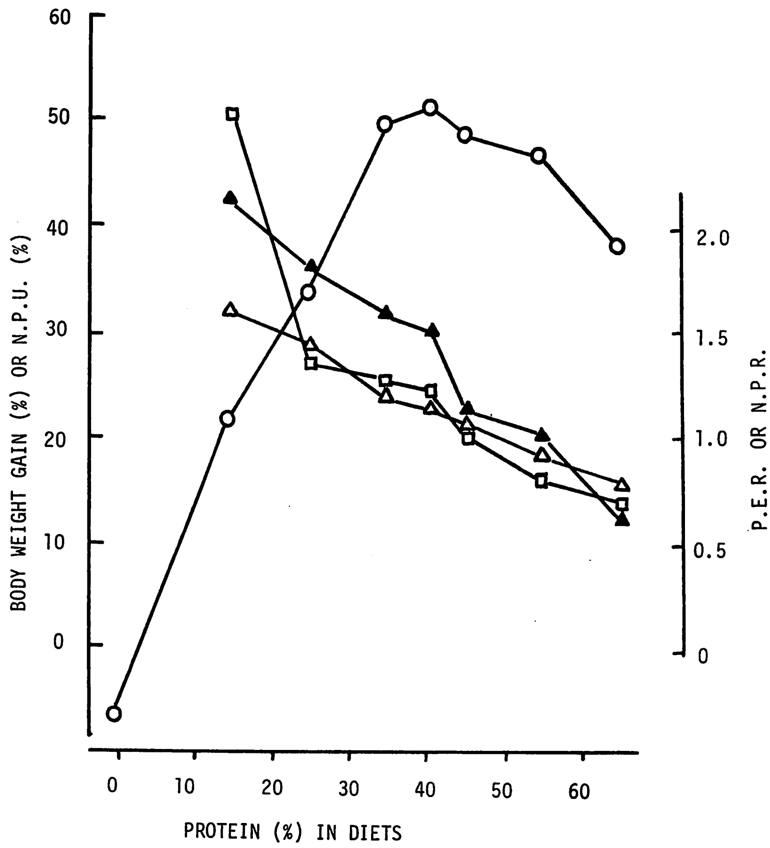

Fig. 1. The effects of dietary protein levels on body weight gain, P. E. R., N. P. U. and N. P. R.
o, body weight gain; △, P. E. R.; ▲, N. P. U.; □, N. P. R.

Table 2. Results of the feeding trials in Experiment-1

Experiment-1*1	Diet							
	1	2	3	4	5	6	7	8
Protein level (%)	0	15	25	35	40	45	55	65
Number of fish	25	25	25	25	25	25	25	25
Mortality (%)	0	0	0	0	0	0	0	0
Initial body wt. (g)	1.84	1.81	1.64	1.54	1.56	1.59	1.58	1.79
Final body wt. (g)	1.72	2.21	2.22	2.31	2.37	2.35	2.32	2.47
Body weight gain (%)	−6.8	22.0	34.7	50.3	51.7	48.0	46 7	38.0
P. E. R.		1.71	1.47	1.38	1.30	1.00	0.86	0.64
N. P. U.		50.2	27.3	25.7	24.7	20.0	15.3	13.3
N. P. R.		2.27	1.81	1.61	1.51	1.06	1.02	0.75
Feed efficiency	−0.10	0.26	0.37	0.48	0.52	0.47	0.48	0.41

*1 Experiment-1 was conducted during the perior of Sept. 30—Oct. 26.

diets, after the optimum growth was attained, did not result in the decrease of body weight gain. The estimated optimum protein level for *T. zillii* in the present study was similar to those reported for other fish; namely, 40% (at 47°F) and 55% (at 58°F) for chinook salmon[13], 35% (at 69°F) and 40% (at 76°F) for channel catfish[14], 38% (at 23°C) for carp[9], and 45% (at 25°C) for eel[7].

The diets containing 35–40% casein also gave a high feed efficiency for *T. zillii* as compared with other test diets. The P. E. R. estimated in this study was smaller than those determined on the fish such such as the carp[9] and rainbow trout[15], and it decreased with the increase in casein levels in the diets. OGINO and SAITO[9] have shown that the feeding experiments on the carp revealed an inverse linear relation between the levels of casein and P. E. R. (ranging from 3.14 to 1.75). Such a relation between the dietary protein content and P. E. P. seems to be typical for the fish received casein as a sole protein source[8,16,~19]. However, NOSE[15] has reported that the shape of curve between absorbed nitrogen and P. E. R. in the rainbow trout fed casein, white fish meal, or soybean meal, was remarkably different with those observed on the carp and higher animals; in rainbow trout, P. E. R. did not increase in the diets containing low levels of proteins.

As to N. P. R. and N. P. U., these values decreased almost linearly with the increase of casein levels in the diets of *T. zillii*. As shown in Table 4, the analysis of the whole body of *Tilapia* after the feeding trials indicated that the increase of dietary protein levels resulted in a slight increase of lipid content (% of fresh body), but did not increase the protein content.

The results of Experiment-2 are given in Tables 3 and 4 and Fig. 2. In Experiment-2, the best body weight gain was attained in the diet No. 12 containing 35% casein, 36.87% dextrin, 15% lipids, 4% minerals, and calorie (4400 kcal/kg diet) as shown in Table 3. Fig. 2 shows the effects of energy levels

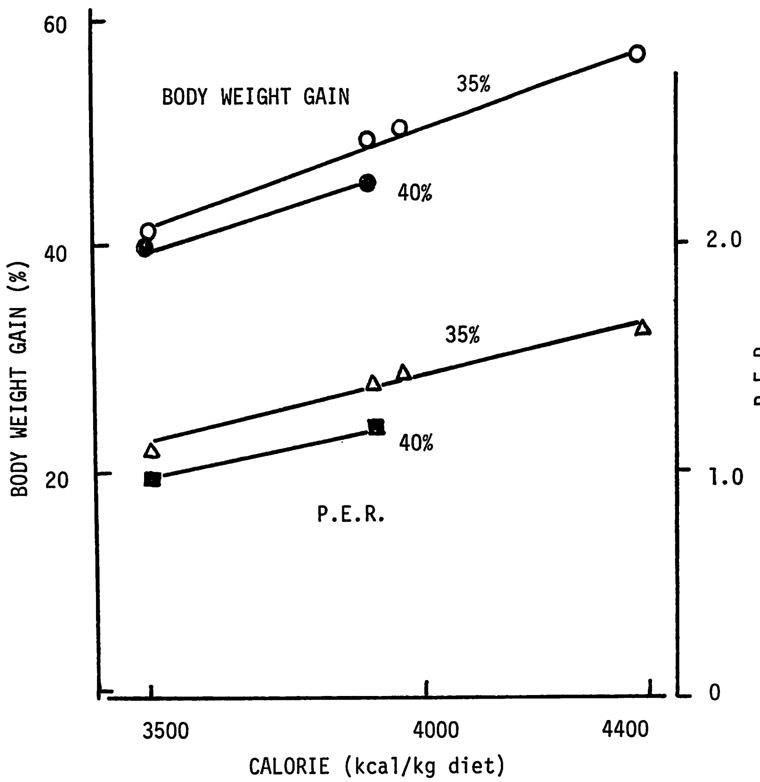

Fig. 2. The effects of energy levels on body weight gain and P. E. R. Percentages indicate the levels of casein in the diets.

Table 3. Results of the feeding trials in Experiment-2

Experiment-2*1	Diet								
	4	5	9	10	11	12	13	14	15
Number of fish	20	20	20	20	20	20	20	20	20
Mortality (%)	0	0	0	0	0	0	0	0	0
Initial body wt. (g)	1.39	1.51	1.54	1.50	1.54	1.53	1.50	1.50	1.55
Final body wt. (g)*2	1.96	2.12	2.24	2.24	2.33	2.40	1.78	2.00	2.12
Body weight gain (%)	41.3	40.6	45.6	49.1	51.5	56.6	18.6	33.7	37.3
P. E. R.	1.06	0.99	1.14	1.37	1.47	1.61	0.49	0.94	1.07
Feed efficiency	0.37	0.39	0.46	0.48	0.51	0.56	0.17	0.33	0.37

*1 Experiment-2 was conducted during the period of Nov. 1—Nov. 28.

*2 S. E. were as follows: diet 4, 0.11; diet 5, 0.18; diet 9, 0.17; diet 10, 0.14; diet 11, 0.21; diet 12, 0.21; diet 13, 0.13; diet 14, 0.14; diet 15, 0.19.

on the body weight gain and P. E. R. in *T. zillii*. As shown in Fig. 2, the diets containing 35 % casein attained a little higher body weight gain and P. E. R. than the diets containing 40 % casein. Also, both body weight gain and P. E. R

Table 4. Effects of the levels of dietary proteins and calories on the content of proteins and lipids in the whole body of *Tilapia* after the feeding trials

Experiment	Diet			Content (% of fresh body)*1	
	No.	Protein (%)	Calorie (kcal/kg)	Protein	Lipid
Experiment-1					
	1	0	3500	15.94	3.43
	2	15	3500	16.46	3.43
	3	25	3500	16.35	3.43
	4	35	3500	17.03	3.42
	5	40	3500	17.09	4.20
	6	45	3500	16.10	4.87
	7	55	3500	16.65	4.83
	8	65	3500	14.66	4.95
Experiment-2					
	4	35	3500	14.72	3.49
	5	40	3500	15.27	4.09
	9	40	3900	16.57	4.50
	10	35	3900	16.49	5.09
	11	35	3950	17.96	6.50
	12	35	4400	18.04	6.02
	13	35	3500	15.79	3.89
	14	35	3500	18.04	4.49
	15	35	3500	16.18	4.85

*1 The average content (%) of proteins and lipids of *Tilapia* whole body before the feeding trials was as follows: proteins (14.89 %) and lipids (3.43 %) in Experiment-1; proteins (13.66%) and lipids (2.43 %) in Experiment-2.

increased linearly to the increase of energy levels in the diets. A similar relationship between energy levels and either body weight gain or P. E. R. has been observed in the rainbow trout[19], carp[16], plaice[8], yellowtail[17], channel catfish[18], and turbot[20].

The diets No. 9 and No. 11 contained the almost same energy level, however the higher body weight gain was attained in the diet No. 11 containing larger amounts of lipids and less amounts of casein. As shown in Table 4, the increse of dietary lipid levels (diets No. 11 and No. 12) resulted in the increase of both lipid and protein contents in the whole body of *Tilapia*. These results assume that lipids are more effective for *T. zillii* than carbohydrates as an energy source, and also that the addition of lipids to the diet for *T. zillii* may be effective in sparing protein supplement to some extent. The partial replacement of casein to gelatin (diets No. 13 and 14) did not improve the weight gain and feed efficiency as highly as observed in the chinook salmon by HALVER[21], although the supplement of L-methionine and L-tryptophan to the casein-gelatin diet (diet No. 13) slightly improved the body weight gain and efficiency (see diet No. 14). Quite recently, MAZID *et al.*[22] have reported that *T. zillii* requires arginine, histidine, isoluecine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine as well as other fish[23~28]. However, the optimum growth rate of basal amino acid-diet was about half of that of the casein-diet[22]. The quantitative requirements of amino acids for *T. zillii* remain still to be resolved.

In addition, the present experiment showed that the increase of mineral levels did not improve so markedly body weight gain, P. E. R. and feed efficiency (see diets No. 14 and 15). Also, the growth rates on diets No. 4 and No. 5 were different in Experiment-1 and Experiment-2. Since Experiment-2 was conducted at lower water temperature than in Experiment-1, the authors assume that poor weight gain in Experiment-2 is due to the reduction of metabolic rates. The similar phenomenon has been also observed in the sockeye salmon by BRETT *et al.*[29]. DELONG *et al.*[13] have shown that the minimum protein requirement of chinook salmon enhances with the increase of water temperature. As to *T. zillii*, therefore, the protein requirements may vary with water temperature. This point should be investigated in future.

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