# Effects of Feeding Rate, Fish Size, and Dietary Protein and Cellulose Levels on the Growth of Tilapia nilotica

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# Effects of Feeding Rate, Fish Size, and Dietary Protein and Cellulose Levels on the Growth of *Tilapia nilotica*

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**Abstract**

Two feeding experiments were conducted to examine the effects of feeding rate, fish size, and dietary protein and cellulose levels on the weight gain, feed conversion efficiency (FCE), protein efficiency ratio (PER), and feed consumption of *Tilapia nilotica* fingerlings. The effects of factors were evaluated with 2 or 4 levels in a factorial design using an orthogonal array $L_8$. In Experiment I, the weight gain (%) was slightly higher ($P<0.10$) in small fish (about 0.36g) than in large fish (about 6.8g) but not significantly different with the feeding rates (1.5%, 3.5%, 5.5%, and *ad libitum* feeding) and dietary protein levels (25% and 35%). The FCE and PER were decreased with increasing feeding rates ($P<0.05$) and were higher ($P<0.05$) in small fish than in large fish but not significantly differed between 25% and 35 protein diets.. In Experiment II, the weight gain (%) and PER were decreased with increasing dietary cellulose levels (2%, 7%, 12%, and 17%)($P<0.05$) and were higher ($P<0.05$) on 35% protein diet than 25% protein diet. However, the feed consumption and FCE were not significantly variable with dietary cellulose and protein levels.

Growth of fish is affected by various factors such as rearing and feeding conditions besides nutritive value of diets. In the first paper[1] of this series, we have investigated the effects of dietary protein source, feeding rate, feeding frequency, stocking density, vitamin level, and a binder on the growth of *Tilapia nilotica* fingerlings. The results showed that the growth of *T. nilotica* was markedly affected by the feeding rate and protein source. On the other hand, interestingly, WANG *et al.*[2] reported that the growth of *T. nilotica* was decreased with increasing dietary cellulose levels when fed low (22%)-protein diets in contrast to high (32% and 41%)-protein diets. For these findings, it appeared of interest to investigate the effects of feeding rate and dietary cellulose level on the growth of *Tilapia* in detail.

In the present study, two feeding experiments designed using an orthogonal array $L_8$ were conducted to see the effects of feeding rate and dietary cellulose level besides those of fish size and dietary protein level on the growth of *T. nilotica.*

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## Materials and Methods

*T. nilotica* fingerlings were obtained from a commercial *Tilapia* farm (Fuji-Enterprise Co., Kagoshima) and maintained on a commercial carp ration until used. Feeding experiments were designed by using an orthogonal array $L_8$ to examine the effects of some factors on the weight gain, feed conversion efficiency (FCE), protein efficiency ratio (PER), and feed consumption of *T. nilotica* fingerlings. The effects of factors were tested with 2 or 4 levels under the rearing conditions listed in Table 1 and evaluated by analysis of variance at the significant levels of 5% or 10%[3]. Table 2 shows the compositions of test diets. The basal ration of test diets was the same as reported previously[1]. Table 3 gives the factors and levels examined in the present study.

Table 1. Rearing conditions of *Tilapia* in Experiments I and II

| Condition | Experiment I | Experiment II |
|---|---|---|
| Feeding period | 5 weeks | 5 weeks |
| Average initial body wt. | 0.36g, 6.86g | 0.35g |
| Number of fish/tank (30 ℓ) | 15 | 15 |
| Feeding rate (% of body wt.) | Various*1 | *ad libitum* |
| Daily feeding frequency*2 | Twice | Twice |
| Water temperature | 28℃ | 24–28℃ |
| Illumination | 7 : 00–19 : 00 | 7 : 00–19 : 00 |

*1 1.5%, 3.5%, 5.5%, and *ad libitum*.
*2 9 : 00 and 15 : 00 o'clocks.

Table 2. Composition of test diets

| Ingredient | Diet No. (% composition) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 11 | 12 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| Casein-gelatin | 25 | 35 | 25 | 25 | 25 | 25 | 35 | 35 | 35 | 35 |
| L-Trp : L-Met ( 1 : 1 ) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Dextrin | 41.25 | 30.0 | 51.6 | 42.6 | 33.6 | 24.6 | 42.6 | 33.6 | 24.6 | 15.6 |
| PLO : SBO ( 1 : 1 )*1 | 14 | 14 | 9.4 | 13.4 | 17.4 | 21.4 | 8.4 | 12.4 | 16.4 | 20.4 |
| Linoleic acid | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Minerals | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Vitamins | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| α-Cellulose | 8.75 | 10 | 2 | 7 | 12 | 17 | 2 | 7 | 12 | 17 |
| Agar | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Provisional DE*2 (kcal/100g) | 417 | 417 | 417 | 417 | 417 | 417 | 417 | 417 | 417 | 417 |

*1 A mixture of pollack liver oil and soybean oil (1 : 1, w/w).
*2 Digestible energy (DE) was provisionally calculated by using the following values (kcal/g) : protein, 4.5 ; carbohydrate, 4.0 ; lipid, 9.0.

In Experiment I, the feeding trials were conducted to examine the effects of feeding rate (factor A), fish size (factor B), and dietary protein level (factor C) on the weight gain, FCE, and PER (Table 4). *Tilapia* fingerlings, each weighing 0.36 g or 6.86 g in average body weight, were reared with 2 diets containing 25% or 35% casein-gelatin (3 : 1) as protein sources at various feeding rates (1.5%, 3.5%, and 5.5% of body weight per day and *ad libitum*) for 5 weeks. Experiment II dealt with the effects of dietary cellulose (factor D) and protein (factor C) levels on the weight gain, FCE, PER, and feed consumption. In Experiment II, the fingerlings, each weighing 0.36 g in average body weight, were reared with 8 diets containing varying levels of cellulose (2%, 7%, 12%, and 17%) and casein-gelatin (3 : 1) (25% and 35%). The fish were fed the diets *ad libitum* for the period of 5 weeks.

Table 3. Factors and levels examined in Experiments I and II

| Factor*[1] | Level |
|---|---|
| Experiment I | |
| Factor A : Feeding rate (% of body wt./day) | $A_1$ : 1.5% |
| | $A_2$ : 3.5% |
| | $A_3$ : 5.5% |
| | $A_4$ : *ad lib.* |
| Factor B : Fish size | $B_1$ : Small |
| | $B_2$ : Large |
| Factor C : Protein level in diets*[2] | $C_1$ : 25% |
| | $C_2$ : 35% |
| Experiment II | |
| Factor C : Protein level in diets*[2] | $C_1$ : 25% |
| | $C_2$ : 35% |
| Factor D : Cellulose level in diets | $D_1$ : 2% |
| | $D_2$ : 7% |
| | $D_3$ : 12% |
| | $D_4$ : 17% |

*[1] The factors were alloted to the orthogonal array $L_8$ as shown in Table 4.

*[2] Diets contained 1% L-Trp : L-Met (1 : 1) as nitrogen sources besides 25% or 35% protein, a mixture of casein-gelatin (3 : 1).

## Results and Discussion

Table 5 shows the results of Experiment I. The highest weight gain was obtained in group No. 17 of small fish receiving 35% protein diet *ad libitum* (feeding rate determined = 7.6% of body weight). The FCE and PER were the highest in group No. 11 of small fish

Table 4. Experimental groups and the allotment of factors and levels to orthogonal array $L_8$ in Experiments I and II

| Experiment I *1 | | | | | Experiment II *2 | | | |
|---|---|---|---|---|---|---|---|---|
| Exptl. group | Feeding rate | Fish size | Protein level | Diet given | Exptl. group | Cellulose level | Protein level | Diet given |
| 11 | 1.5% | 0.39 g | 25% | No. 11 | 21 | 2% | 25% | No. 21 |
| 12 | 1.5% | 6.37 g | 35% | No. 12 | 22 | 2% | 35% | No. 25 |
| 13 | 3.5% | 0.45 g | 35% | No. 12 | 23 | 7% | 25% | No. 22 |
| 14 | 3.5% | 6.49 g | 25% | No. 11 | 24 | 7% | 35% | No. 26 |
| 15 | 5.5% | 0.32 g | 25% | No. 11 | 25 | 12% | 25% | No. 23 |
| 16 | 5.5% | 7.39 g | 35% | No. 12 | 26 | 12% | 35% | No. 27 |
| 17 | *ad lib**3 | 0.28 g | 35% | No. 12 | 27 | 17% | 25% | No. 24 |
| 18 | *ad lib**4 | 7.18 g | 25% | No. 11 | 28 | 17% | 35% | No. 28 |

*1 The factors (see Table 3) were alloted to the orthogonal array as follows : factor A (array No. 1, 2, and 3), factor B (array No. 4), and factor C (array No. 6).

*2 The factors (see Table 3) were alloted to the orthogonal array as follows : factor C (array No. 4) and factor D (array No. 1, 2, and 3).

*3 Feeding rate determined was 7.6%.

*4 Feeding rate determined was 6.2%.

Table 5. Results of the feeding trial in Experiment I

| Exptl. group | Mean body wt. (g) Initial | Mean body wt. (g) Final | Diet consumed (g)*1 | Wt. gain (%) | FCE*2 | PER*3 |
|---|---|---|---|---|---|---|
| 11 | 0.39 | 0.98 | 0.36 | 151 | 162 | 5.0 |
| 12 | 6.37 | 11.35 | 3.92 | 78 | 127 | 3.6 |
| 13 | 0.45 | 1.70 | 1.00 | 278 | 125 | 3.6 |
| 14 | 6.49 | 11.81 | 9.63 | 82 | 55 | 2.2 |
| 15 | 0.32 | 1.22 | 1.26 | 340 | 71 | 2.9 |
| 16 | 7.39 | 14.26 | 16.51 | 93 | 41 | 1.6 |
| 17 | 0.28 | 1.62 | 1.95 | 479 | 69 | 2.0 |
| 18 | 7.18 | 13.92 | 18.73 | 94 | 36 | 1.4 |

*1 Diet consumed (g)/one fish during the period of 5 weeks.

*2 Gain (g) × 100/feed (g)

*3 Gain (g)/protein intake (g)

receiving 25% protein diet at 1.5% feeding rate. KOYAMA* has recommended the feeding rate of 6-8% for *T. nilotica* fingerlings weighing less than 50 g at the water temperature of 25-30℃. The weight gain, FCE, and PER data were analyzed by analysis of variance[3] to assess the effects of factors examined (Table 6).

In agreement with results previously reported[1], the growth of *Tilapia* was markedly affected by the feeding rates (Fig. 1), but a significant difference ($P<0.05$) was not detected on the feeding rate (factor A), fish size (factor B), and dietary protein level

* KOYAMA : *Yoshoku*, **10**, 49-53 (1983).

Table 6 . Effects of the feeding rate, fish size, and dietary protein level on the weight gain, FCE, and PER of *Tilapia* in Experiment 1

| Factor and level* | Mean ± confidence limit (P=0.95) | | |
|---|---|---|---|
| | Weight gain (%) | FCE | PER |
| Feeding rate | | | |
| $A_1$ : 1.5% | 155±276 | 145±40 | 4.3±0.86 |
| $A_2$ : 3.5% | 180±276 | 90±40 | 2.9±0.86 |
| $A_3$ : 5.5% | 217±276 | 56±40 | 2.3±0.86 |
| $A_4$ : *ab lib.* (about 7%) | 287±276 | 53±40 | 1.7±0.86 |
| Fish size | | | |
| $B_1$ : Small (0.36g) | 312±195 | 107±40 | 3.4±0.61 |
| $B_2$ : Large (6.9g) | 86±195 | 65±40 | 2.2±0.61 |
| Dietary protein level (%) | | | |
| $C_1$ : 25% | 166±195 | 81±28 | 2.9±0.61 |
| $C_2$ : 35% | 232±195 | 91±28 | 2.6±0.61 |

* A significant difference (P<0.05) was detected in the following factors. FCE data : fish size and dietary protein level. PER data : feeding rate and fish size.
In addition, a significant difference (P<0.10) was detected in the size of fish on weight gain (%) data.

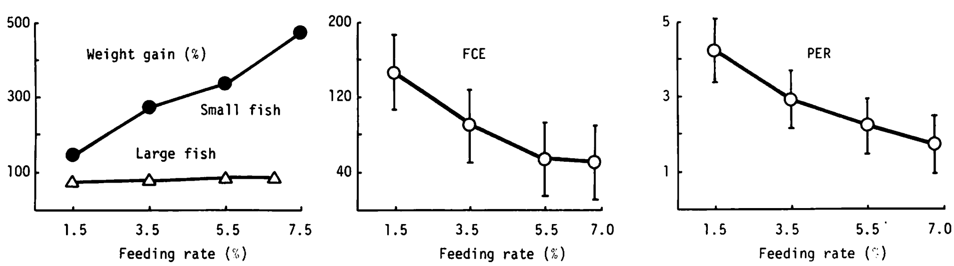


Fig. 1. Effects of feeding rate on the weight gain, FCE, and PER in Experiment I.
├──┤ ; confidence limits (P=0.95)

(factor C) as for the weight gain data. The failure to detect a significant difference on the weight gain data is plausibly attributable to the discrepancy in growth between the small and large fingerlings which enlarged the variablities of data. These results indicate that future studies should perhaps take more into account the interaction between feeding rates and fish sizes in feeding trials using *T. nilotica,* because the weight gain seemed to increase with increasing feeding rates from 1.5% to 6.8% (*ad libitum* feeding) in both small and large fish (Fig. 1) and also to be higher on 35% protein diet than 25% protein diet (Fig. 2). The FCE and PER were decreased significantly (P<0.05) with increasing feeding rates and were also higher on small fish than large fish. However, neither FCE nor PER differed significantly with dietary protein levels (25% and 35%). Analogous effects of feeding rate

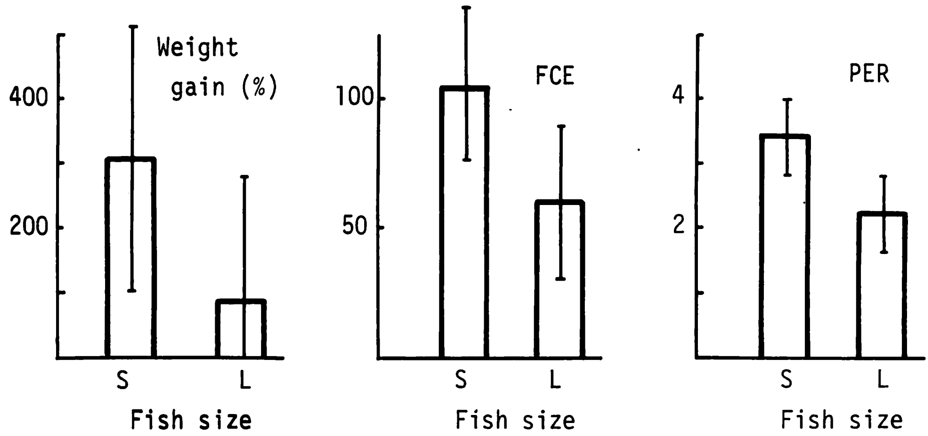


Fig. 2. Effects of fish size on the weight gain, FCE, and PER in Experiment I.
⊢—⊣ ; confidence limits (P=0.95)

on the FCE and PER have been demonstrated in large *T. nilotica*, weighing about 120 g by VIOLA and ARIELI[4]. They examined the effects of feeding rate (1.5%, 2.25%, and 3.0% of body weight per day) and protein level (25% and 30%) on growth in a factorial design, and pointed that each increase in feeding rate brought forth an increase in growth rate but the growth response was diminished at the highest rate, whereas the feed conversion factor, protein retention, and energy retention were stepwise impaired.

Tables 7 and 8 and Figs. 3 and 4 show the results of Experiment II. In Experiment II, the highest weight gain was obtained in group No. 22 receiving the diet with 2% cellulose and 35% protein. As for the weight gain and PER data, a significant difference ($P < 0.05$) was detected on both dietary protein (factor C) and cellulose (factor D) levels. The weight gain and PER were higher on 35% protein diet than on 25% protein diet and also diets with 2% cellulose than with higher cellulose levels. Optimum dietary protein levels for *T. nilotica* have been estimated by several workers using casein or casein-gelatin (3 : 1) as protein sources[5-9]. Generally, the optimum weight gain has been attained on diets containing 30-40% protein in diets. Recently, WANG *et al.*[10] have shown that an optimum dietary protein level required for the maximum growth of *T. nilotica* was 25% in diets when the feeding rate was 3.5% of body weight per day. The FCE was not significantly different with dietary cellulose levels but tended to be higher ($P<0.10$) on 35% protein diet rather than on 25% protein diet. The effects of dietary protein levels on the FCE and PER in Experiment II did not agree with those in Experiment I. This discrepancy may be ascribed to the difference in the size of fish used.

In the present study, the feed consumption was not significantly different with either dietary cellulose or protein levels. On the other hand, WANG *et al.*[2] reported that the weight gain of *T. nilotica* tended to be decreased with increasing dietary cellulose levels from 0% to 15% when the fish were fed 22% protein diets to satiation, showing that the reduction of

Table 7. Results of the feeding trial in Experiment II

| Exptl. group | Mean body wt. (g) Initial | Final | Diet consumed (g)*1 | Wt. gain (%) | FCE | PER | Daily feed consumption (%)*2 |
|---|---|---|---|---|---|---|---|
| 21 | 0.33 | 1.09 | 1.52 | 230 | 50 | 2.0 | 7.6 |
| 22 | 0.48 | 1.90 | 2.22 | 296 | 64 | 2.5 | 7.8 |
| 23 | 0.34 | 0.84 | 1.24 | 147 | 40 | 1.6 | 7.0 |
| 24 | 0.35 | 0.93 | 1.36 | 166 | 43 | 1.7 | 7.4 |
| 25 | 0.36 | 1.02 | 1.43 | 183 | 46 | 1.3 | 7.2 |
| 26 | 0.33 | 1.11 | 1.28 | 236 | 61 | 1.7 | 7.5 |
| 27 | 0.33 | 0.92 | 1.19 | 179 | 50 | 1.4 | 7.3 |
| 28 | 0.38 | 1.20 | 1.48 | 216 | 55 | 1.6 | 7.3 |

*1 Diet consumed (g)/one fish during the period of 5 weeks.
*2 % of body wt.

Table 8. Effects of the dietary cellulose and protein levels on the diet consumption, weight gain, FCE, and PER of *Tilapia* in Experiment II

| Factor and level * | Mean ± confidence limit (P=0.95) Diet consumed (g) | Weight gain (%) | FCE | PER |
|---|---|---|---|---|
| Dietary cellulose level (%) | | | | |
| $D_1$ : 2% | 1.9±0.54 | 264±32 | 57±9.8 | 2.3±0.32 |
| $D_2$ : 7% | 1.3±0.54 | 157±32 | 42±9.8 | 1.7±0.32 |
| $D_3$ : 12% | 1.4±0.54 | 210±32 | 54±9.8 | 1.5±0.32 |
| $D_4$ : 17% | 1.3±0.54 | 198±32 | 53±9.8 | 1.5±0.32 |
| Dietary protein level (%) | | | | |
| $C_1$ : 25% | 1.2±0.38 | 185±22 | 47±6.9 | 1.6±0.22 |
| $C_2$ : 35% | 1.6±0.38 | 229±22 | 56±6.9 | 1.9±0.22 |

* A significant difference ($P<0.05$) was detected in both dietary cellulose and protein levels on the weight gain and PER data. A significant difference ($P<0.10$) was also detected in the dietary protein level on the FCE data.

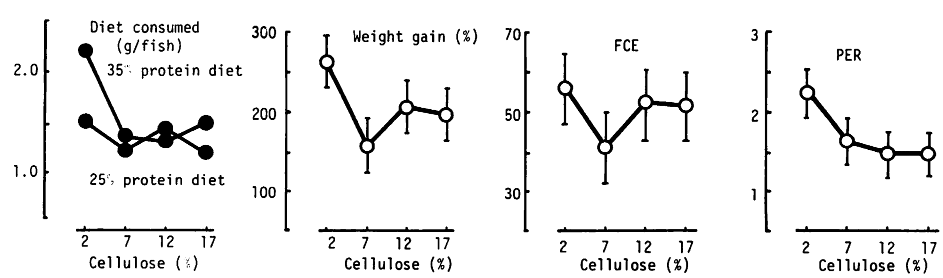


Fig. 3. Effects of dietary cellulose level on the feed consumption, weight gain, FCE, and PER in Experiment II. ⟼ ; confidence limits (P=0.95)

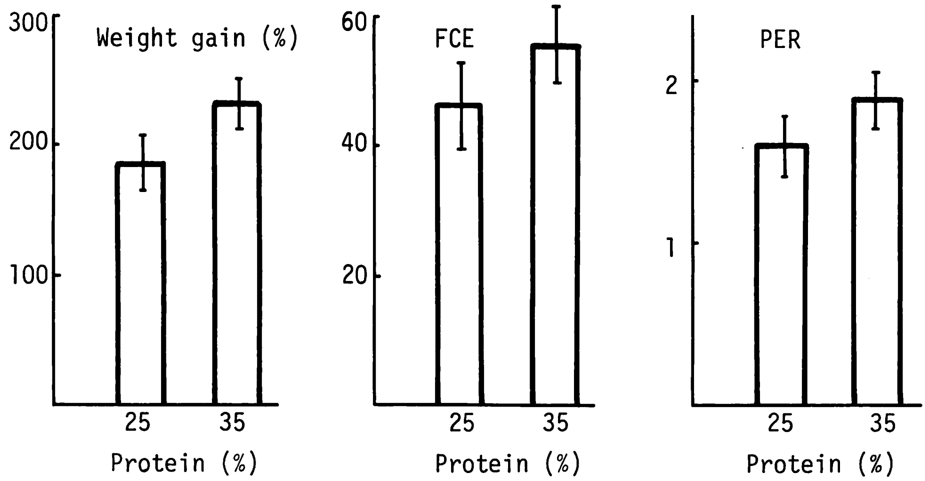


Fig. 4. Effects of dietary protein level on the weight gain, FCE, and PER in Experiment II. ├──┤ ; confidence limits (P=0.95)

dialy feed consumption was responsible for the decrease in weight gain. They have also shown that the digestibilities of carbohydrates ( $\alpha$-starch and dextrin) by *Tilapia* were decreased from 93-96% to 87-88% when dietary cellulose levels were increased from 4.5% to 14.5%[10]. In the present study, the feed consumption tended to be slightly higher on low (2%)-cellulose diets than on higher (7%, 12%, and 17%)-cellulose diets, but it was not significantly different. Interestingly, WANG *et al.*[2] have also shown that the *Tilapia* fed high (32% and 41%)-protein diets *ad libitum* gave an almost constant feed consumption regardless dietary cellulose levels. Further detailed work is required to manifest the interaction between dietary cellulose and protein levels on the growth and feed consumption in *Tilapia* species.

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## References

1 ) TESHIMA, S., A. KANAZAWA, and Y. UCHIYAMA (1986) : Effect of several protein sources and other factors on the growth of *Tilapia nilotica*. *Nippon Suisan Gakkaishi*, **52**, 525-430.

2 ) WANG, K., T. TAKEUCHI, and T. WATANABE (1985) : Effect of dietary protein levels on growth of *Tilapia nilotica*. *Nippon Suisan Gakkaishi*, **51**, 133-140.

3 ) ISHIKAWA, H., T. FUJIMORI, and T. KUME : "Design of Experiments for Chemists and Chemical Technologists (in Japanese)", Upper Vol., Tokyo-Kagakudojin, Tokyo, 1976, pp. 79-142.

4 ) VIOLA, and Y. ARIELI (1982) : Nutritional studies with a high-protein level for carp and *Sarotherodon* spp. (*Tilapia*). *Bamidgek*, **34**, 39-46.

5 ) TESHIMA, S., G. M. OJEDA GONZALEZ, and A. KANAZAWA (1978) : Nutritional requirements of *Tilapia* : Utilization of dietary protein by *Tilapia zillii*. *Mem. Fac. Fish. Kagoshima Univ.*, **27**, 49-57.

6 ) MAZID, M. A., Y. TANAKA, T. KATAYAMA, M. ASADUR RAHMAN, K. L. SIMPSON, and C. O. CHICHESTER (1979) : Growth response of *Tilapia zillii* fingerlings fed isocarolic diets with variable protein levels. *Aquaculture*, **18**, 115-122.

7 ) KESAMARU, K., N. OKAMURA, H. TAKEDA, and A. KUROKI (1982) : Studies on the nutrition of *Tilapia nilotica*. Ⅲ. Protein requirements of fingerling *Tilapia nilotica*. *Bull. Fac. Agr. Miyazaki Univ.*, **29**, 285-291.

8 ) TESHIMA, S., A. KANAZAWA, and Y. UCHIYAMA (1985) : Effects of dietary protein, lipid, and digestible carbohydrate levels on the weight gain, feed conversion efficiency, and protein efficiency ratio of *Tilapia nilotica*. *Mem. Kagoshima Univ. Res. Center S. Pac.*, **6**, 56-71.

9 ) TESHIMA, S., A. KANAZAWA, and Y. UCHIYAMA (1985) : Optimun protein levels in casein-gelatin diets for *Tilapia nilotica* fingerlings. *Mem. Fac. Fish. Kagoshima Univ.*, **34**, 45-52.

10) WANG, K., T. TAKEUCHI, and T. WATANABE (1985) : Optimun protein and digestible energy levels in diets for *Tilapia nilotica*. *Nippon Suisan Gakkaishi*, **51**, 141-146.