The Composition and Level of Dietary Lipid Appropriate for Growth of Prawn*¹

Osamu DESHIMARU*², Katsunobu KUROKI*², and Yasuo YONE*³

(Received December 11, 1978)

The effect of dietary lipid and its levels on the growth, feed efficiency, and fatty acid composition of prawn, *Penaeus japonicus*, was studied with pollack liver oil and soybean oil, used singly or in various combinations in purified diets.

At a 6% dietary lipid level, the mixed oils were more effective than either of the individual oils in growth performance and feed efficiency. In particular, the mixed oils in a ratio of 3:1 or 1:1 produced remarkably high growth and feed efficiency. Among diets containing 3, 6, 9, and 12% of the mixed oil in a 1:1 ratio, the highest growth and feed efficiency were obtained at a 6% level. The dietary mixed oil in ratios from 3:1 to 1:1 contained approximately 20-30% ω 3 and 10-17% ω 3 fatty acids with the ratio of ω 6 to ω 3 ranging from 3:1 to 1:1, and the total body lipid of the prawn fed the oils exhibited compositions of 12-20% ω 3 and 20-24% ω 3 fatty acids.

From these results, it is concluded that a mixture of pollack liver oil and soybean oil in a ratio ranging from 3:1 to 1:1, containing approximately 20-30% ω 6 and 10-20% ω 3 fatty acids, is desirable as a dietary lipid source for prawn, and that a suitable lipid level is approximately 6%.

It has been reported by GUARY *et al.*¹⁾ and KANAZAWA *et al.*²⁾ that fish oils such as sardine oil, pollack liver oil, mollusk oil, and short-necked clam oil were more effective as dietary lipid for the growth of prawn, *Penaeus japonicus*, than plant oils such as soybean oil and linseed oil. Furthermore, KANAZAWA *et al.*³⁾ demonstrated that prawn requires not only linolenic acid, but also linoleic acid in the diet. These findings suggest that a combination of fish oil rich in ω 3 fatty acids and plant oil rich in ω 6 fatty acids may be more effective for growth of prawn than the respective oils. In addition, DESHIMARU and KUROKI⁴⁾ found that prawn grew faster at a dietary lipid level of 6% than 12% or without lipid supplementation using a mixture of pollack liver oil and soybean oil in a ratio of 1:1.

In the present study, the effect of composition and level of dietary lipid on growth, feed efficiency, and fatty acid composition of prawn were examined using a purified diet with mixtures of pollack liver oil and soybean oil in various ratios and levels.

Materials and Methods

Prawn

Prawn, weighing approximately 0.4 g and 1.9 g in average, were obtained from Mitsui-Nohrin Shrimp Farm Inc. in Kagoshima. They were initially fed on a compounded feed for one week, and then twenty-five prawn were selected for each test group and maintained in plastic aquaria (70 liters).

Lipids

Pollack liver oil purified by molecular distillation and refined cuttlefish liver oil were supplied by Riken Vitamin Oils Co. Ltd. Soybean oil was obtained from a commercial source.

Test Diet and Feeding Experiment

The compositions of test diets are summarized in Table 1. Diets 1 and 5 were supplemented with pollack liver oil and soybean oil, respectively. Diets 2, 3, 4, and 9 were supplemented with a mixture of pollack liver oil and soybean oil in a ratio of 3:1, 1:1, 1:3, and 2:1, respectively. Diet 10 was supplemented with a mixture of cuttlefish liver oil and soybean oil in a 2:1 ratio. The

*¹ Studies on a purified diet for prawn—XV.

*² Kagoshima Pref. Fish. Exper. Sta., 21-1 kinkocho, Kagoshima 892 Japan (弟子丸修・黒木克宣, 鹿児島県水産試験場).

*³ Fish. Res. Lab., Kyushu Univ., Tsuyazaki, Munakata, Fukuoka 811-33 Japan (米 康夫, 九州大学農学部附属水産実験所).

Table 1. Composition of the test diets (g)

No. of diet	1	2	3	4	5	6	7	8	9	10
Protein* ¹	60	60	60	60	60	63	57	54	60	60
Lipid	6	6	6	6	6	3	9	12	6	6
Pollack liver oil	6	4.5	3	1.5	0	1.5	4.5	6	4	—
Soybean oil	0	1.5	3	4.5	6	1.5	4.5	6	2	2
Cuttlefish liver oil	—	—	—	—	—	—	—	—	—	4
Other ingredients* ²	34	34	34	34	34	34	34	34	34	34

*¹ A mixture of casein and egg albumin in a 9:1 ratio.

*² Glycogen, 10; NaH₂PO₄·2H₂O, 10; KCl, 2; Trace metals, 0.2; Vitamin mixture, 4; Glycine, 2; Cholesterol, 2; and cellulose, 3.8 in g.

supplementary lipid level was fixed at a 6%. Diets 6, 7, and 8 contained a mixture of pollack liver oil and soybean oil in a 1:1 ratio at a level of 3, 9, and 12%, respectively. The amount of protein in diets 6 through 8 was adjusted to compensate the different lipid levels. The diets were prepared as a dry pellet, with less than 10% moisture, after adjusting the pH to 6.5–6.7 with 25% NaOH solution. The feeding experiments were conducted at a water temperature of 23–26°C for four weeks on diets 1 through 8 with prawn weighing 0.4 g in average, and for six weeks on diets 9 and 10 with prawn weighing 1.9 g in average. Other rearing conditions were the same as those described in the previous paper⁴¹.

Analysis

The prawn fed diets of a 6% lipid level, Nos. 1, 3, 5, 9, and 10, were sampled and pooled in each group at the end of the feeding experiment, and total lipid of the prawn as well as that of the test diets were extracted by the method of BLIGH and DYER⁵¹. The extracted lipids were saponified and the unsaponifiable matters were removed, then the fatty acid fraction was methylated with boron trifluoride-methanol⁵¹. The fatty acid composition was analysed by a gas-liquid chromatography (Shimadzu GC-7A) with a hydrogen flame ionization detector using a glass column (2 m long × 3 mm i.d.) packed with 15% DEGS on Shimalite (80–100 mesh) at a 190°C isothermal condition.

Results and Discussion

Growth and Feed Efficiency

Regarding the effect of dietary lipids at a fixed level of 6% on the growth and feed efficiency of prawn, the mixtures of pollack liver oil and soybean oil were superior to the respectively oils (Fig. 1). Particularly, diets 2 and 3 with the mixed oil in a ratio of 3:1 and 1:1, respectively, produced

Fig. 1. Relationship between the dietary lipid composition or level and the percent gain or feed efficiency of prawn.

*¹ No. of diet.

*² Pollack liver oil.

*³ Soybean oil.

Twenty-five prawn, 0.42 g in average, were reared in a plastic aquarium (70 liters) for each test group at a water temperature of 23–26°C for four weeks.

a remarkably high percent gain and feed efficiency.

Among the diets having various lipid levels of the mixed oil in a fixed 1:1 ratio, the highest gain and feed efficiency were obtained on diet 3 with 6% lipid, followed by diet 6 with 3% and diet 7 with 9% lipid in decreasing order. Diet 8 with 12% lipid produced the lowest growth and feed efficiency.

As shown in Fig. 2, the prawn fed diet 9 containing a mixture of pollack liver oil and soybean oil

Fig. 2. Growth curve of prawn fed diets with pollack liver oil (diet 9, ○—○) and cuttlefish liver oil (diet 10, ●—●) in combination with soybean oil. Twenty-five prawn, 1.94 g in average, were reared in a plastic aquarium (70 liters) for each test group at a water temperature of 23–26°C for six weeks.

in a 2:1 ratio exhibited high growth rate similar to that of the group fed diet 10 with a mixture of cuttlefish liver oil and soybean oil in the same ratio. However, the feed efficiency of diet 9 was 23.8%, being somewhat lower than 29.8% of diet 10.

Relationship between Fatty Acid Composition and Nutritive Value of Dietary Lipid

As shown in Table 2, the lipid of diets 3, 9, and 10, which produced high growth and feed efficiency, contained approximately 20–30% $\omega 6$ and 10–17% $\omega 3$ fatty acids and the ratio of $\omega 6$ to $\omega 3$ in these diets were 2.9:1, 1.8:1, and 1.2:1, respectively. On the other hand, diet 1 contained an extremely low $\omega 6$ and high $\omega 3$ fatty acids (3 and 12%), 0.25:1 in the ratio of $\omega 6$ to $\omega 3$, and diet 5 was considerably high in linoleic acid (52%) and low in linolenic acid (7%), 7.4:1 in the ratio, and these diets resulted in low growth and low feed efficiency. These findings suggest that the lipid having both $\omega 6$ and $\omega 3$ fatty acids in the ratio ranging from 1:1 to 3:1 is desirable for prawn diet. It is also presumed that the requirements of prawn for $\omega 6$ and $\omega 3$ fatty acids are approximately 1.2–1.8 g and 0.6–1.0 g per 100 g diet, respectively. The above mentioned requirement of prawn for $\omega 3$ fatty acids is similar to that of rainbow trout^{7,8)} and of red sea bream⁹⁾ for linolenic acid or $\omega 3$ highly unsaturated fatty acids (20:5 and 22:6).

Fatty Acid Composition of Whole Body Lipid

The prawn fed diets 3, 9, and 10 exhibited high growth and high feed efficiency, and contained similar levels of $\omega 6$ and $\omega 3$ fatty acids, 12–20% and 20–24%, respectively, in the whole body lipid (Table 2). On the other hand, the lipid of the

Table 2. Fatty acid composition (%) of the dietary lipids and of the total lipid from the whole body of prawn at the end of the feeding experiment

No. of diet	1		3		5		9		10	
Fatty acids	Dietary lipid	Prawn	Dietary lipid	Prawn	Dietary lipid	Prawn	Dietary lipid	Prawn	Dietary lipid	Prawn
14:0	9.8	1.0	5.0	0.9	0.1	1.0	6.5	1.5	4.5	1.1
16:0	16.1	16.6	13.7	20.8	11.2	10.8	14.4	18.1	16.4	20.4
16:1 ω 7	12.1	5.7	6.1	3.1	0.1	2.8	8.1	2.5	3.7	1.6
18:0	2.0	7.0	3.3	7.9	4.5	8.8	2.8	7.6	3.8	6.5
18:1 ω 9	16.7	23.4	20.6	20.9	24.4	20.1	19.2	19.1	20.8	19.8
18:2 ω 6	1.2	3.9	26.7	7.2	52.2	23.4	18.2	16.8	18.4	14.7
18:3 ω 3	0.3	0.9	3.6	1.3	6.9	1.1	2.5	1.1	3.0	1.2
20:1 ω 9	16.8	3.8	8.6	2.5	0.3	1.6	11.3	6.6	7.9	3.8
20:2 ω 6	—	0.8	—	1.0	—	1.5	—	0.7	—	1.1
20:3 ω 6	—	2.3	—	2.5	—	3.1	—	trace	—	0.9
20:4 ω 6	1.8	0.9	0.9	1.1	—	0.9	0.9	1.4	0.7	2.7
20:5 ω 3	9.1	12.5	4.6	10.1	—	7.1	6.1	11.3	6.4	9.9
22:4 ω 6	0.4	0.2	0.2	0.5	—	0.5	0.3	0.3	0.3	0.2
22:5 ω 3	0.5	1.5	0.3	1.0	—	0.7	0.3	0.7	0.7	0.8
22:6 ω 3	2.4	9.4	1.2	8.6	—	7.4	1.6	7.3	6.4	12.2
$\Sigma \omega 6$	3.4	8.1	27.8	12.3	52.2	29.4	19.4	19.2	19.4	19.6
$\Sigma \omega 3$	12.3	24.3	9.7	21.0	6.9	16.3	10.5	20.4	16.5	24.1

prawn fed only pollack liver oil exhibited considerably low level (8%) of $\omega 6$ fatty acids and the ratio of $\omega 6$ to $\omega 3$ were 0.3: 1, being similar to the ratio of the dietary lipid. The lipid of the prawn fed only soybean oil showed a low level (16%) of $\omega 3$ fatty acids and the ratio was 1.8: 1.

In conclusion, a mixture of pollack liver oil and soybean oil in the ratio ranging from 3: 1 to 1: 1, containing approximately 20–30% $\omega 6$ and 10–20% $\omega 3$ fatty acids, is desirable as a dietary lipid source for prawn, and a suitable lipid level is assumed to be approximately 6%.

Acknowledgement

The authors wish to thank Riken Vitamin Oils Co. Ltd. for supplying pollack liver oil and cuttlefish liver oil.

References

- 1) J. C. GUARY, M. KAYAMA, Y. MURAKAMI, and H. J. CECCALDI: *Aquaculture*, **7**, 245–254 (1976).
- 2) A. KANAZAWA, S. TESHIMA, and S. TOKIWA: *Bull. Japan. Soc. Sci. Fish.*, **43**, 849–856 (1977).
- 3) A. KANAZAWA, S. TOKIWA, M. KAYAMA, and M. HIRATA: *Bull. Japan. Soc. Sci. Fish.*, **43**, 1111–1114 (1977).
- 4) O. DESHIMARU and K. KUROKI: *Bull. Japan. Soc. Sci. Fish.*, **40**, 413–419 (1974).
- 5) E. G. BLIGH and W. L. DYER: *Can. J. Biochem. Physiol.*, **37**, 911–917 (1959).
- 6) L. P. METCALF and A. A. SCHMITZ: *Anal. Chem.*, **32**, 363–365 (1961).
- 7) T. WATANABE, C. OGINO, Y. KOSHIISHI, and T. MATSUNAGA: *Bull. Japan. Soc. Sci. Fish.*, **40**, 493–499 (1974).
- 8) T. TAKEUCHI and T. WATANABE: *Bull. Japan. Soc. Sci. Fish.*, **42**, 907–919 (1976).
- 9) M. FUJII, H. NAKAYAMA, and Y. YONE: *Rept. Fish. Res. Lab., Kyushu Univ.*, No. 3, 65–86 (1976).