マダイにおける低魚粉・無魚粉飼料の利用性

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Use of Low or Non-fish Meal Diets for Red Sea Bream

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Abstract: Feeding experiments were conducted to examine the possibility to utilize low or non fish meal diets for red sea bream, *Pagrus major*. In Expt. I, three low-fish meal (10% fish meal) and one non-fish meal diets were prepared to contain soy protein concentrate (SPC, a main ingredient), defatted soybean meal (SBM), corn gluten meal (CGM), meat meal (MM), and poultry feather meal (PFM) in different combinations, and fed to juvenile red sea bream weighing 27 g on average for 56 days. In Expt. II, adult fish with an initial body weight of around 550 g were fed the four experimental non-fish meal diets for 183 days.

Palatability of the experimental diets was not affected by dietary fish meal levels in both sizes of fish. In both the experiments, growth and feed gain ratio were the highest in fish fed the control fish meal diet and tended to decrease with reduction of the SPC content in the test diets. However, in Expt. II, these performances in fish on the non fish meal diet containing 40% SPC were comparable to those of the control. Supplemental effects of crystalline amino acids to low-fish meal diets on growth and feed performances were not observed in Expt. I. Moreover, hemochemical examination at the end of feeding revealed that both juvenile and adult fish kept in good health status.

Therefore, it was suggested that a combination of SPC, SBM, CGM, MM, and PFM can be effectively employed as alternate protein sources to develop low or non-fish meal diets if these ingredients were adequately incorporated.

Key words: Red sea bream; Non-fish meal diets; Alternative protein source

With the rapid decrease of the catch of feed-grade fish and increasing demand of formula feed production for marine fish culture, effective alternate protein sources to replace or reduce the amount of fish meal, the main protein sources, are desired. In red sea bream, there have been several studies on the utilization of various plant and animal protein ingredients as partial replacements for fish meal in the feeds[1-6]. In our pervious experiment[1], we have found that defatted soybean meal (SBM), both processed and unprocessed by extruder, could be employed as fish meal replacer at around 30% in the diets for juvenile fish. And, it was showed that SBM combined with corn gluten meal (CGM) and meat meal (MM) could substitute about 60% of fish meal component without any ill effects on the growth and feed parameters in the diets for both juvenile and adult fish[2,3]. In addition, our studies on the availability of non-fish meal diets with yellowtail[7] and rainbow trout[8] showed that there was certain difference in the feed utilization between the two species. The present study was conducted with red sea bream to examine availability of low or non-fish meal diets formulated with soy protein concentrate (SPC), SBM, CGM, MM, and poultry feather meal (PFM) as protein sources.

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Materials and Methods

Experimental Diets

In this study, two feeding experiments were performed using different test diets. The ingredient composition of the experimental diets and their proximate composition in Expts. I and II are shown in Table 1.

Expt. I (low or non-fish meal diets): Diet 1 was a commercial diet for red sea bream containing fish meal as a main protein source, and was used as the control. Diet 2 was a non-fish meal diet containing 30% SPC, 10% SBM, 8% CGM, and 10% MM as dietary proteins, and was supplemented with a crystalline amino acid mixture (1.5% L-lysine, 0.5% DL-methionine, 0.5% L-threonine, and 0.2% L-tryptophan) to match the essential amino acid (EAA) profile with that of the control diet for red sea bream. Diets 3-5 contained 10% fish meal with 20 or 10% SPC, 10% SBM, 8 or 10% CGM, 10 or 15% MM, and 5-8% PFM. The proportion of protein ingredients in diets 3 and 4 was the same, and EAA mixture was added to diet 4 only to investigate the supplemental effect. There was no marked difference in dietary protein content among the treatments, but diet 2 was slightly lower. The crude lipid content was high in diet 2, reflecting the amount of feed oil added in the diet.

Expt. II (non-fish meal diet): The experimental diets were the same as those used in the previous trial with yellowtail[7]. Commercial pellets prepared using a twin screw extruder was used as the control diet (diet 1). In diets 2-5, 20-30% SPC, 10% SBM, 3-23% CGM, and 12-15% MM were incorporated in combination, and all the diets contained 2.7% EAA mixture with the same composition as that used in Expt. I. All of the non-fish meal diets were produced using small size twin screw extruder[3]. The crude protein and lipid contents were almost the same for all the experimental diets. The amino acid composition

Table 1. Composition of the low or non-fish meal diets for red sea bream

Ingredient (%)	Experiment I					Experiment II				
	Diet no.					Diet no.				
	1	2	3	4	5	1	2	3	4	5
Fish meal	Commercial diet	0	10	10	10	Commercial diet	0	0	0	0
Soy protein concentrate		30	20	20	10		40	30	25	20
Defatted soybean meal		10	10	10	10		10	10	10	10
Corn gluten meal		8	8	8	10		3	13	18	23
Meat meal		10	10	10	15		12	13	15	14
Poultry feather meal		0	7	5	8		0	0	0	0
Krill meal		10	5	5	5		2	2	2	2
α-starch		0	8	10	10		0	0	0	0
Wheat flour		8	0	0	0		8	8	8	8
Vitamin mixture		2	3	3	3		2.55	2.55	2.55	2.55
Mineral mixture		5	5	5	5		2.45	2.45	2.45	2.45
Feed oil		17	14	14	14		20	19	17	18
Amino acid mixture*		2.7	0	2.7	2.7		2.7	2.7	2.7	2.7
Total		102.7	100	102.7	102.7		102.7	102.7	102.7	102.7
Nutrient contents determined (% as is basis)										
Crude protein	44.4	42.4	44.6	44.5	45.6	47.1	46.5	47.4	47.7	47.7
Crude lipid	15.1	21.0	17.5	16.9	13.3	23.0	23.9	23.7	23.2	23.5
Crude ash	9.4	8.3	8.3	8.2	8.3	9.9	5.7	5.3	5.1	4.8
Moisture	8.3	3.8	7.2	7.4	7.9	6.5	4.3	4.2	6.2	5.4
Dry matter basis (%)										
Crude protein	48.4	44.1	48.1	48.1	49.5	50.4	48.6	49.5	50.9	50.4
Crude lipid	16.5	21.8	18.9	18.3	14.4	24.6	25.0	24.7	24.7	24.8
Crude ash	10.3	8.6	8.9	8.9	9.0	10.6	6.0	5.5	5.4	5.1

* Lysine 1.5, methionine 0.5, threonine 0.5, and tryptophan 0.2.

Table 2. Amino acid composition of the fish meal and non-fish meal diets for red sea bream (Expt. II)

Amino acid (g/100g diet)	Diet no. 1	2	3	4	5
Arginine	2.66	3.03	2.84	2.74	2.63
Lysine	3.42	3.71	3.52	3.36	3.27
Histidine	1.32	1.19	1.13	1.15	1.13
Phenylalanine	1.89	2.18	2.26	2.32	2.42
Tyrosine	1.51	1.47	1.58	1.65	1.73
Leucine	3.38	3.54	4.16	4.51	4.92
Isoleucine	1.95	1.89	1.88	1.88	1.91
Methionine	1.24	1.06	1.15	1.18	1.26
Cystine	0.49	0.60	0.64	0.66	0.67
Valine	2.34	2.15	2.17	2.20	2.22
Alanine	2.78	2.28	2.63	2.85	3.05
Glycine	2.94	2.57	2.61	2.67	2.62
Proline	2.19	2.85	3.15	3.30	3.55
Glutamic acid	6.13	8.11	8.38	8.58	8.83
Serine	1.89	2.25	2.31	2.32	2.36
Threonine	1.95	2.15	2.16	2.17	2.16
Aspartic acid	4.29	4.59	4.32	4.16	4.08
Tryptophan	0.56	0.72	0.68	0.67	0.64
Total	42.93	46.34	47.57	48.37	49.45
Total EAA*	22.71	23.69	24.17	24.49	24.96

* Total essential amino acids (including tyrosine and cystine).

of the experimental diets analyzed by the Japan Food Research Laboratories is shown in Table 2. Each EAA content of the non-fish meal diets was comparable to that of the control fish meal diet, and satisfied the requirement of yellowtail*5.

The control and test diets in both experiments were added with the vitamin and mineral mixtures to satisfy the requirements of yellowtail[9]. All the experimental diets were kept at -20°C during the rearing period.

Feeding Conditions

The feeding experiments were conducted at the Fishery Research Laboratory of Kyushu University in aquariums (Expt. I), and at the Owase Branch of Fisheries Research Institute of Mie in net cages (Expt. II).

Expt. I: Juvenile red sea bream, *Pagrus major*, with a mean body weight of about 27 g were divided into five groups of 30 fish each in 150-*l* rectangular aquariums. They were reared on each experimental diet for 56 days (8 weeks, 50 days feeding), from Jan. 12 to Mar. 10. Fish were fed the respective diets to near satiation twice a day. The aquariums were continuously supplied with filtered sea water, and water temperature was kept at 22.0 ± 0.5°C. During the experimental period, all the fish in each lot were weighed every two weeks to determine the average body weight. At the final, 5 fish were taken from each aquarium for proximate analysis of dorsal muscle and liver at Kyushu University as described in a previous paper[3].

Expt. II: Adult red sea bream (one-year-old) weighing 538-579 g on average were used. They were reared on a commercial dry pelleted feed for about 10 months before the initiation of the experiment. Then they were divided into five groups of 240 fish each and stocked in net cages (3 × 3 × 3 m), and reared for 183 days (from Nov. 11 to May 12 of the next year, 87 days feeding). The water temperature at farming site (2 m in depth) ranged from 14.5-20.6°C (average 16.9°C). The respective diets were fed to each group, once a day in the morning to near satiation, 3-4 times per week. At the start and end of the experiment, all the fish in net cages were counted and weighed, and average body weight of 60 fish, which were randomly collected from each lot, was recorded on Dec. 26 and Feb. 13.

Hematological and Hemochemical Assessments

In both experiments, 5 fish were randomly taken from each lot on termination and hematological characteristics and hemochemical constituents were determined to evaluate the health condition, by the same methods described previously[10,11]. Statistical analysis of the data was carried out using analysis of valiance (ANOVA). Fisher's PLSD test or Duncan's multiple range test was used to compare the differences of treatment mean value at a significant level of 0.05.

Results and Discussion

Feed Performances

The results of growth and feed performances

*5 Watanabe, T., S. Satoh, and T. Takeuchi: Abst. Metg. Japan. Soc. Fish. Sci., April, 1995, p.33.

in Expts. I and II are shown in Tables 3 and 4, respectively.

Expt. I: Both final average body weight and growth rate (GR) were highest in fish fed the control fish meal diet, and significant difference ($p<0.05$) was found in body weight between the control (71.5 g) and test groups (47.5-64.1 g). Among the low or non-fish meal diets, the average body weight of fish fed diet 2 (non-fish meal diet) was significantly higher than that of fish on diets 3-5. The worst growth performance was obtained for the diet 5 group. The same tendency was observed for feed performances in terms of feed gain ratio (FGR) and protein efficiency ratio (PER), though these values were almost similar between the control and diet 2 groups. Thus, the feed quality of diet 2 seemed to be superior to other test diets. The growth per-

Table 3. Growth and feed gain ratio of red sea bream fed the low or non-fish meal diets in aquariums (Expt. I)

Diet no.	Av. body wt.*1 (g)		Growth rate (%)	Feed gain ratio*2	Daily feed intake*3	Protein efficiency ratio*4	Mortality (fish)
	Initial	Final					
Jan. 12-Mar. 10 (50 days feeding)							
1	27.0±1.6	71.5±7.3[a]	164.8	1.13	1.98	2.00	0
2	27.1±1.7	64.1±11.9[b]	136.5	1.11	1.56	2.12	2
3	27.1±1.6	57.4±8.2[c]	111.8	1.34	1.84	1.67	0
4	27.0±1.6	55.3±9.2[c]	104.8	1.24	1.64	1.81	0
5	27.0±1.6	47.5±7.7[d]	75.9	1.68	1.78	1.31	0

*1 Mean ± standard deviation (n = 28-30). Values in the same row bearing different letters are significantly different ($p<0.05$, Fisher's PLSD test).
*2 g feed/g weight gain.
*3 g/100g body weight.
*4 g gain/g protein intake.

Table 4. Growth and feed gain ratio of red sea bream fed the non-fish meal diets in net cages (Expt. II)

Diet no.	Av. body wt. (g)		Growth rate (%)	Feed gain ratio	Daily feed intake	Protein efficiency ratio	Mortality (%)
	Initial	Final					
Nov. 11-Dec. 26 '93 (30 days feeding)							
1	560	650	16.1	1.60	0.79	1.33	0.0
2	579	657	13.4	1.67	0.70	1.29	0.0
3	551	625	13.5	1.67	0.70	1.26	0.4
4	544	615	13.1	1.76	0.72	1.19	0.8
5	538	610	13.4	1.67	0.70	1.25	0.0
Dec. 27-Feb. 13 '94 (19 days feeding)							
1	650	690	6.2	1.44	0.54	1.48	0.0
2	657	700	6.5	1.39	0.52	1.55	0.0
3	625	705	12.8	0.77	0.51	2.74	0.4
4	615	637	3.6	2.04	0.51	1.03	0.4
5	610	618	1.3	3.27	0.52	0.64	0.0
Feb. 14-May 12 '94 (38 days feeding)							
1	690	714	3.5	6.73	0.62	0.32	0.6
2	700	736	5.1	4.70	0.61	0.89	0.6
3	705	675	-	-	0.56	-	1.1
4	637	655	2.9	8.24	0.63	0.25	0.6
5	618	641	3.7	6.04	0.64	0.35	0.0
Total feeding period (87 days feeding)							
1	560	714	27.5	2.32	0.61	0.92	0.4
2	579	736	27.0	2.27	0.57	0.95	0.4
3	551	675	22.6	3.09	0.57	0.68	1.7
4	544	655	20.5	3.20	0.59	0.66	1.7
5	538	641	19.1	3.06	0.58	0.69	0.0

formance tended to decrease with reduction of proportion of SPC in the test diets. We have already examined the availability of SPC to juvenile red sea bream, and have shown that SPC could utilize as an alternative protein source for fish meal in the diet[3]. These facts suggest that the nutritional value of SPC was superior to other alternate ingredients. However, the lipid content of diet 5 was the lowest among the experimental diets, indicating that poor growth and feed performance in fish on this diet were due to the insufficiency of energy content. Therefore, the distinct cause of reduction of growth performances in fish on the low-fish meal diets was unknown in the present study. On the other hand, on comparing the feeding results between fish fed diets 3 and 4, there was no clear supplemental effect of the crystalline amino acid mixture. Similarly in a previous study[3], we did not observe the supplemental effect of crystalline lysine to a fish meal replaced diet for juvenile red sea bream; the same diet produced growth and feed performance parameters comparable to the commercial fish meal diet. Further study should be done to investigate the effectiveness of supplemental amino acids on the feed protein utilization.

Expt. II: Palatability and acceptability of the experimental diets were not affected by the entire elimination of fish meal component, irrespective of the combination of alternate proteins. The GR ranged from 19.1% for the diet 5 group to 27.5% for the control group, and tended to decrease with decrease of SPC content in the diets, as shown in Expt. I. This value was generally low for all the treatments due to low water temperature during the winter season. The growth performance of fish fed diet 2 (40% SPC + 10% SBM + 3% CGM + 12% MM) was comparable to that of the control group, and was superior to other test diets, though nutrient contents were almost in the same levels among the non-fish meal diets. FGR of fish on the control diet and diet 2 were better than those on diets 3-5, 2.32 and 2.27 for the former groups and 3.06-3.20 for the latter groups. The same tendency was observed for PER. These results indicated that there was no difference in nutritional quality between the fish meal diet and the non-fish meal diet containing 40% SPC. It was also suggested that SPC had excellent quality as alternate dietary proteins to adult red sea bream, compared to other feed ingredients. The cumulative mortality of fish during the experimental period was low for all the treatments. However, the dissection of the fish at the end of feeding revealed that fish had green liver status for both the control and test groups. The occurrence rate of this symptom was 60% for the control group and 60-100% for the test groups ($n = 5$). These results indicated that physiological condition of the experimental fish was generally poor for both the control and test groups, although the reason remained unknown.

In a previous trial[7], the same non-fish meal diets were shown to be efficient to sustain normal growth and health of young yellowtail for about one and a half months after initiation of the feeding, but thereafter the growth slowed down and high mortality was observed, irrespective of the dietary composition. Moreover, most of fish on the non-fish meal diets developed green liver symptom, which caused by occlusion of the bile duct due to parasitic mucosporozoa, in all the treatments. On the contrary, both retardation of the growth and mass mortality were not found in fish of all groups in this experiment, though the growth performance of the test groups was inferior to the control. Therefore, it was suggested that there was difference in availability of the non-fish meal diets between red sea bream and yellowtail. In the present experiment, the good growth and feed performances comparable to the control fish were obtained in the fish on the non-fish meal diet formulated with 40% SPC as a main protein source. These findings demonstrated that there would be no difference in nutritive value between diets with and without fish meal component for both juvenile and adult red sea bream when non-fish meal diets are formulated with alternate protein ingredients in an adequate balance. Further researches should be carried out to clarify suitable ingredient and proximate compositions of the non-fish meal diets for red sea bream.

Proximate Composition

Results of proximate analysis for dorsal muscle and liver from fish in Expt. I are shown in Table 5. The protein content of dorsal muscle was not greatly affected by the dietary compositions. The lipid content of this tissue in fish fed diets 1-3 was higher than those of fish fed diets 4 and 5. The lipid value in the diet 5 group was lowest among the treatments, reflected by a lower dietary lipid level. There was an inverse relationship between lipid and moisture contents, and the highest moisture value was obtained for fish on diet 5. The muscle ash content was slightly higher in fish fed the control diet than those fed the test diets, reflected by the ash content in the diet. In the liver, the protein content in fish fed the control diet was not different from fish fed diets 2 and 3, and was slightly higher than that in fish on diets 4 and 5. The lipid, ash, and moisture contents of liver showed the same tendencies as those observed in dorsal muscle.

Table 5. Proximate composition (%) of dorsal muscle and liver from juvenile red sea bream fed the low or non-fish meal diets in aquariums (Expt. I)

Diet no.	Moisture	Crude protein	Crude lipid	Crude ash
Dorsal muscle				
1	75.3	20.6 (83.4)*	2.1 (8.5)	1.7 (6.9)
2	75.2	21.5 (86.7)	2.3 (9.3)	1.6 (6.5)
3	74.5	22.3 (87.5)	2.2 (8.6)	1.6 (6.3)
4	75.9	21.9 (90.9)	1.6 (6.6)	1.6 (6.6)
5	76.1	20.5 (85.8)	1.6 (6.7)	1.6 (6.7)
Liver				
1	61.0	13.1 (33.6)	19.8 (50.8)	2.0 (5.1)
2	58.2	13.2 (31.6)	21.3 (51.0)	1.3 (3.1)
3	59.7	13.2 (32.8)	20.8 (51.6)	1.8 (4.5)
4	64.5	11.2 (31.5)	16.5 (46.5)	1.7 (4.8)
5	67.2	11.4 (34.8)	13.2 (40.2)	1.6 (4.9)

* Data in the parentheses are in dry basis.

Hematological and Hemochemical Characteristics

Results of hematological and hemochemical examinations in Expts. I and II were shown in Table 6.

Expt. I: The hematocrit (Ht) value varied from 31.4 to 36.4% and was within the normal range for all the groups. There was no significant difference in hemoglobin (Hb) concentration between fish fed the control diet and test diets.

Table 6. Results of hemochemical examination in red sea bream fed the low or non-fish meal diets in Expts. I and II

		Diet no.				
		1	2	3	4	5
Expt. I*1						
Ht	(%)	32.1 ± 1.6^{bc}	34.5 ± 1.7^{ab}	36.4 ± 4.7^{a}	31.8 ± 2.9^{c}	31.4 ± 2.4^{c}
Hb	(g/100 *ml*)	8.1 ± 0.7^{a}	8.4 ± 0.8^{a}	8.4 ± 1.3^{a}	8.4 ± 1.3^{a}	8.1 ± 0.5^{a}
TG	(mg/100 *ml*)	591	699	543	490	339
TP	(g/100 *ml*)	6.6 ± 0.4^{bc}	7.2 ± 0.6^{a}	6.8 ± 0.6^{ab}	6.1 ± 0.7^{d}	6.2 ± 0.4^{cd}
P	(mg/100 *ml*)	9.5	10.6	10.5	10.4	9.7
Ca	(mg/100 *ml*)	14.1	15.6	15.5	13.5	14.5
Expt. II*2						
Ht	(%)	32.2±3.1	28.2±2.5	28.4±5.0	30.8±3.6	29.0±1.9
ALP	(IU/*l*)	64±73	75±71	47±23	104±114	97±105
GLU	(mg/100 *ml*)	113 ± 75^{a}	46 ± 14^{b}	44 ± 13^{b}	45 ± 5^{b}	51 ± 12^{b}
TG	(mg/100 *ml*)	190±135	276±165	138±88	74±57	184±130
PL	(mg/100 *ml*)	704±197	676±95	638±328	623±124	518±120
TCHO	(mg/100 *ml*)	260±61	217±36	175±56	183±61	182±39
FCHO	(mg/100 *ml*)	113±34	114±23	84±37	99±25	81±23
ER	(%)	56.7±6.5	47.5±6.0	53.6±8.9	44.2±9.9	56.1±5.3
BUN	(mg/100 *ml*)	3.7±0.6	4.9±1.4	3.7±0.8	5.1±1.9	3.8±0.3
TP	(g/100 *ml*)	3.2±0.4	3.0±0.5	2.6±0.4	2.8±0.3	2.7±0.2
Condition factor		21.3 ± 1.1^{a}	21.9 ± 1.4^{a}	18.7 ± 1.4^{b}	22.8 ± 2.2^{a}	19.9 ± 1.7^{ab}
Hepatosomatic index		2.25 ± 0.45^{a}	1.85 ± 0.44^{a}	1.26 ± 0.50^{b}	1.80 ± 0.36^{a}	1.65 ± 0.53^{a}

*1 Mean ± standard deviation ($n=5$). Values in the same row bearing different letters are significantly different ($p<0.05$, Fisher's PLSD test).

*2 Mean ± standard deviation ($n=5$). Figures in a row with different superscripts are significantly different from each other ($p<0.05$, Duncan's multiple range test).

The triglyceride (TG) content in plasma was the highest for the diet 2 group and lowest for the diet 5 group, probably reflected by dietary lipid levels. Total plasma protein (TP) value indicated the normality irrespective of the dietary treatments, although this level in fish fed diets 4 and 5 were significantly lower than those on diets 1-3. The almost similar levels were found in both phosphorus (P) and calcium (Ca) in plasma, suggesting the normal health status of fish. From these data, the indication was that the physiological condition was not markedly different between fish fed the fish meal diet and low or non-fish meal diets, and that all the fish were kept in good health status.

Expt. II: The Ht values were not markedly different among the treatments and were within the normal levels (around 30%). Some of fish in all the groups, however, showed a very high alkaline phosphatase (ALP) activity, suggesting a slightly poor health status. The glucose (GLU) level of fish fed the non-fish meal diets was significantly lower than that of the control diet, though its definite reason was unknown. The items related to lipid metabolism, phospholipid (PL), total cholesterol (TCHO), free cholesterol (FCHO), and cholesterol ester ratio, were not significantly different among the treatments, though these levels in fish on the control diet were slightly higher than those on the test diets. These results indicated better lipid metabolism or liver function in the control group than in the test groups. There were no marked differences in the blood urea nitrogen (BUN) and TP levels among the groups, suggesting that all the fish had normal protein metabolism.

Summarizing the hematological and hemochemical examinations in both the experiments, the physiological condition of fish fed the low or non-fish meal diets was comparable to those fed the control diet. Therefore, it appears that health status of red sea bream was not affected largely by rearing them on diets without fish meal.

In conclusion, present experiments have shown that feed utilization of low or non-fish meal diets was somewhat lower than that of the fish meal diet. However, it seemed that there were no adverse effect on growth and health status of red sea bream due to feeding the low or non-fish meal diets. Therefore, red sea bream could use the low or non-fish meal diets unlike yellowtail if dietary protein ingredients were appropriately incorporated to balance EAA profiles.

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マダイにおける低魚粉・無魚粉飼料の利用性

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魚粉代替タンパク質源として濃縮大豆タンパク質，大豆油粕，コーングルテンミール，ミートミールを併用配合した低魚粉（魚粉含量10%）および無魚粉飼料のマダイに対する利用性を調べた。試験Ⅰでは平均体重27 gのマダイを3種類の低魚粉飼料と1種類の無魚粉飼料を用いて56日間飼育した。試験Ⅱでは平均体重550 g前後のマダイを4種類の無魚粉飼料を用いて183日間飼育した。両試験とも市販のドライペレット（魚粉飼料）給餌区を対照区として設け，飼育成績および血液検査から判断した供試魚の生理状態について試験区と比較した。その結果，低・無魚粉飼料に対するマダイの摂餌性は良好であった。試験Ⅰでは低・無魚粉飼料区の成長および増肉係数は対照区に比べて劣ったが，試験Ⅱでは濃縮大豆タンパク質40%配合の無魚粉飼料区は対照区に匹敵する成績を示した。試験区の成績は配合組成によって異なり，濃縮大豆タンパク質の配合率の少ない区ほど劣る傾向がみられた。試験Ⅰでは低魚粉飼料に対する結晶アミノ酸の添加効果を調べたが，飼育成績の改善はみられなかった。また血液検査の結果，低・無魚粉飼料区の供試魚の生理状態は魚粉飼料と同等であると評価された。以上の結果から，マダイでは代替タンパク質を適切な配合割合で併用することによって魚粉飼料と同等の栄養価を有する低・無魚粉飼料を開発できる可能性が示唆された。