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Dietary Protein Requirement for Young Far Eastern Catfish *Silurus asotus*

Kyoung-Duck Kim[1]*, Kang-Woong Kim[1], Bong-Joo Lee[1], Maeng Hyun Son[1], Hyon-Sob Han[1] and Jin Do Kim[2]

[1]Aquafeed Research Center, National Fisheries Research and Development Institute, Pohang 791-923, Korea
[2]Inland Aquaculture Research Center, National Fisheries Research and Development Institute, Jinhae 645-806, Korea

Abstract

A feeding trial was conducted to determine the optimum dietary protein requirement of young far eastern catfish *Silurus asotus*. Five isocaloric diets were formulated to contain graded levels of protein (35, 40, 45, 50, and 55%). Triplicate groups of fish (initial body weight of 44 g) were hand-fed to apparent satiation for 9-weeks. Weight gain and specific growth rate of fish fed 55% protein diet were significantly higher than those of fish fed 35 and 40% protein diets, but not significantly different from those of fish fed 45 and 50% protein diets. The feed efficiency of fish fed 50 and 55% protein diets was significantly higher than that of fish fed 35, 40 and 45% protein diets. The protein efficiency ratio of fish fed 40% protein diet was significantly higher than that of fish fed 45, 50 and 55% protein diets, but not significantly different from that of fish fed 35% protein diet. The dietary protein level significantly affected whole body lipid and moisture contents. The results of this study suggest that the 45% protein in the diet is optimal for maximum growth of young far eastern catfish weighing in the range of 44 to 227 g.

Key words: *Silurus asotus*, Protein requirement, Far eastern catfish, Growth, Body composition

Introduction

Balanced nutrients and enough calories in aquafeed are essential for growth and maintenance of farmed fish. Fish are known to utilize protein preferentially to lipid or carbohydrate as an energy source (Walton and Cowey, 1982). Dietary protein is the most important factor affecting both growth performance of fish and feed cost (Lovell, 1989). Accurate information on the protein requirements of fish is crucial for any aquaculture initiative owing to the high cost of protein ingredients which are usually required at high levels by most fishes (NRC, 1993).

Far eastern catfish is one of the most important commercial freshwater fish species, because this species has high consumer demand in Korea. This species is distributed in Korea, Japan, China and Taiwan (Chyoung, 1996). Aquaculture production of far eastern catfish has steadily increased during the last decade, and its production in 2012 reached 3,676 metric tons, which is second only to eel (4,259 metric tons) among freshwater fish aquaculture in Korea (Statistics Korea, 2013).

Recently, nutritional studies evaluating the effects of dietary protein and lipid levels, availability of dietary lipid sources, and substitution of fishmeal with soybean meal for growth in this species have been performed (Kim et al., 2009; Kim et al., 2010; Kim et al., 2012). Although the dietary protein requirement for 7 to 36 g juvenile far eastern catfish had been studied (Kang and Jeong, 1993), limited information about optimum dietary protein level is available for this fish species of different sizes. In an attempt to formulate an efficiently economical feed for the far eastern catfish, this study was conducted to determine the optimum protein level in the isoenergetic diets for attaining the maximal growth of young far eastern catfish.

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***Corresponding Author**
E-mail: kimkd92@korea.kr

Materials and methods

Experimental diet

Ingredients and nutrient contents of the experimental diets are given in Table 1. Five experimental diets containing protein levels of 35, 40, 45, 50 and 55% were prepared. Gross energy levels of the diets were calculated based on 4, 9 and 4 kcal/g diets for protein, lipid and nitrogen-free extract, respectively (Garling and Wilson, 1976). Protein of fishmeal increased mainly at the expense of dextrin and α-cellulose. The dietary energy and lipid levels were designed to be isocaloric (3.7 kcal/g diet) and isolipidic (10%), respectively, by adjusting the levels of dextrin and squid liver oil. Diets were prepared with a laboratory pellet machine after 35–40 g water was mixed with 100 g mixture of ingredients, and dried over night at room temperature. The experimental diets were stored in a freezer at –24°C until use.

Fish and rearing conditions

Far eastern catfish (*Silurus asotus*) were obtained from a local fish farm (Jinhae, Korea). They were acclimated to laboratory conditions for 2 weeks. Experimental fish (initial body weight 44 ± 0.1 g) were randomly distributed into each of fifteen 1,000 L cylindrical plastic tanks with 20 fish to each tank in semi-recirculation system. Partial sedimentation and biofitration was used to maintain stable conditions. Fish were hand-fed to apparent satiation twice a day (09:00 and 17:00 h, 6 days a week) for 9 weeks. Freshwater was supplied at a flow rate of 10 L/min in each tank. Mean water temperature over the experimental periods was 25.8 ± 1.0°C (± SD). Photoperiod was left at natural conditions during the feeding trial. All fish in each tank were weighed collectively at the beginning and end of the feeding trial after fasting for 48 h. Records were kept of daily feed consumption, mortalities and feeding behavior.

Sample collections and chemical analysis

At the end of the feeding trial, five fish in each tank were collected and stored in a freezer at -70°C for chemical analysis. Crude protein was determined by the Kjeldahl method using Auto Kjeldahl System (Gerhardt VAP50OT/TT125, KG, Germany). Crude lipid was determined by ether extraction using a Soxhlet extractor (Velp SER 148, Usmate, Italy). Moisture was determined by oven drying at 135°C for 2 h. Ash was determined by muffle furnace at 550°C for 6 h. Crude fiber was determined by an automatic analyzer (Fibertec, Tecator, Hoganas, Sweden). Nitrogen free extract was calculated by difference.

Table 1. Ingredients and nutrient contents of the experimental diets

	Dietary protein levels (%)				
	35	40	45	50	55
Ingredients (%)					
Brown fish meal[1]	52.1	59.6	67	74.5	82
Dextrin	30	25	20	15	10
Squid liver oil[2]	4.7	3.9	3.1	2.3	1.5
α-Cellulose	6.7	5	3.4	1.7	
Carboxymethyl cellulose	2	2	2	2	2
Vitamin premix[3]	2	2	2	2	2
Mineral premix[4]	2	2	2	2	2
Choline chloride	0.5	0.5	0.5	0.5	0.5
Nutrient contents (dry matter basis)					
Crude protein (%)	34.2	39.0	44.7	50.2	54.2
Crude lipid (%)	9.9	10.1	10.4	10.9	10.4
Ash (%)	14.4	15.3	16.7	17.7	19.3
Crude fiber (%)	7.9	6.5	4.7	3.2	1.5
Nitrogen-free extract (%)[5]	33.6	29.1	23.5	18.0	14.6
Gross energy (kcal/g diet)	3.61	3.63	3.66	3.71	3.69

[1]Imported from Chile. [2]Provided by E-wha Oil and Fat Industry Corporation, Busan, South Korea.[3]Vitamin premix contained the following amount which were diluted in cellulose (g/kg premix): L-ascorbic acid, 121.2; DL-α-tocopheryl acetate, 18.8; thiamin hydrochloride, 2.7; riboflavin, 9.1; pyridoxine hydrochloride, 1.8; niacin, 36.4; Ca-D-pantothenate, 12.7; myo-inositol, 181.8; D-biotin, 0.27; folic acid, 0.68; p-aminobenzoic acid, 18.2; menadione, 1.8; retinyl acetate, 0.73; cholecalciferol, 0.003; cyanocobalamin, 0.003. [4]Mineral premix contained the following ingredients (g/kg premix): $MgSO_4 \cdot 7H_2O$, 80.0; $NaH_2PO_4 \cdot 2H_2O$, 370.0; KCl, 130.0; Ferric citrate, 40.0; $ZnSO_4 \cdot 7H_2O$, 20.0; Ca-lactate, 356.5; CuCl, 0.2; $AlCl_3 \cdot 6H_2O$, 0.15; KI, 0.15; $Na_2Se_2O_3$, 0.01; $MnSO_4 \cdot H_2O$, 2.0; $CoCl_2 \cdot 6H_2O$, 1.0.
[5]Nitrogen-free extract calculated by the difference (= 100-crude protein-crude lipid-ash-crude fiber).

Statistical analysis

The data were subjected to one-way analysis of variance (ANOVA) using the SPSS program Version 11.5 (SPSS, Chicago, Illinois, USA). Orthogonal-polynomial contrasts were used to determine linear and quadratic effects of increasing dietary protein levels. Significant differences ($P < 0.05$) among means were determined by Duncan's multiple range test (Duncan, 1955).

Results

Growth performance

Survival of far eastern catfish in response to diets containing 35-55% protein for 9 weeks was over 90%, and there were no significant difference among the groups ($P > 0.05$) (Table 2). Weight gain and specific growth rate of fish fed 55% protein diet were significantly higher than those of fish fed fish fed 35 and 40% protein diets ($P < 0.05$), but not significantly different from those of fish fed 45 and 50% protein diets ($P > 0.05$). Feed efficiency of fish fed 50 and 55% protein diets was significantly higher than that of fish fed 35, 40 and 45% protein diets ($P < 0.05$). The protein efficiency ratio of fish fed 40% protein diet was significantly higher than that of fish fed fish fed 45, 50 and 55% protein diets ($P < 0.05$), but not significantly different from that of fish fed 35% protein diet ($P > 0.05$). The daily feed intake of fish was significantly decreased with increasing dietary protein levels ($P < 0.05$). Daily protein intake of fish fed 45, 50, and 55% protein diets was significantly higher than that of fish fed 30 and 35% protein diets ($P < 0.05$).

Body composition

The contents of moisture and crude lipid in the whole body were significantly affected by dietary protein level ($P < 0.05$) (Table 3). Moisture content of whole body in fish fed 50% protein diet was significantly higher than that of fish fed 55% protein diet ($P < 0.05$), but not significantly different from that of fish fed 35, 40 and 45% protein diets ($P > 0.05$). Whole body moisture and crude lipid contents seemed to be inversely related. No significant differences were observed in crude protein and ash contents ($P > 0.05$).

Table 2. Growth performance of young far eastern catfish *Silurus asotus* fed diets containing the different protein levels for 9 weeks

	Dietary protein levels (%)					*P*-value
	35	40	45	50	55	*L*
Initial mean weight (g/fish)	43.7 ± 0.4	43.7 ± 0.4	43.5 ± 0.3	44.0 ± 0.3	43.9 ± 0.3	0.60
Survival (%)	98 ± 1.7	97 ± 1.7	90 ± 2.9	98 ± 1.7	97 ± 1.7	0.92
Weight gain (g/fish)	135 ± 6.2^{a}	145 ± 10.0^{ab}	157 ± 6.6^{abc}	166 ± 9.2^{bc}	183 ± 8.6^{c}	0.001
Specific growth rate (%/day)[1]	2.24 ± 0.07^{a}	2.32 ± 0.09^{ab}	2.43 ± 0.06^{abc}	2.48 ± 0.06^{bc}	2.60 ± 0.07^{c}	0.003
Feed efficiency (%)[2]	69 ± 1.4^{a}	77 ± 2.2^{ab}	81 ± 0.4^{b}	94 ± 4.0^{c}	102 ± 3.5^{c}	0.000
Protein efficiency ratio[3]	2.05 ± 0.04^{ab}	2.12 ± 0.06^{b}	1.87 ± 0.^{03a}	1.92 ± 0.08^{a}	1.91 ± 0.07^{a}	0.025
Daily feed intake[4]	2.78 ± 0.03^{d}	2.59 ± 0.03^{c}	2.42 ± 0.03^{b}	2.21 ± 0.06^{a}	2.09 ± 0.04^{a}	0.000
Daily protein intake[4]	0.94 ± 0.01^{a}	0.93 ± 0.01^{a}	1.13 ± 0.03^{b}	1.08 ± 0.03^{b}	1.12 ± 0.02^{b}	0.000

Values (mean ± SE of three replications) in each row not sharing a common superscript letter are significantly different ($P < 0.05$). [1][ln(final body weight) – ln(initial body weight)] ×100/day.[2]Fish wet weight gain×100/feed intake (dry matter).[3]Fish wet weight gain/protein intake.[4]Feed intake (or protein)×100/[(initial fish wt.+final fish wt.+dead fish wt.)×days fed/2].
L linear effect.

Table 3. Whole body composition of young far eastern catfish *Silurus asotus* fed diets containing the different protein levels for 9 weeks

	Dietary protein levels (%)				
	35	40	45	50	55
Moisture (%)	72.3 ± 0.49^{ab}	72.5 ± 0.44^{ab}	71.8 ± 0.35^{ab}	70.9 ± 0.91^{a}	73.0 ± 0.34^{b}
Crude protein (%)	15.3 ± 0.51	16.1 ± 0.09	16.4 ± 0.32	16.3 ± 0.34	16.1 ± 0.33
Crude lipid (%)	8.1 ± 0.56^{ab}	7.6 ± 0.29^{ab}	8.6 ± 0.03^{ab}	8.8 ± 0.41^{b}	7.3 ± 0.46^{a}
Ash (%)	2.5 ± 0.07	2.6 ± 0.13	2.4 ± 0.27	2.3 ± 0.06	2.6 ± 0.16

Values (mean ± SE of three replications) in each row not sharing a common superscript letter are significantly different ($P < 0.05$).

Discussion

In the present study, growth of young far eastern catfish was increased with increasing levels of dietary protein, but weight gain and specific growth rate were no significant difference among diets containing 45 to 55% protein. The result indicates that 45% dietary protein is the optimal level for maximum growth of young far eastern catfish. The dietary protein requirement for young far eastern catfish determined in this study is comparable to protein requirements (42-44%) estimated for bagrid catfish *Pseudobagrus fulvidraco* (Kim and Lee, 2005), Asian red-tailed catfish *Hemibagrus wyckioides* (Deng et al., 2011) and Malaysian freshwater catfish *Mystus nemurus* (Khan et al., 1993), but is higher compared with the dietary protein requirements of 32-36% reported for channel catfish *Ictalurus punctatus* (Garling and Wilson, 1976). Improved growth and feed efficiency with increasing dietary protein levels is well known in fish (NRC, 1993). In this study, weight gain and specific growth rate were increased up to 45% protein level, and no improved growth was observed beyond that 45% dietary protein levels (50-55%). A similar trend was also reported in juvenile this fish species and other catfish species such as Asian red-tailed catfish and bagrid catfish (Kang and Jeong, 1993; Kim and Lee, 2005; Deng et al., 2011).

Protein requirements of fish are affected by fish species, fish size, water temperature, protein quality, and utilization of non-protein energy (NRC, 1993). Dietary protein requirement of 45% for young fish of 44 to 227 g determined in this study is similar with that of 45% reported for 7 to 36 g juvenile of this species (Kang and Jeong, 1993). Protein requirements, as a proportion of the diet, decrease as fish approach maturity (NRC, 1993). Protein levels of 25% was adequate in the diet of channel catfish of 114 to 500 g, but 35% protein produced improved faster gains than did 25% protein in fish weighing between 14 to 100 g (Page and Andrews, 1973). These differences among studies may be due to differences in fish species or fish size used in the studies.

Specific growth rate is a good indicator of protein quality (Martínez-Palacios et al., 2007), and decrease as fish increase in size (Lee and Kim, 2009). In this study, young far eastern catfish showed similar or slightly lower specific growth rates (2.2-2.6%/day) compared with the juveniles of the same species (2.1-3.0%/day) (Kang and Jeong, 1993), which indicated that the diets used in the present study were well utilized by young far eastern catfish. Similar findings have been reported for rockfish *Sebastes schlegeli* (Lee and Kim, 2009).

In this study, feed efficiency increased with increasing dietary protein level, which can be attributed to enhanced weight gain because of the increased protein level of diet. Similar results of improved feed efficiency with increasing dietary protein level was reported for juvenile far eastern catfish (Kang and Jeong, 1993), and have also been noted for other catfish species such as bagrid catfish and Asian red-tailed catfish (Kim and Lee, 2005; Deng et al., 2011). Feed efficiency may also be influenced by the size of fish. Feed efficiency of 69-102% for young fish fed with the various levels of dietary protein in this study is lower than that of 86-113% reported for juvenile of this species (Kang and Jeong, 1993). In comparison to our earlier study (Kim et al., 2012), feed efficiency, protein efficiency, and daily feed intake of far eastern catfish at early life stage (initial weight 7.6 g) showed better performances than fish (initial weight 44 g) at later life stage. This result is consistent with previous studies that small fish tend to use feed more efficiently for growth than do larger conspecifics (Jobling, 1994; Lee and Kim, 2009).

This study showed decreased daily feed intake with increasing dietary protein level ($r = -0.90$, $P = 0.000$). Similar results of reduced feed consumption of fish fed the high protein diet compared with a low protein diet have been reported in the previous catfish study (Kim et al., 2012) and with other fish species such as hybrid *Clarias* catfish *Clarias macrocephalus* × *Carias gariepinus* (Jantrarotai et al., 1996). Feed efficiency was negatively related to the feed intake ($r = -0.96$, $P = 0.000$) in the present study. It implies that catfish could decrease feed intake as dietary protein levels increase to get higher feed utilization, and then could gain adequate energy and nutrition as described by Liu et al. (2013). The reason is that higher feed intake requires more energy for intake and digestion (Page and Andrews, 1973).

Dietary protein levels could effect protein efficiency rate of fish. In this study, the higher protein efficiency rate was observed in fish fed a 40% protein diet compared to fish fed 45-55% protein diets. Similar results of decreased protein efficiency rate with increasing dietary protein level were reported in other studies (Lee et al., 2002; Kim and Lee, 2005).

In this study, dietary protein levels significantly affected whole body lipid and moisture contents, and body lipid content showed an inverse relationship with body moisture content. Similar results of an inverse relationship between body lipid and moisture contents was observed in a previous catfish study (Kim et al., 2012). Crude protein content of fish was not significantly affected by dietary protein level in this study. Similar results of no significant changes in fish body protein content when fish were fed with various levels of dietary protein were observed in previous catfish studies as well as in the studies of other fish species (Kim et al., 2012; Moore et al., 1988). However, several studies showed body protein content increased with an increase in dietary protein levels (Cowey et al., 1972; Shiau and Huang, 1989). Shearer (1994) pointed out that the proximate composition of fish is influenced by both endogenous factors such as fish size and sex as well as exogenous factors such as diet composition and the culture environment.

The results of this study suggest that the 45% protein in the diet is optimal for maximum growth of young far eastern catfish weighing in the range of 44 to 227 g.

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