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Effect of Various Dietary Protein Levels on Growth and Body Composition of Young Common Carp Reared in Recirculating System

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The effect of various dietary protein levels on growth and body composition of young common carp raised from 56 g to 170 g in recirculating system was investigated for 15 weeks when they were fed to visual satiety three times daily. Five experimental diets were formulated to contain 40, 35, 30, 25 and 21% protein levels and 3.56, 3.59, 3.63, 3.66 and 3.69 kcal/g diet GE levels, respectively.

Mean survival rates of the fish fed the 40, 35, 30 and 25% protein diets were not different, but significantly higher than that of the fish fed the 21% protein diet ($P<0.05$). Weight gain (g/tank) of common carp fed the 30% protein diet was the best. However, weight gain of the fish fed the 25, 30, 35 and 40% protein diets were not different, but significantly better than that of the fish fed the 21% protein diet.

Feed efficiency ratio for the 21% protein diet was significantly lower ($P<0.05$) than for other groups of diets, which were not different among them. Protein efficiency ratio for the 25 and 21% protein diets were significantly higher than for other groups of diets ($P<0.05$). Energy efficiency ratio for the 21% protein diet was significantly lower ($P<0.05$) than for other groups of diets, which were not different among them ($P>0.05$).

Dietary protein level had no effect on hemoglobin content in the fish ($P>0.05$). Crude protein contents of whole body of the fish fed the 35 and 40% protein diets were significantly higher than that of the fish fed the 21% or 25% protein diet ($P<0.05$). Body crude lipid contents of the fish fed the 21 and 25% protein diets were significantly higher than that of the fish fed the 30% or 35% protein diet. Crude ash contents of the fish fed the 35 and 40% protein diets were significantly higher than that of the fish fed the 21% or 25% protein diet ($P<0.05$). Moisture content of the fish fed the 35% protein diet was significantly higher than that of the fish fed the 21% protein diet ($P<0.05$).

In considering growth performance of common carp and efficiency of diet, dietary protein level could be lowered up to 25% without the reduction of young common carp production in recirculating system.

Key words : Common Carp, Protein Level, Gross Energy, GE/P, Body Composition, Satiety

Introduction

Deterioration of water quality resulted from waste feeds and ammonia by-products of metabolism by freshwater fish in net cage culture in river and lake or overstocking of fish have caused not only a reduction of their growth in fish culture system but also frequent occurrence of eutrophication in lake or river when the repeated fish culture was performed long. This may eventually hazard human's life. Therefore, those fish culture systems are recently being prohibited in the several countries including Korea and production of freshwater fish will be reduced. The best way to get it over is probably adapting and improving recirculating system for freshwater fish culture.

The optimum dietary protein level for the maximum growth of common carp which is a stomachless species was reported to be 32% (Takeuchi et al., 1979a, b; NRC 1993). Protein levels in commercial feed vary 25 to 45% based on the size of fish. Protein is probably

one of the most important factors because of not only a nutrient largely affecting the growth of fish but also its high proportion in feed and the most expensive component in making feed. Therefore, the effects of lowering dietary protein levels on the performance of fish have been reported (Watanabe et al., 1987; Siddiqui et al., 1988; Robinson and Li, 1997). Recently, Robinson and Li (1997) showed that a diet containing 24% protein level would be proper for channel catfish in earthen pond, for which the optimum dietary protein level previously reported as 28% when they were fed to satiety daily. This would provide lots of economical benefit to fish farmer in terms of saving dietary protein. Lovell (1989) mentioned that feed allowance, dietary energy level, fish size, availability of live food organism should be concerned in determining dietary protein requirements on feeding trial. The performance of fish is probably affected by rearing culture system used as well.

This study was performed to determine the effect of various dietary protein levels for young common carp in recirculating system when they were fed to satiety daily.

MATERIAL AND METHODS

Preparation of fish and rearing condition

Two sets of recirculating system, 10 tanks for each were used for feeding trial at Pukyong National University, Pusan, Korea. Thirty young common carp average weighing 56 g were stocked in the rectangular tanks (60 cm × 90 cm × 60 cm, water volume; 220 L) and their total weight was about 1,690 g. They were acclimated for a week before the initiation of feeding trial and fed commercial feed at the rate of 3% of total weight of fish. Water temperature and dissolved oxygen level before sunset ranged from 26.0 to 33.4 ℃ and 2.0 to 4.0 mg/L, respectively, in which carp achieved good growth (Kim and Kim, 1986) during feeding trial. However, the supplementary aeration was supplied into tanks due to low dissolved oxygen level in 11 week after the initiation of the experiment. All fish were fed to visual satiety three times daily at 10:00, 14:00 and 18:00 for 6 days a week. And feeding trial lasted for 15 weeks. Weight gain were measured in week 5 and 10 after the initiation of feeding trial.

Preparation of the experimental diets

Ingredients of the experimental diets were similar to commercial feed and given in Table 1. Corn gluten meal and fish meal were used as the primary protein sources in the diets and their proportions decreased to lower dietary protein level whereas proportions of soybean meal and wheat middlings in the diets increased.

Five experimental diets were formulated to contain 40, 35, 30, 25 and 21% protein levels and 3.56, 3.59, 3.63, 3.66 and 3.69 kcal/g diet gross energy (GE) levels, respectively. One percent of fish oil (Ewha Co., Korea) for freshwater fish was added to all experimental diets. A mixture of ingredients of the experimental diets to water at the ratio of 4 to 1 were well mixed and pelleted by a laboratory pellet machine. And the experimental diets were dried for overnight and stored into freezer at -40℃ until use. Each exp

erimental diet had three replications.

Chemical analysis

Three fish from each diet were randomly chosen for the chemical analysis at the end of experiment. Proximate analysis was followed by the method of AOAC (1984). And protein (Kjeldahl method), lipid (Ether extraction method), ash (Muffler furnace, 600℃ for 3 hours) and moisture contents (Dry oven, 105℃ for 24 hours) of the whole body composition of the fish were measured. Also blood was drawn from the caudal artery of fish randomly chosen 5 fish in each tank and hemoglobin was measured to evaluate the effect of various dietary protein levels on blood composition of fish according to Brown's method (1980).

Statistical analysis

Mean values of the several measurements were statistically analyzed by ANOVA and Duncan's mul-

Table 1. Composition of the experimental diets

Composition	Protein level (%)				
	40	35	30	25	21
Ingredients (%)					
Corn gluten meal	30	23	16	9	2
Soybean meal	9	12	15	18	21
White fish meal	16	12	8	4	0
Wheat middlings	6	14	22	30	38
Wheat flour	30	30	30	30	30
Yeast	2	2	2	2	2
Vitamin premix[1]	2	2	2	2	2
Vitamin C	1	1	1	1	1
Mineral premix.[2]	2	2	2	2	2
Fish oil	1	1	1	1	1
Sodium phosphate	1	1	1	1	1
Composition					
Crude protein (%)	40.4	35.6	30.6	25.8	21.0
Crude lipid (%)	3.44	3.48	3.37	2.64	2.41
Crude ash (%)	7.82	7.9	7.0	7.23	7.21
Gross energy (kcal/g diet)[3]	3.56	3.59	3.63	3.66	3.69
Gross energy/crude protein (kcal/g protein)	8.8	10.1	11.8	14.2	17.7

[1]Each kilogram vitamin premix contains vitamin A, 500,000 IU; vitamin D_3 100,000 IU; vitamin E, 5,000 mg; vitamin K, 1,000 mg; vitamin B_1, 20,000 mg; vitamin B_2, 2,000 mg; vitamin B_{12}, 2 mg; vitamin C, 20,000 mg; niacin, 10,000 mg; panthonthenic calcium, 5,000 mg; folic acid, 500 mg; choline chloride, 60,000 mg; biotin, 10 mg; inositol, 10,000 mg; B.H.T., 1,000 mg.

[2]Mineral premix. provided all of the following minerals in the amounts presented per kg: Mn, 4,000 mg; Zn, 30,000 mg; Fe, 20,000 mg; Cu, 2,000 mg; I, 1,000 mg; Co, 600 mg; Se, 40 mg.

[3]Measured by bomb calorimeter.

tiple range test (1955) on SAS version 6.12 (SAS Institute, Cary, NC, 1987).

RESULTS AND DISCUSSION

Amount of feed fed during feeding trial, survival rate and weight gain of common carp fed the experimental diets are given in Table 2. Amount of feed fed for the 30% protein diet was the highest followed by the 25%, 40%, 21% and 35% protein diets. Mean survival rates of the fish fed the 40, 35, 30 and 25% protein diets were not significantly different, but significantly higher than that of the fish fed the 21% protein diet ($P<0.05$).

Weight gain (g/tank) of common carp fed the 30% protein diet was the best, 4858 g. However, weight gain of the fish fed the 25, 30, 35 and 40% protein diets were not significantly different, but significantly better than that of the fish fed the 21% protein diet. The different optimum dietary protein level for the growth of carp has been reported. Takeuchi et al., (1979b) and NRC (1993) reported that the dietary protein level would be 32% for growth of carp. The optimum dietary protein level for carp fry and fingerling was reported to be 45% (Sen et al., 1978) and 38% for initial average weighing 6 g carp (Ogino and Saito, 1970). These differences were probably resulted from size differences of fish used for each experiment. As channel catfish grew, their dietary protein and energy requirements decreased (Gatlin et al., 1986; Mangalik 1986). Siddiqui et al., (1988) showed that the optimum dietary protein level for the growth of fry Nile tilapia, *Oreochromis niloticus* was 40%, but that for young tilapia was 30% under generous feeding rate. When catfish were fed to satiety daily in earthen ponds, dietary protein level could be lowered up to

Table 2. Amount of feed fed, survival rate and weight gain of common carp fed the experimental diets for 15 weeks (Mean±SE)

	Protein level (%)				
	40	35	30	25	21
Item:					
Initial weight of the fish (g/tank)	1691.7±2.85	687.7±4.63	1691.0±2.08	1687.0±3.61	1692.7±2.40
Final weight of the fish (g/tank)	6375.3±356.80	5999.0±309.08	6549.3±286.04	6221.3±185.57	5849.0±118.00
Amount of feed fed (g/tank)	7725.5±232.44^{a}	7305.9±379.66^{a}	8269.0±342.61^{a}	7959.5±169.14^{a}	7685.7±197.40^{a}
Survival rate (%)	98.9±0.91^{a}	95.6±1.81^{ab}	95.6±0.91^{ab}	98.9±0.91^{a}	90.0±4.71^{b}
Weight gain of the fish (g/tank)	4683.7±359.33^{ab}	4311.3±306.64^{ab}	4858.3±285.08^{a}	4534.3±182.79^{ab}	3792.0±119.00^{b}

Different superscript letters in rows are significantly different (P<0.05).
Initial number of fish stocked for all tanks was 30.

24% without a reduction of weight gain (Robinson and Li, 1997). This indicated that when fish were fed to satiety daily, dietary protein level could be lowered than as known previously without the reduction of fish production.

Because common carp was grown in recirculating system, in which water quality was more stable than other culture system, toxicity of ammonia by-products like Li and Lovell's study (1992c) in earthen pond was not seriously concerned. Therefore, it was expected that the high protein (35% or 40%) diet would produce better growth than the 25% or 30% protein diet in this study, but it would not. When common carp were fed to visual satiety three times daily, the 25% protein diet achieved same fish production as the diets containing protein level above 25% when dietary GE level ranged from 8.8 to 14.2 kcal/g diet. However, the 21% protein diet containing GE 17.7 kcal/g diet was very poor for the growth of fish. This indicated that the 21% protein diet with high energy would not be proper for the growth of common carp raised from 56 g to 170 g in recirculating system when they were fed to visual satiety three times daily. Watanabe et al., (1987) showed that the low (32~37%) protein and high energy (digestible energy above 340 kcal/100 g diet) diets called "less polluting diets" were more effective for carp in terms of growth, feed efficiency and reduction of total nitrogen excretion from carp culture than commercial diet containing above 40% protein.

Kim et al., (1984) showed that 20% of soybean meal could be substituted with fishmeal without the significant reduction of growth of carp when graded levels (10~40%) of fishmeal was substituted with soybean meal in iso-protein (35%) diets. Therefore, the proportion of soybean meal in this study was limited about 20% in maximum in the 21% protein diet.

Feed efficiency ratio, protein efficiency ratio and energy efficiency ratio of the experimental diets is presented in Table 3. Feed efficiency ratio for the 21% protein diet was significantly lower (P<0.05) than for other groups of diets, which were not significantly

Table 3. Feed efficiency ratio, protein efficiency ratio and energy efficiency ratio of the experimental diet for common carp during feeding trial (Mean±SE)

	Protein level (%)				
	40	35	30	25	21
Item:					
Feed efficiency ratio (weight gain/dry feed fed)	0.60±0.03^{a}	0.59±0.01^{a}	0.59±0.01^{a}	0.57±0.02^{a}	0.50±0.03^{b}
Protein efficiency ratio (weight gain/protein fed)	1 .49±0.07^{c}	1 .66±0.03^{c}	1.94±0.05^{b}	2.26±0.06^{a}	2.46±0.14^{a}
Energy efficiency ratio (weight gain/energy fed)	0.171±0.0082^{a}	0.165±0.0033^{a}	0.163±0.0041^{a}	0.156±0.0042^{a}	0.135±0.0077^{b}

Different superscript letters in rows are significantly different (P<0.05).

different among them. Because the fish were fed to satiety three times daily for 15 weeks in this study, feed efficiency ratio for all experimental diets were comparatively lower than for other studies (Takeuchi et al., 1979a, b; Kim et al., 1984). Protein efficiency ratio for the 25 and 21% protein diets were significantly higher than for other groups of diets ($P<0.05$) and protein efficiency ratio for the 30% protein diet was significantly higher than for the 35% or 40% protein diet ($P<0.05$). Energy efficiency ratio for the 21% protein diet was significantly lower ($P<0.05$) than for other groups of diets, which were not significantly different among them ($P>0.05$).

The performance of common carp fed the experimental diets in 5th and 10th week after the initiation of feeding trial are given in Table 4. Weight gain of the fish fed the 30, 35 and 40% protein diets were significantly better ($P<0.05$) than that of the fish fed the 21% protein diet in week 5, but not significantly better that of the fish fed the 25% protein diet ($P>0.05$). Feed efficiency ratio for the 40% protein diet was significantly higher than for the 21% and 25% protein diet ($P<0.05$), but not significantly higher than for the either 30% or 35% protein diet ($P>0.05$). Also feed efficiency ratio for the 30% and 35% protein diets were significantly higher than for the 21% protein diet ($P<0.05$). Weight gain of the fish for the 30 and 40% protein diets were significantly better than for the 21% protein diet in week 10 ($P<0.05$). However, feed efficiency ratio for the 25, 30, 35 and 40% protein diets, which were not different among them ($P>0.05$) were significantly higher than for the 21% protein diet ($P<0.05$). Feed efficiency ratio tended to lower as the fish grew during feeding trial in this study. When catfish were fed to less than satiation, they responded to low protein diet while catfish responded to high protein diet when they were fed to satiety (Li and Lovell, 1992a, b). And when fish were fed to satiety daily, feed efficiency lowered (Minton 1978; Andrews 1979; Li and Lovell, 1992b; Munsiri 1992; Cho 1998).

Results of hemoglobin analysis of blood and proximate analysis of the whole body of the fish are shown in Table 5. Dietary protein level had no significant effect on hemoglobin content in the fish ($P>0.05$) and it ranged from 7.7% to 8.2%.

Crude protein contents of the fish fed the 35 and 40% protein diets were significantly higher than that of the fish fed the 21% or 25% protein diet ($P<0.05$). Body crude lipid contents of the fish fed the 21 and 25% protein diets containing relatively high energy were significantly higher than that of the fish fed the 30% or 35% protein diet containing low energy. Crude protein and lipid contents of the fish appeared to be well reflected from dietary protein and energy

Table 4. Amount of feed fed, weight gain and feed efficiency ratio of common carp fed the experimental diets at each sample period with 5 week interval (Mean±SE)

	Protein level (%)				
	1	2	3	4	5
Weight gain of the fish until 5 week (g/tank)	1294.3±72.66^{a}	1219.7±93.07^{a}	1313.7±71.43^{a}	1143.0±47.17^{ab}	972.7±27.65^{b}
Amount of feed fed until 5 week (g/tank)	1832.9±25.13	1755.9±74.14	1951.4±72.46	1826.4±45.45	1873.9±46.79
FER[1] in 5 week	0.71±0.03^{a}	0.70±0.03^{ab}	0.67±0.01^{ab}	0.62±0.02^{bc}	0.52±0.02^{c}
Weight gain of the fish until 10 week (g/tank)	2852.0±119.07^{a}	2659.3±171.17^{ab}	2883.7±162.36^{a}	2589.3±129.35^{ab}	2290.5±24.50^{b}
Amount of feed fed until 10 week (g/tank)	4488.2±26.31	4264.0±182.42	4715.5±164.50	4492.6±56.08	4495.7±50.65
FER[1] in 10 week	0.64±0.03^{a}	0.62±0.02^{a}	0.61±0.02^{a}	0.58±0.03^{a}	0.51±0.01^{b}

Different superscript letters in rows are significantly different ($P<0.05$).
[1]Feed efficiency ratio (FER) = weight gain (g) / dry feed fed (g).

Table 5. Results of hemoglobin analysis of common carp and the proximate analysis of the whole body of common carp at the end of the feeding trial (Mean±SE)

	Protein level (%)				
	40	35	30	25	21
Hemoglobin (%)	7.7 ± 0.14^{a}	7.9 ± 0.26^{a}	8.2 ± 0.31^{a}	7.7 ± 0.20^{a}	7.7 ± 0.14^{a}
Crude protein (%)	59.9 ± 1.96^{a}	59.4 ± 1.12^{a}	54.8 ± 0.48^{ab}	51.2 ± 1.62^{b}	49.4 ± 2.63^{b}
Crude lipid (%)	38.5 ± 0.92^{ab}	31.6 ± 2.67^{b}	38.0 ± 1.81^{ab}	44.0 ± 2.63^{a}	43.0 ± 0.26^{a}
Crude ash (%)	11.6 ± 0.42^{ab}	12.5 ± 0.66^{a}	9.4 ± 0.43^{bc}	8.2 ± 1.48^{c}	8.3 ± 1.15^{c}
Moisture (%)	74.1 ± 0.16^{ab}	75.0 ± 1.23^{a}	72.7 ± 1.42^{ab}	72.2 ± 0.72^{ab}	71.1 ± 0.69^{b}

Different superscript letters in rows are significantly different ($P<0.05$).
Crude protein, crude lipid, crude ash and moisture contents of common carp at the beginning of feeding trial were 60.4, 34.9, 8.8, and 76.8%, respectively.

levels in this study. However, high dietary energy was not utilized for the growth and stored into body fat. This agreed to other studies showing that body protein and lipid contents were largely affected by dietary protein and energy levels and body lipid content decreased with an increase of body protein level in fish (Takeuchi et al., 1979a, b; Deru 1985; Raymond 1985; Li and Lovell, 1992b). Deru (1985) showed that an increase of lipid in the diet increased body lipid content of fish and reduced shelf life.

Crude ash contents of the fish fed the 35 and 40% protein diets were significantly higher than that of the fish fed the 21% or 25% protein diet ($P<0.05$). Moisture content of the fish fed the 35% protein diet was significantly higher than that of the fish fed the 21% protein diet ($P<0.05$). Generally speaking, protein and moisture contents of fish increased as lipid content of fish decreased.

In considering growth performance of common carp and efficiency of diet, dietary protein level could be lowered up to 25% without the reduction of young common carp production in recirculating system.

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