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Optimal Dietary Protein and Lipid Levels for Growth of Juvenile Israeli Carp *Cyprinus carpio*

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Abstract

A feeding trial of four dietary protein levels (20, 30, 40, and 50%) and two lipid levels (7 and 14%) with a factorial design was conducted to determine the optimal dietary protein and lipid levels for juvenile Israeli carp *Cyprinus carpio*. Triplicate groups of fish (average body weight, 1.3 ± 0.02 g) were fed the experimental diets for 9 weeks. Survival of fish was not affected by either dietary protein or dietary lipid level. Weight gain and feed efficiency increased as dietary protein levels increased up to 40 and 50%, respectively. Weight gain was higher in fish fed the high-lipid diets with 20 and 40% protein content. Feeding efficiency increased as the dietary lipid level increased for the 30, 40, and 50% protein diets. Daily feed intake decreased with increasing protein level and the minimum feed consumption was observed in fish fed the 50% protein diet with 14% lipid content. Moisture and lipid contents of the whole body were affected by both dietary protein and lipid levels. The crude lipid content of fish fed the 14% lipid diet was higher than that of fish fed the 7% lipid diet at each protein level. The results of this study indicate that a diet containing 40% protein with 14% lipid content is optimal for the growth and effective protein utilization of juvenile Israeli carp.

Key words: *Cyprinus carpio*, Israeli Carp, Dietary Protein, Dietary Lipid

Introduction

Cyprinids are quantitatively the most important group of teleost fish cultivated around the world. The global fishery and aquaculture production of common carp reached approx. 3.3 million tons in 2009 (FAO, 2010). Throughout more than 2000 years of rearing common carp the cumulative founder effects, genetic drift, and natural or artificial selection have led to the formation of many distinct strain of this fish (Hulata, 1995; Bakos and Gorda, 1995). Israeli carp *Cyprinus carpio* is a famous strain of common carp with a long history of aquaculture. Its aquaculture has become popular in South Korea (Yoon, 2001).

To develop cost-effective and practical dietary formulations for target fishes, we must know their essential nutrient requirements. Dietary protein is the most important factor affecting the growth performance of fish and feed costs (NRC, 1993). Generally, fish growth can be improved by increasing dietary protein level. Protein utilization for growth may be improved by partially replacing dietary protein with lipid and/or carbohydrate to produce a protein-sparing effect. However, excessive energy in diets can lead to increased body lipid deposition and growth reduction of fish due to a lack of necessary nutrients for growth resulting from a reduction in feed consumption (Ali and Jauncey, 2005; Daniels and Robinson, 1986). On the contrary, insufficient non-protein energy in diet causes protein waste as the proportion of dietary protein used for energy increases, and ammonia excreted after amino acids are metabolized can reduce water quality (Yang et al., 2002). Therefore, it is important to increase dietary protein utilization for body protein synthesis rather than for energy purposes. Higher energy levels generally come from increased dietary

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lipid as lipid is an energy-dense nutrient and readily metabolized by fish. The present study, therefore, was conducted to investigate the effect of dietary protein and lipid levels on the growth and feed utilization of Israeli carp *Cyprinus carpio*.

Materials and Methods

Experimental diets

A 4 × 2 factorial design with three replicates was used. Eight experimental diets were formulated to contain four protein levels (20, 30, 40 and 50%) and two lipid levels (7 and 14%). Ingredient and proximate composition of the experimental diets are presented in Table 1. Fish meal as the primary protein source, fish oil and mixture of soybean and linseed oil as lipid sources and wheat flour as carbohydrate source were used. Proportion of fish oil decreased with an increase in dietary fish meal level. Fatty acid compositions of the experimental diets are shown in Table 2. The experimental diets were pelletized by a laboratory pellet machine after 400 g of water was mixed with 1 kg of ingredients and dried overnight at room temperature. All pellets were stored at -30°C until use.

Experimental fish and feeding trial

Juvenile Israeli carp were obtained from the Inland Aquaculture Research Center, National Fisheries Research & Development Institute (Changwon, Korea). Fish were acclimated to experimental tank conditions and fed a standard commercial diet for 2 weeks prior to the start of the feeding trial. Fifty fish (initial mean weight, 1.3 ± 0.02 g) were then distributed randomly into 24 cylindrical plastic tanks (50 L water volume) for the feeding trial after being collectively weighed. Three replicate groups of fish were hand-fed to apparent satiation twice a day (09:00 and 17:00 for 6 days per week) for 9 weeks. Water temperature was maintained at 24.1 ± 0.82°C (mean ± SD), and the photoperiod was set to natural conditions during the feeding trail. Records were kept of daily feed consumption, mortalities, and feeding behavior in each tank.

Sample collection and analytical methods

At the end of the feeding trial, all fish in each tank were collectively weighed after being anesthetized with tricaine methanesulfonate (MS222, Sigma, St. Louis, MO, USA) at a concentration of 100 ppm after starvation for 24 h. Blood

Table 1. Ingredients and proximate composition of experimental diets

Protein levels (%)	20		30		40		50	
Lipid levels (%)	7	14	7	14	7	14	7	14
Ingredients (%)								
Fish meal	14.0	14.0	32.0	32.0	50.0	50.0	68.0	68.0
Wheat flour	53.0	34.0	43.0	24.0	33.0	14.0	23.0	4.0
Corn gluten meal	4.0	7.0	3.0	6.0	2.0	5.0	1.0	4.0
α-potato-starch		9.0		9.0		9.0		9.0
Brewer yeast	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Fish oil	3.0	3.0	2.0	2.0	1.0	1.0		
Soybean oil + Linseed oil	2.0	9.0	2.0	9.0	2.0	9.0	2.0	9.0
Cellulose	18.0	18.0	12.0	12.0	6.0	6.0		
Vitamin premix*	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Mineral premix†	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Vitamin C (50%)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Choline salt (50%)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Proximate composition (% dry matter basis)								
Crude protein	20.9	20.2	31.5	31.0	41.1	41.6	51.5	51.6
Crude lipid	6.7	14.6	6.7	13.9	6.6	13.2	6.6	13.4
Crude fiber‡	18.6	18.6	12.6	12.6	6.6	6.6	0.6	0.6
Ash	5.0	4.6	8.7	8.8	13.3	12.7	16.6	16.4
Carbohydrate§	48.8	42.0	40.5	33.7	32.4	25.9	24.7	18.0
Energy (kJ g^{-1})¶	15.9	17.7	17.0	18.5	17.8	19.4	18.9	20.4
Protein/ energy (mg kJ^{-1})	13.1	11.4	18.6	16.8	23.1	21.5	27.3	25.3
Non-protein energy : protein ratio (kJ g^{-1})	52.7	64.1	30.5	36.3	19.9	23.1	13.3	16.2

*Vitamin premix contained the following amount which were diluted in cellulose (g kg^{-1} mix): 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 (98%), 0.68; p-aminobenzoic acid, 18.2; menadione, 1.8; retinyl acetate, 0.73; cholecalciferol, 0.003; cyanocobalamin, 0.003.

†Mineral premix contained the following ingredients (g kg^{-1} mix): $MgSO_4 \cdot 7H_2O$, 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.

‡Calculated based on the crude fiber content of ingredients.

§Calculated, 100 - (crude protein + crude lipid + crude fiber + ash).

¶Calculated based on 23.4 MJ kg^{-1} protein, 39.2 MJ kg^{-1} lipid and 17.2 MJ kg^{-1} carbohydrate.

was drawn from the caudal vessel with 1 mL heparinized syringes from ten fish in each tank. The collected blood was centrifuged at 3,500 *g* for 10 min at 4°C, and the separated plasma was pooled and stored at -75°C for biochemical analysis. Total plasma protein, glucose, triglyceride, and cholesterol content were determined using an automatic analyzer (Toshiba-200FR, Tokyo, Japan). At the end of the feeding trials, fifteen fish from each tank were pooled and used for chemical composition analysis. Crude protein content was determined using the Auto Kjeldahl System (Buchi, Flawil, Switzerland), the crude lipid content was determined by the ether-extraction method, using a Soxhlet extractor (VELP Scientifica, Milano, Italy), the moisture content was determined with a dry oven (105°C for 6 h and the ash content was determined using a muffler furnace (600°C for 4 h). Lipid for fatty acid analyses was extracted by a mixture of chloroform and methanol (2:l v/v) according to the method of Folch et al. (1957), and fatty acid methyl esters were prepared by transesterification with 14% BF_3-MeOH (Sigma, St. Louis, MO, USA). Fatty acid methyl esters were analyzed using a gas chromatography (PerkinElmer, Clarus 600, GC, USA) with a flame ionization detector, equipped with SP™-2560 capillary column (100 m × 0.25 mm i. d. film thickness 0.20 μm; Supelco, Bellefonte, PA, USA). Injector and detector temperatures were both set to 240°C. The column temperature was programmed to increase from 140 to 240°C at a rate of 5°C min^{-1}. Helium was used as the carrier gas. Fatty acids were identified by comparison with retention times of the standard fatty acid methyl esters (PUFA 37 component FAME Mix; Supelco).

Statistical analyses

Data were subjected to one-way and/or two-way analysis of variance (ANOVA) to test the effect of dietary protein and lipid levels on fish performance. When significant ($P < 0.05$) differences were found, Duncan's multiple range test (Duncan, 1955) was used to rank the groups. All statistical analyses were conducted using the SPSS program version 20.0 (SPSS, Michigan Avenue, Chicago, IL, USA).

Results

The growth performance data of juvenile Israeli carp fed the diets containing various protein and lipid levels for 9 weeks are presented in Table 3. Survival of each group was over than 97% and there was no significant difference among treatments ($P > 0.05$). Weight gain, specific growth rate (SGR), and feed

Table 2. Major fatty acid composition (% of the total fatty acids) of the experimental diets

Protein levels (%)	20		30		40		50	
Lipid levels (%)	**7**	**14**	**7**	**14**	**7**	**14**	**7**	**14**
C16:0	16.3	13.0	17.1	13.5	17.9	14.1	18.7	15.2
C18:1n-9	16.3	17.2	15.0	15.9	14.1	15.2	13.5	15.1
C18:2n-6	28.6	29.9	21.8	23.4	14.8	18.6	10.1	14.4
C18:3n-3	8.2	18.0	7.3	16.3	5.4	14.3	3.9	12.6
C20:4n-6	0.3	0.1	0.3	0.2	0.4	0.3	0.4	0.3
C20:5n-3	4.4	2.9	5.3	3.8	6.2	4.5	6.3	5.1
C22:6n-3	8.7	5.9	14.1	10.6	20.4	14.5	22.9	17.8

Table 3. Growth performances of juvenile Israeli carp *Cyprinus carpio* fed the experimental diets containing various levels of protein and lipid

Protein levels (%)	Lipid levels (%)	Initial weight (g $fish^{-1}$)	Survival (%)	Weight gain (%)*	Specific growth rate †
20	7	1.3	99 ± 0.7	161 ± 2.8^{a}	1.3 ± 0.01^{a}
	14	1.3	100	197 ± 14.2^{b}	1.5 ± 0.07^{b}
30	7	1.3	100	230 ± 7.1^{c}	1.6 ± 0.03^{c}
	14	1.3	99 ± 1.0	256 ± 7.7^{c}	1.7 ± 0.03^{c}
40	7	1.3	100	304 ± 4.1^{d}	1.9 ± 0.01^{d}
	14	1.3	97 ± 2.0	338 ± 17.0^{e}	2.0 ± 0.05^{de}
50	7	1.3	99 ± 0.7	340 ± 12.2^{e}	2.0 ± 0.04^{de}
	14	1.3	100	357 ± 14.0^{e}	2.1 ± 0.04^{e}
Two-way ANOVA: P-values					
Dietary protein			0.4	0.001	0.001
Dietary lipid			0.2	0.002	0.001
Interaction			0.09	0.8	0.5

Values (mean ± SE of three replications) in the same column not sharing a common superscript are significantly different ($P < 0.05$).

*(final fish wt. - initial fish wt.) × 100 / initial fish wt.

†[ln (final fish weight) – ln (initial fish weight)] × 100/days reared.

efficiency were significantly affected by dietary protein and lipid levels ($P < 0.001$). Weight gain and SGR increased as the dietary protein levels increased up to 40%. Weight gain of fish fed the high-lipid diet at 20 and 40% protein levels were significantly higher than that of fish fed the low-lipid diet. As shown in Table 4, feed efficiency of fish increased as dietary protein increased up to 50% at the same lipid level. At 30, 40, and 50% protein levels, feed efficiency increased as the

Table 4. Feed utilization of juvenile Israeli carp *Cyprinus carpio* fed the experimental diets containing various levels of protein and lipid

Protein levels (%)	Lipid levels (%)	Feed efficiency (%)*	Daily feed intake (%)†	Protein efficiency ratio‡	Daily protein intake (%)§
20	7	43.4 ± 0.9^{a}	2.9 ± 0.04^{e}	2.0 ± 0.04^{d}	0.7 ± 0.01^{a}
	14	45.1 ± 3.2^{a}	3.2 ± 0.11^{f}	2.1 ± 0.15^{e}	0.7 ± 0.02^{a}
30	7	53.2 ± 0.6^{b}	2.9 ± 0.01^{de}	1.7 ± 0.02^{bc}	0.9 ± 0.00^{b}
	14	59.0 ± 1.0^{c}	2.7 ± 0.03^{cd}	1.8 ± 0.03^{cd}	0.9 ± 0.01^{b}
40	7	63.5 ± 0.4^{e}	2.7 ± 0.01^{cd}	1.5 ± 0.01^{ab}	1.1 ± 0.01^{c}
	14	69.0 ± 3.1^{d}	2.6 ± 0.07^{bc}	1.6 ± 0.07^{b}	1.1 ± 0.03^{c}
50	7	71.5 ± 1.5^{d}	2.5 ± 0.02^{b}	1.3 ± 0.03^{a}	1.3 ± 0.01^{e}
	14	79.0 ± 1.7^{e}	2.3 ± 0.04^{a}	1.5 ± 0.03^{ab}	1.2 ± 0.02^{d}
Two-way ANOVA: P-values					
Dietary protein		0.001	0.001	0.001	0.001
Dietary lipid		0.001	0.1	0.002	0.001
Interaction		0.5	0.003	0.6	0.01

Values (mean ± SE of three replications) in the same column not sharing a common superscript are significantly different ($P<0.05$).
*Wet weight gain × 100 / feed intake.
†Feed intake × 100 / [(initial fish wt. + final fish wt. + dead fish wt.) × days reared / 2].
‡Wet weight gain / protein intake.
§Protein intake × 100 / [(initial fish wt. + final fish wt. + dead fish wt.) × days reared / 2].

Table 5. Proximate composition of the whole body of juvenile Israeli carp *Cyprinus carpio* fed the experimental diets containing various levels of protein and lipid

Protein levels (%)	Lipid levels (%)	Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)
	Initial	80.1	16.1	1.1	3.0
20	7	70.6 ± 1.03^{b}	13.6 ± 0.96	11.3 ± 0.6^{de}	2.2 ± 0.14^{ab}
	14	67.0 ± 0.15^{a}	12.6 ± 1.00	16.6 ± 0.20^{f}	2.1 ± 0.05^{ab}
30	7	72.0 ± 0.43^{bc}	14.1 ± 0.83	10.0 ± 0.71^{cd}	2.2 ± 0.05^{ab}
	14	70.1 ± 0.68^{b}	13.5 ± 0.84	12.5 ± 0.46^{e}	1.8 ± 0.05^{a}
40	7	73.8 ± 0.06^{c}	14.7 ± 1.04	7.7 ± 0.53^{b}	2.5 ± 0.11^{b}
	14	71.7 ± 0.47^{bc}	15.0 ± 1.62	10.0 ± 0.25^{c}	2.3 ± 0.20^{ab}
50	7	73.2 ± 1.11^{c}	15.6 ± 0.27	6.2 ± 0.17^{a}	2.5 ± 0.25^{b}
	14	73.6 ± 0.73^{c}	15.8 ± 0.71	7.7 ± 0.31^{b}	2.4 ± 0.25^{b}
Two-way ANOVA: P-values					
Dietary protein		0.001	0.08	0.001	0.06
Dietary lipid		0.001	0.7	0.001	0.09
Interaction		0.07	0.9	0.002	0.7

Values (mean ± SE of three replications) in the same column not sharing a common superscript are significantly different ($P<0.05$).

Table 6. Hematological change of the plasma of juvenile Israeli carp *Cyprinus carpio* fed the experimental diets containing various levels of protein and lipid

Protein levels (%)	Lipid levels (%)	Total protein (g/dL)	Glucose (mg/dL)	Cholesterol (mg/dL)	Triglyceride (mg/dL)
20	7	2.5 ± 0.30	101 ± 5.5^{a}	206 ± 24.5	172 ± 71.0^{bc}
	14	3.1 ± 0.23	132 ± 5.6^{bc}	297 ± 26.5	226 ± 38.0^{c}
30	7	2.2 ± 0.58	114 ± 16.3^{ab}	261 ± 35.4	130 ± 15.7^{ab}
	14	2.9 ± 0.06	150 ± 4.7^{c}	186 ± 64.3	177 ± 22.0^{bc}
40	7	2.7 ± 0.07	117 ± 11.7^{ab}	244 ± 30.0	94 ± 8.0^{a}
	14	2.8 ± 0.03	125 ± 6.0^{abc}	247 ± 10.0	134 ± 13.0^{ab}
50	7	1.5 ± 0.67	109 ± 5.0^{ab}	210 ± 18.2	75 ± 0.6^{a}
	14	2.5 ± 0.20	119 ± 3.5^{ab}	203 ± 19.5	99 ± 1.5^{a}
Two-way ANOVA : P- values					
Dietary protein		0.2	0.3	0.6	0.001
Dietary lipid		0.1	0.01	0.9	0.01
Interaction		0.7	0.3	0.2	0.9

Values (mean ± SE of three replications) in the same column not sharing a common superscript are significantly different ($P<0.05$).

dietary lipid content increased. Daily feed intake was affected by dietary protein content, but not by dietary lipid content. Daily feed intake decreased as the dietary protein content increased, and feed intake in fish fed 50% protein with 14% lipid content was significantly lower than the other groups. Protein efficiency ratio of fish decreased as dietary protein increased. Fish fed the 14% lipid diet had a better protein efficiency ratio than fish fed the 7% lipid diet at 20 and 30% protein level. Daily protein intake gradually increased as the dietary protein level increased.

The proximate composition of whole body is given in Table 5. The moisture and crude lipid contents of whole bodies were significantly affected by dietary protein and lipid levels ($P < 0.001$). Moisture content tended to increase with dietary protein level. A lower moisture content was observed in fish fed the high-lipid diet compared with the low-lipid diet at the 20% protein level, but no significant difference was found between the two lipid levels at 30, 40, and 50% protein diets. Crude lipid levels decreased as dietary protein content increased, and fish fed the high-lipid diet had higher body lipid content than fish fed the low-lipid diet at each protein level. Crude protein and ash contents were not affected by either dietary protein or lipid levels ($P > 0.05$).

Hematological changes in the plasma of juvenile Israeli carp fed the diets containing various protein and lipid levels for 9 weeks are presented in Table 6. Total protein and cholesterol of the plasma of fish were not affected by either dietary protein or lipid levels. Glucose content of the plasma was affected by dietary lipid, but not by dietary protein. The increased dietary lipid resulted in higher glucose in plasma at 20 and 30% protein diet. Triglyceride of plasma of fish decreased with increasing dietary protein. Major fatty acid compositions (Table 7) of whole body in juvenile carp were not affected by dietary protein and lipid levels ($P > 0.05$).

Discussion

The results of this study showed that the 40% protein in the diet with 14% lipid is sufficient for growth of juvenile Israeli carp. This value is somewhat higher compared with the dietary protein requirement reported for some other cyprinids fish such as 30% for fingerling Indian major carp *Labeo rohita* (Debnath et al., 2007) and 34.1% for juvenile Jian carp *Cyprinus carpio* var. Jian. (Liu et al., 2009) but is comparable with 40% for fingerling catla *Catla catla* (Mohanty et al., 1990) and 41.7% for *Barbodes altus* (Elangovan and Shim, 1997), and lower than 45%-50% for endangered cyprinid *Tor putitora* (Islam and Tanaka, 2004). Protein requirements among the fish species are complicated by the difference in fish size or age, culture conditions, and nutrient interactions in experimental diets such as protein and non-protein energy levels (NRC, 1993). In this study, increasing dietary lipid level resulted in a higher weight gain at 20 and 40% protein diets and improved

Table 7. Major fatty acid composition (% of the total fatty acids) of whole body of juvenile Israeli carp *Cyprinus carpio* fed the experimental diets containing various levels of protein and lipid

Fatty acids	Protein levels (%)								Two-way ANOVA: P values		
	20		30		40		50				
	Lipid levels (%)										
	7	14	7	14	7	14	7	14	Protein	Lipid	Interaction
C16:0	15.8 ± 0.80	16.5 ± 1.14	17.0 ± 1.06	15.5 ± 0.71	18.8 ± 1.13	15.5 ± 0.66	17.9 ± 1.39	18.5 ± 1.37	0.2	0.3	0.2
C18:1n-9	39.6 ± 1.39	36.3 ± 0.96	38.9 ± 3.02	36.5 ± 1.12	37.1 ± 1.69	38.1 ± 2.35	37.9 ± 1.39	36.7 ± 1.49	1.0	0.3	0.7
C18:2n-6	15.3 ± 2.01	16.4 ± 2.28	14.1 ± 2.23	17.8 ± 1.64	13.0 ± 2.56	16.7 ± 1.68	13.9 ± 2.21	14.3 ± 2.56	0.8	0.2	0.8
C18:3n-3	5.0 ± 1.26	6.9 ± 1.57	6.2 ± 1.96	7.0 ± 1.28	5.5 ± 2.02	6.9 ± 1.45	4.5 ± 1.48	6.4 ± 1.55	0.9	0.2	1.0
C20:4n-6	0.8 ± 0.28	0.4 ± 0.04	0.6 ± 0.13	0.6 ± 0.04	0.5 ± 0.02	0.8 ± 0.25	0.5 ± 0.03	0.4 ± 0.03	0.6	0.6	0.2
C20:5n-3	0.9 ± 0.24	0.9 ± 0.19	0.8 ± 0.21	1.0 ± 0.20	1.1 ± 0.18	0.6 ± 0.06	0.9 ± 0.14	0.6 ± 0.07	0.6	0.3	0.3
C22:6n-3	1.8 ± 0.39	1.8 ± 0.46	1.9 ± 0.28	2.1 ± 0.46	2.2 ± 0.39	1.4 ± 0.24	1.8 ± 0.33	1.2 ± 0.15	0.5	0.3	0.5

Values are mean ± SE of three replications.

feed efficiency of fish at 30, 40 and 50% protein diets. These results suggest that the higher dietary lipid level will provide a more efficient utilization of dietary protein for growth of fish. This protein-sparing effect has been reported in several fish species fed high energy diets containing lipid as a major energy source (Page and Andrews, 1973; Torstensen et al., 2001; Guerreiro et al., 2012). Improvement of fish performance with increasing dietary lipid level was observed in other studies (Harpaz et al., 1999; Lee et al., 2002).

A positive correlation was found between the dietary protein to energy (P/E) ratio and fish weight gain ($r = 0.89$; $P < 0.01$) in this study. The maximum weight gain was obtained from diets containing 40 and 50% protein in this experiment, corresponding to a P/E ratio of 22-27 mg kJ^{-1}, which is similar to the ratio of 24-27 mg kJ^{-1} reported for sunshine bass (Keembiyehetty and Wilson, 1998), but higher than the 20 mg kJ^{-1} reported for silver barb *Puntius gonionotus* (Mohanta et al., 2009) and bagrid catfish *Mystus nemurus* (Ng et al., 2001), and lower than the 29-31 mg kJ^{-1} reported for juvenile Chinese sucker *Myxocyprinus asiaticus* (Yuan et al., 2009). The apparent differences of the optimum P/E ratio among the fish species indicate that optimum levels of protein and energy in the diets must be carefully considered when optimum P/E ratio is estimated.

Several studies have demonstrated that feed intake is regulated by the dietary available energy (Lee and Putnam, 1973; Jobling and Wandsvik, 1983), probably because the fish eat to satisfy their energy requirements. In this study, maximum daily feed intake was shown in fish fed 20% protein diet with 14% lipid, which corresponded to the lowest P/E ratio (11.4 mg kJ^{-1}) and the highest level of non-protein energy/protein (64.1 kJ g^{-1}) in the diet. This finding suggests that feed intake in juvenile Israeli carp is directly related to dietary protein and non-protein energy levels and ratios. It has been reported that feed intake is affected by dietary protein or lipid levels in channel catfish and grass carp (Page and Andrews, 1973; Du et al., 2005). Feed intake could be increased to compensate for the available essential amino acids or energy when inadequate amount of protein or energy in the diet is provided to fish.

The body moisture content in this study was positively correlated with dietary protein level ($r = 0.74$; $P < 0.01$) in this study, but body lipid content was negatively correlated with dietary protein level ($r = -0.83$; $P < 0.01$). The decreased lipid and increased moisture contents of the body in fish fed higher dietary protein were observed in silver perch (Yang et al., 2002). The higher lipid deposition in fish fed low-protein diet can be explained by an overconsumption of non-protein nutrient per unit weight gain. Inadequate dietary composition of essential amino acids limits body protein synthesis and increases fat deposition (Arzel et al., 1995). The body lipid content of fish fed a high-lipid diet was higher than that of fish fed a low-lipid diet at all protein levels. This is an agreement with other studies showing that lipid content of fish fed high energy diets is higher than that of fish fed low-energy diets (Lie et al., 1988; Biswas et al., 2009).

The results of this study indicate that an increase in the dietary lipid level has a protein-sparing effect, and a diet containing 40% protein with 14% lipid would be optimal for the growth and effective protein utilization of juvenile Israeli carp.

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