EFFECTS OF DIETARY FULL-FAT SOYBEAN LEVELS ON GROWTH PERFORMANCE AND FEED UTILIZATION AND PHOSPHORUS EXCRETION OF CARP (*Cyprinus carpio*)

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Summary

In order to estimate the nutritive value of roasted full-fat soybean (FFS) in carp diet, growth performance and excretion of protein and phosphorus were examined using carps having mean body weight of 111 g. Growth trial was conducted for 4 weeks using the fishes fed 5 diets (Control, $F_{24}S_{13}$, $F_{16}S_{27}$, F_8S_{40} and F_0S_{56}) containing 32%, 24%, 16%, 8% and 0% of fish meal (F) and 0%, 13%, 27%, 40% and 56% of full-fat soybean, respectively. A total of 800 fishes were allotted randomly by groups of 40 to 5 treatments with 4 replicates per treatment. Fishes were fed to satiation eight times daily. Feeding trial was conducted for 4 weeks. As dietary FFS increased from 0% to 56%, weight gain of fish decreased from 91 g to 39 g and feed conversion ratio increased from 1.06 to 1.95. Protein efficiency ratio (PER) was highest (2.35) in control group which had the highest protein intake, while PER significantly decreased with decrease in protein intake as dietary FFS level increased. Although dietary protein and energy levels were maintained constant, protein excretion per kg weight gain varied from 273 g to 579 g for the groups control and F_0S_{56}, respectively. However, the value for control group was not significantly different to those for the groups $F_{24}S_{13}$ and $F_{16}S_{27}$. On the other hand, the highest protein retention efficiency was found in group fed the diet $F_{24}S_{13}$. Fish fed the diet F_8S_{40} excreted the lowest phosphorus (P) based on kg weight gain showing the highest P retention efficiency of 62%. P excretion per kg feed intake was in the range of 5 g to 10 g for the groups F_8S_{40} and $F_{24}S_{13}$, respectively. The present results indicated that as dietary FFS level increased, growth performance and feed utilization decreased while excretion of protein and phosphorus increased. Therefore, it was concluded that more than 25% substitution by FFS for fish meal could exert negative effects on growth and feed utilization of carp.

(**Key Words** : Full-fat soybean, Fish meal, Carp, Growth, PER, Phosphorus excretion)

Introduction

Korean inland fish farming rapidly developed during last decade with the advent of the formulated fish feed in the beginning of the 1980. Due to an increased interest in environmental protection, however, the farming practices are now faced with a crisis to be disappeared unless a qualitative improvement of fish feed is achieved. Water pollution by fish farming is caused by unconsumed feeds, feces and metabolic wastes, which result in an increase in nitrogen, phosphorus and the biochemical oxygen demand into water (Beveridge, 1987; Matty, 1990). These pollution factors are totally originated from the feed given to the fish.

Carps excrete about 60-70% of ingested nitrogen (N) via both gill and digestive tract (Takeuchi et al., 1989; Watanabe et al., 1989; Kim and Woo, 1994), and the availability of phosphorus (P) in fish meal by carp is below 10% due to a lack of gastric juice secretion (Yone and Toshima, 1979). The large wastages of two major water pollution factors, N and P, would be basically

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resulted from a deficit of available data on carp nutrition such as the optimal digestible protein/energy ratio and the availability and the optimal levels of phosphorus in diet.

Full-fat soybean (FFS) contains low level of P and high amount of linoleic acid, which is not found in fish meal but essential for growth of carp (NRC, 1993). Though the P in vegetable feedstuffs has also low availability by carp (Ogino et al., 1979), total phosphorus content of the FFS-based diet can be maintained much lower than that of fish meal-based diet. This fact means that once optimal growth is achieved, excretion of the P by feeding the FFS-based diet could be severly reduced. Therefore, this experiment was conducted to investigate the effects of the FFS addition levels in carp diet on their growth and feed utilization and on N and P excretion.

Materials and Methods

Diets and Experimental design

Five experimental diets, Control, $F_{24}S_{13}$, $F_{16}S_{27}$, F_8S_{40} and F_0S_{56} were formulated using conventional brown fish meal, roasted full-fat soybean and wheat flour. The control diet contained 32% of fish meal and 0% of full-fat soybean. The other diets were designated from dietary levels of two ingredients, fish meal (F) and roasted full-fat soybean (S). Ingredients formula and nutrients of the diets are shown in table 1. The supplemental level of monocalcium phosphate in diets increased from 1.5% for control to 3.5% for the F_0S_{56} to satisfy the requirement (NRC, 1993) of available phosphorus for carp. Methionine and lysine were also supplemented to maintain the requirement levels. After thoroughly grinding the ingradients, fully mixed each diet was pelletized (4 mm in diameter) using a commercial pellet mill (CPM, California).

A total of 800 carps (*Cyprinus carpio*) weighting 111 ± 1.2 g (M ± SD)/fish were allotted randomly to 5 treatments with 4 replications per treatment (40 fishes/replication).

TABLE 1. FORMULA AND CHEMICAL COMPOSITION OF EXPERIMENTAL DIETS

Ingredients %	Diets				
	Control	$F_{24}S_{13}$	$F_{16}S_{27}$	F_8S_{40}	F_0S_{56}
Brown fish meal	32.00	24.00	16.00	8.00	0.00
Full-fat soybean	0.00	13.50	27.00	40.08	55.93
Wheat flour	46.28	40.28	34.58	28.80	22.25
Fish oil	6.00	4.50	3.00	2.00	0.00
SCP	6.00	6.00	6.00	6.00	6.00
Corn gluten meal	5.00	6.50	7.50	8.50	8.50
Monocalcium phosphate	1.50	2.00	2.50	3.00	3.50
Vitamin mixture[1]	2.00	2.00	2.00	2.00	2.00
Mineral mixture[1]	0.50	0.50	0.50	0.50	0.50
Choline-HCl (50%)	0.50	0.50	0.50	0.50	0.50
dl-Methionine (50%)	0.20	0.20	0.30	0.40	0.50
Lysine	0.00	0.00	0.10	0.20	0.30
Antioxidant	0.02	0.02	0.02	0.02	0.02
Total	100.00	100.00	100.00	100.00	100.00
Chemical analysis(g or Kcal/100 g);					
Moisture	9.72	9.58	9.79	9.31	10.02
C. protein[2]	40.18	38.93	37.69	38.58	39.05
C. lipid[2]	11.03	12.18	12.37	13.15	12.95
C. fiber[2]	1.64	3.41	3.29	3.30	3.41
C. ash[2]	7.96	7.91	7.47	5.73	6.42
Ca[2]	3.15	2.75	2.07	2.00	1.97
P[2]	1.46	1.50	1.45	1.35	1.33
Gross energy[2]	509.53	513.05	512.91	519.35	517.67

[1] Won, 1993.

[2] DM basis.

Feeding Conditions

A recirculated rearing system was composed of 24 cylindro-conical tanks, settling basin, and filtering and decomposing tanks. Water volumn in each rearing tank was maintained at 130 L with flow rate of 10-12 L/min. The water temperature was in the range of 24 to 28℃ during the experimental periods (May 30- June 26 1994: 28 days). The photoperiod was under natural condition. Dissolved oxygen, pH and ammonia-N levels in water were checked once a week and the values averaged, which were 6.1 mg/L, 6.8 and 1.2 mg/L, respectively.

Fishes were fed to satiation eight times daily with an interval of one hour from 9 a.m. except for the day before weighing when they were fasted. All fish actively consumed the diets and no fish died in all the groups during the experimental period.

Items Investigated

In order to investigate a fish meal sparing effect by full-fat soybean in diet of carp, weight gain, feed conversion ratio, protein efficiency ratio and daily growth index (DGI : Iwama and Tautz, 1981) were examined.

$DGI : = 100(F^{1/3} - I^{1/3}) / ED,$

where F=final fish weight, I=initial fish weight and ED=experimental days. And also, 10 fishes in the beginning of the experiment and 5 fishes from each final group were randomly selected. They were totally minced and chemically analyzed to estimate the retention of nitrogen and phosphorus into fish whole body.

Analytical Methods

Proximate composition of the experimental diets, dried feces and whole body were determined following the AOAC (1990) procedures. Amino acid analysis in the experimental diets was carried out using an automatic amino acid analyzer (Hitachi-835, Japan). Aliquots (100 mg) of each diets were hydrolyzed with 6N HCl in an oven at 110℃ for 24 h. Sulfur-containing amino acids were analyzed after formic acid treatment. Analyses of fatty acid methylesters were performed on a gas chromatograph (Varian 3,600) equipped with a FFAP-grass capillary column (30 m × 0.25 um). N_2 was used as the carrier gas. The chromatographic conditions were as follows: column temeprature, 220℃; injection port temperature, 240℃; and flame ionization detector, 250℃. Methylester peaks were identified by direct comparison of retention time with those of known standards.

Statistical analyses were performed according to the analysis of variance and multiple range test ($p < 0.05$) of Duncan (1955) using the SAS package (SAS Inst. Inc., NC, USA).

Results

Chemical Composition of Experimental Diets

Table 2 shows the essential amino acid composition of the diets. The dietary methionine level was in the range of 2.07% for the F_0S_{56} to 2.28% for control, which were all found to meet the requirement level of the NRC (1993)

TABLE 2. AMINO ACID(AA) COMPOSITION OF EXPERIMENTAL DIETS (% OF PROTEIN)[1]

AA	Diets						Requirement[2]
	Control	$F_{24}S_{13}$	$F_{16}S_{27}$	F_8S_{40}	F_0S_{56}	SEM	
Cys	1.06	1.14	1.26	1.29	1.43	0.11	–
Met	2.28	2.15	2.29	2.21	2.07	0.08	3.1[3]
Thr	4.17	4.17	3.84	4.06	3.71	0.18	3.9
Val	5.19	5.06	4.69	4.90	4.50	0.25	3.6
Ileu	4.17	4.36	4.30	4.41	4.10	0.13	2.3
Leu	8.06	8.57	8.58	9.12	8.37	0.38	3.4
Tyr	3.39	3.57	3.73	3.78	3.61	0.16	–
Phe	4.25	4.62	4.68	5.02	4.75	0.25	6.5[4]
Lys	5.42	5.30	5.15	4.95	4.48	0.34	5.7
His	2.47	2.26	2.11	1.99	1.85	0.22	2.1
Arg	4.63	4.93	6.04	5.10	4.85	0.49	4.3
Trp[3,4]							0.8

[1] Values are means of three determinations; nd=not determined.
[2] NRC(1993) requirements of juvenile common carp.
[3,4] In the absence of cystine and tyroine, respectively.

considering cystine content. threonine, valine, isoleucine, arginine and leucine also satisfies the requirement levels. The leucine content was found to be two-fold more than that of the NRC level in all diets. The phenylalanine level in all diets was lower than the NRC level (6.5%), ranging from 4.25% to 5.02%. However, it seemed to be in the range of the requirement, considering tyrosine level in the diets.

The fatty acid composition of experimental diets is presented in table 3. Dietary fatty acid profiles were greatly changed based on dietary ingredient composition. The major fatty acids were palmitic and oleic acid in control diet. With increase of full-fat soybean level in diets, however, palmitic acid decreased from 23.7% for control to 11.6% for the F_0S_{56}. Linoleic acid increased from 14.9% for control to 53.8% for the F_0S_{56}, while the levels of EPA (20:5ω3) and DHA (22:6ω3) concomitantly decreased with increase of the FFS in diets. These trends resulted in a decrease of dietary ω3/ω6 ratio from 1.12 to 0.17.

TABLE 3. FATTY ACID(FA) COMPOSITION OF EXPERIMENTAL DIETS (% OF TOTAL AREAS)[1]

FA	Diets				
	Control	$F_{24}S_{13}$	$F_{16}S_{27}$	F_8S_{40}	F_0S_{56}
14:0	7.43±0.11	2.64±0.09	2.97±0.14	1.58±0.13	0.25±0.07
16:0	23.06±0.08	20.32±0.03	16.19±0.11	13.22±0.15	11.56±0.11
16:1ω7	7.68±0.09	5.88±0.06	2.99±0.13	1.81±0.02	0.23±0.01
18:0	4.28±0.01	3.46±0.02	1.60±0.01	3.62±0.04	3.65±0.04
18:1ω9	20.86±0.11	19.35±0.16	21.28±0.11	20.47±0.09	21.06±0.03
18:2ω6	14.94±0.14	26.83±0.11	41.12±0.06	45.95±0.04	53.79±0.07
18:3ω3	1.64±0.13	3.44±0.11	6.57±0.15	7.23±0.13	8.64±0.09
20:1ω9	3.84±0.02	2.69±0.01	0.00±0.01	1.16±0.01	0.32±0.03
20:5ω3	10.41±0.17	7.82±0.09	4.08±0.04	2.78±0.01	0.50±0.02
22:6ω3	5.86±0.09	7.59±0.11	3.19±0.01	2.18±0.03	0.00±0.01
Saturated	34.77	27.42	20.76	18.42	15.46
ω3	17.91(2.0)[2]	18.85(2.3)	13.84(1.7)	12.19(1.6)	9.14(1.2)
ω6	14.94(1.7)	31.83(3.9)	41.12(5.1)	45.95(6.0)	53.79(7.0)
ω3/ω6 ratio	1.12	0.59	0.34	0.27	0.17

[1] Values are means±SD of three determinations.
[2] Calculated level based on total lipid (% of dried diet).

Growth and Feed Utilization

Weight gain and feed utilization of carp fed experimental diets for 4 weeks are shown in table 4. Weight gain and daily growth index of fish decreased from 91.2 g to 38.9 g and from 3.79 to 1.80 as full-fat soybean (FFS) level increased from 0 to 56%. Dried feed intakes were in the range of 107 g for control group to 81 g for fish fed the diet F_8S_{40} which contained 8% of fish meal and 40% of the FFS. However, feed conversion ratio was lowest (1.06) in fish fed control diet, while those fed the diet F_0S_{56} with the FFS of 56% showed the highest value (1.95). Protein intake varied from 38.9 g for control to 28.3 g for the group F_8S_{40}. Protein efficiency ratio decreased from 2.35 for control to 1.32 for the group F_0S_{56}.

Whole Body Composition

Table 5 shows whole body composition of initial and final carp fed experimental diets for 4 weeks. Compared to initial fish, moisture content decreased in all groups which ranged from 72.5% for control to 75.2% for the group F_8S_{40}. Protein level was not significantly ($p > 0.05$) different among final fish, ranging from 14.5% to 15.1% for control and the $F_{24}S_{13}$, respectively. Lipid level of final fish was highest (8.1%) in fish fed control diet and lowest (5.3%) in those of the group F_8S_{40} which was lower than that (5.8%) of the initial. There was no significant difference in energy content of final fish. Ash level was from 1.9% for the group $F_{24}S_{13}$ to 3.1% for the group F_8S_{40}, and this difference was concomitantly shown in phosphorus content rather than that of calcium. Fish fed the diet F_8S_{40} showed the highest phosphorus content (0.7%) in their body, while the content was lowest (0.4%) in those fed the diet $F_{24}S_{13}$ which was similar to that of the initial. On the other hand, calcium level ranged from 1.1% to 1.4%, showing no significant difference.

TABLE 4. WEIGHT GAIN AND FEED UTILIZATION OF CARP FED EXPERIMENTAL DIETS FOR 4 WEEKS[1]

Items	Diets					
	Control	$F_{24}S_{13}$	$F_{16}S_{27}$	F_8S_{40}	F_0S_{56}	SEM
Initial Wt.(g/fish)	111.2	110.4	110.6	111.3	111.6	1.2
Wt. Gain(g/fish)	91.2[a]	73.7[b]	68.2[b]	49.5[c]	38.9[d]	18.5
DGI[2]	3.79[a]	3.18[b]	2.98[b]	2.24[c]	1.80[d]	0.71
Feed intake(DM): g/fish/28d	107.2[a]	95.2[b]	93.8[b]	80.9[c]	84.1[c]	9.6
DFR, %[3]	2.20[a]	2.09[ab]	2.09[ab]	1.93[b]	2.06[ab]	0.10
FCR[4]	1.06[d]	1.17[c]	1.24[c]	1.48[b]	1.95[a]	0.32
Protein intake: g/fish/28d	38.89[a]	33.52[b]	31.89[bc]	28.29[d]	29.56[cd]	3.8
PER[5]	2.35[a]	2.20[ab]	2.14[b]	1.75[c]	1.32[d]	0.38

[1] Values (means of four replicates) in the same row not sharing a common superscript letter are significantly different ($p < 0.05$).
[2] Daily growth index = 100(Final Wt.$^{1/3}$ − Initial Wt.$^{1/3}$) / No. of feeding days.
[3] Daily feeding rate = 100[feed intake, DM/{(initial wt. + final wt.)/2} / 28].
[4] Feed conversion ratio = Feed intake, DM/wet wt. gain.
[5] Protein efficiency ratio = wet wt. gain/protein intake.

TABLE 5. WHOLE BODY COMPOSITION OF CARP FED EXPERIMENTAL DIETS FOR 4 WEEKS (G OR KCAL/100G WET WEIGHT)[1]

Diets	Moisture	Protein	Lipid	Energy	Ash	Ca	P
Control	72.50[b]	14.46[a]	8.14[a]	158.14[a]	2.08[bc]	1.12[a]	0.52[bc]
$F_{24}S_{13}$	75.04[a]	15.13[a]	6.74[ab]	148.84[a]	1.86[c]	1.29[a]	0.44[c]
$F_{16}S_{27}$	73.71[ab]	15.00[a]	6.47[ab]	145.57[a]	2.78[ab]	1.14[a]	0.60[ab]
F_8S_{40}	75.18[a]	14.73[a]	5.25[b]	132.53[a]	3.08[a]	1.36[a]	0.69[a]
F_0S_{56}	74.68[ab]	14.83[a]	5.67[ab]	137.01[a]	2.51[abc]	1.06[a]	0.54[bc]
SEM	1.17	0.41	2.25	11.45	0.50	0.15	0.09
Initial	76.99	13.67	5.77	131.47	2.03	1.25	0.45
SD	0.12	0.09	0.14	4.42	0.18	0.05	0.01

[1] Values are the means of four replicates, each pooled from 5 fish and values in the same column not sharing a common superscript letter are significantly different ($p < 0.05$).

Protein and phosphorus Excretion

Data on protein (Pr) excretion per kg weight gain and protein retention efficiency (PrRE) are shown in table 6. Based on kg Wt. gain, the Pr intake was in the range of 427 g to 761 g for fish fed the diets control and F_0S_{56}, respectively. The retained Pr of fish fed control diet was 154 g which lowest among treatments, while that of the group F_0S_{56} showed the highest Pr retention. However, the other groups showed no significant ($p > 0.05$) difference in Pr retention. The Pr excretion varied from 273 g to 579 g for fish fed the diets control and F_0S_{56}, respectively. Based on these results, the PrRE was estimated from 24% to 38% for fish fed the diets F_0S_{56} and $F_{24}S_{13}$, respectively. On the other hand, it was calculated that the Pr excretion was in range of 215 g to 268 g per kg feed intake.

Phosphorus (P) retention and excretion per unit gain and the P retention efficiency (PRE) of fish fed experimental diets for 4 weeks are presented in table 7. The P intake per kg weight gain increased from 16 g to 26 g as dietary fish meal level decreased. However, the retained P was highest (12 g) in fish fed the diet F_8S_{40} and lowest (4 g) in those fed the diet $F_{24}S_{13}$. The excreted P level varied from 8 g to 18 g for the groups F_8S_{40} and F_0S_{56}, respectively. From these data, it was calculated that the PRE ranged from 24% to 62%. On the other hand, it was found that 5 g to 10 g of the P were excreted per kg feed intake by fish.

Discussion

Utilization of FFS was widely studied in tilapia (Wee and Shu, 1989; Shiau et al., 1990), in carp (Viola et al.,

TABLE 6. PROTEIN(Pr) EXCRETION BASED ON RETAINED Pr IN WHOLE BODY OF CARP[1]

Diet	Pr(g) per kg weight gain			Pr excretion(g) / kg feed intake	PrRE[2] %
	Fed	Retained	Excreted		
Control	426.6^{d}	154.1^{c}	272.5^{c}	231.6^{c}	36.2^{a}
$F_{24}S_{13}$	454.9^{cd}	173.2^{b}	281.7^{c}	271.9^{d}	38.1^{a}
$F_{16}S_{27}$	467.8^{c}	171.6^{b}	296.3^{c}	215.3^{d}	36.7^{a}
$F_{8}S_{40}$	571.9^{b}	171.2^{b}	400.7^{b}	245.2^{b}	29.9^{b}
$F_{0}S_{56}$	760.5^{a}	181.4^{a}	579.1^{a}	267.6^{a}	23.9^{c}
SEM	122.9	8.9	116.5	19.4	5.4

[1] Values(means of four replicates) in the same column not sharing a common superscript letter are significantly different ($p < 0.05$).
[2] Protein retention efficicency = 100[(final body wt. × % Pr in whole body) − (initial body wt. × % Pr in whole body)] / Pr intake.

TABLE 7. PHOSPHORUS(P) EXCRETION BASED ON RETAINED P IN WHOLE BODY OF CARP[1]

Diet	P(g) per kg weight gain			P excretion(g) / kg feed intake	PRE[2] %
	Fed	Retained	Excreted		
Control	15.5^{d}	6.1^{d}	9.5^{c}	8.1^{b}	39.0^{c}
$F_{24}S_{13}$	17.6^{c}	4.3^{e}	13.3^{b}	10.3^{a}	24.2^{e}
$F_{16}S_{27}$	18.0^{c}	8.4^{b}	9.6^{c}	7.0^{c}	46.8^{b}
$F_{8}S_{40}$	19.9^{b}	12.3^{a}	7.6^{d}	4.7^{b}	61.7^{a}
$F_{0}S_{56}$	26.0^{a}	8.0^{a}	18.0^{a}	8.3^{b}	30.8^{d}
SEM	3.6	2.7	3.7	1.8	13.1

[1] Values (means of four replicates) in the same column not sharing a common superscript letter are significantly different ($p < 0.05$).
[2] Phosphorus retention efficiency (means ± SE of four replicates) = 100[(final body wt. × % P in whole body) − (initial body wt. × % P in whole body)] / P intake.

1983; Abel et al., 1984), in channel catfish (Brandt, 1979; Lovell, 1980) and in rainbow trout (Smith, 1977; Reinitz et al., 1978; Cocker et al., 1978; Tacon et al., 1983). Smith (1977) reported that trout fed a diet having 80% of FFS grew well. Cocker et al. (1978), however, found that the fish fed a diet containing 84% of FFS resulted in a markedly retarded gain compared to that of fish fed a diet having both 34% of fish meal and 20% of soybean meal.

The present results showed that carp fed control diet containing 32% of fish meal without the FFS had the best performance in terms of all the criteria measured (table 4). As dieatry fish meal level decreased from 32% to 0% with the concomitant increase of the FFS from 0% to 56%, weight gain and protein efficiency ratio linearly decreased, while feed conversión ratio progressively increased. Differently from these results, Tacon et al. (1983) observed that trout fed a diet containing 32% toasted full-fat soybean meal as replacements of half of fish meal attained 143% of the weight gain obtained with the fish meal control diet. However, Abel et al. (1984) found that relative weight gain of carp fed diets with 50% heat-treated FFS and 31% fish meal reached to only 60-65%, compared to that obtained by fish fed diet containing 62% fish meal. They mentioned that the better results for fish fed the fish meal diet could be attributed to higher availability and/or more balanced amino acid composition of fish meal protein. Considering such a suggestion, the present poor performance of fish fed diets with increasing levels of FFS could be partly explained by lysine deficiency. The lysine level decreased from 5.4% for control to 4.5% for the diet $F_{0}S_{56}$ and those values were all under the NRC (1993) requirement level (table 2). Viola et al. (1983) reported that the limiting factor for growth of carp fed diet containing properly heated soybean meal was not the residual trypsin inhibitor but inadequate lysine. It seemed that the poor performance could be clarified by a further experiment with an extra amount of synthetic lysine.

In addition, the present results might also be due to an excess level of $\omega 6$ fatty acid by dietary FFS inclusion. Though all diets contained the same levels of protein and energy, linoleic acid content greatly varied from 15% to

54% with dieatry FFS substitution. Carps need both linoleic and linolenic acids at the level of 1%, respectively, in their diet (NRC, 1993) and the all present diets satisfied each requirement level. However, linear reduction in $\omega 3/\omega 6$ acid ratio from 1.12 to 0.17 was found (table 3) and the calculated levels of $\omega 3$ and $\omega 6$ acids in diets were in the range from 2% to 1.2% and from 1.7% to 7%, respectively. Takeuchi and Watanabe (1979) reported negative effect of essential fatty acid in rainbow trout. They found that 4% of linolenic acid ($18{:}3\omega 3$) level in diet resulted in poor growth and low feed utilization. Yu and Sinnhuber (1976) observed that growth of rainbow trout was depressed as dietary linoleic acid ($18{:}2\omega 6$) level increased from 2.5% to 5%. Based on these observations, decreased growth and feed utilization with increase of the FFS in diets could be originated from the possible negative effect of increasing $18{:}2\omega 6$ level. Cocker et al. (1978) suggested that less weight gain of fish fed the FFS-based diet was caused by the absence of fish oil or highly unsaturated fatty acids. And also, they indicated low palatability of the full-fat soybean diet.

Protein excretion per kg weight gain showed an increasing trend as dietary FFS level increased, though significant difference was not found among the groups control, $F_{24}S_{13}$ and $F_{16}S_{27}$. The highest PrRE of 38% found in fish fed the diet $F_{24}S_{13}$ (table 6) was almost the same as the highest value obtained by commercial carp feed, which was previously reported by Kim and Woo (1994). They found that the PrRE of carp was in the range of 30% to 38%. The fish fed the diets F_8S_{40} and F_0S_{56} excreted protein much more than that (273 g) of control group, indicating a decrease in protein utilization with higher level of the FFS. Phosphorus is required for the development and maintenance of the skeletal system and in several physiological processes (Lall, 1991). And the P also acts as the first limiting factor for algal growth (Aizaki et al., 1984; Auer et al., 1986; Waston et al., 1992). Therefore, fish feed should contain the least possible level of P with ingredients having the high P availability in order to achieve both maximum growth and minimum P excretion (Kim and Ahn, 1993; Lall, 1991). The present results indicated that fish fed the diet F_8S_{40} showed the lowest P excretion (7.6 g) with the highest PRE of 62% (table 7), which resulted from high deposition of the P in whole body (table 5). However, it may be practically not significant since these best values were obtained without optimum growth.

Conclusions

The present results revealed that as dietary roasted full-fat soybean level (FFS) increased, weight gain and feed utilization efficiency decreased. And also, it was shown that excretion of protein and phosphorus increased with increase of the FFS in diet. Such a trend might have been due to an increase in linoleic acid level and a decrease in available lysine content. This unbalance of essential nutrients in diets could resulted in decreased feed utilization. From these results, it was concluded that more than 25% substitution by the FFS for fish meal could exert negative effects on growth and feed utilization of carp. With this conclusion, it was suggested that the inclusion level of the FFS should be in the range of satisfying only the $\omega 6$ fatty acid requirement.

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