

EFFECT OF DIFFERENT LEVELS OF ROASTED FULL-FAT SOYBEAN ON THE APPARENT DIGESTIBILITY OF DIETARY COMPONENTS BY CARP (*Cyprinus carpio*) GROWER

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Summary

Digestibility trial was performed with carps weighing 200 g/fish. Fecal collection was made over 7 days using a settling column. The water temperature was in the range of 27 to 30°C during whole experimental period. Fishes were fed 5 diets (Control, F₂₄S₁₃, F₁₆S₂₇, F₈S₄₀ and F₀S₅₆) containing both 32%, 24%, 16%, 8% and 0% of fish meal (F) and 0%, 13%, 27%, 40% and 56% of roasted full-fat soybean (S), respectively. Water volume in each recirculated rearing tank was maintained at 130 l with flow rate of 10-12 l/min. Apparent digestibility coefficients (ADCs) of dry matter, protein, lipid, total carbohydrates and energy in diets showed a reduction ($p < 0.05$) with the increase of dietary full-fat soybean level, although there was no difference in the ADCs between Control and F₂₄S₁₃ ($p > 0.05$). The ADCs of ash, Ca and P in diets significantly increased with the increase of dietary full-fat soybean level, suggesting the high availability of phosphorus in monocalcium phosphate.

(Key Words :Carp, Digestibility, Roasted Full-Fat Soybean, Fish Meal)

Introduction

Fish meal is the most expensive protein source in fish diet. Earlier studies to replace fish meal with vegetable meals (Viola et al., 1982; Viola et al., 1983) focused on the economical point of view due to both variable quality and quantity of fish meal. However, for a sustainable fish farming, increase of fish production should be considered with water quality protection (Folke and Kautsky, 1989). It is well known that fish meal is a good source of essential amino acids and essential fatty acids for the normal growth of fish, while the availability of phosphorus in it is negligible by carp (NRC, 1993). This

is because phosphorus in fish meal exists mainly in the form of insoluble $\text{CaCO}_3 \cdot n\text{Ca}_3(\text{PO}_4)_2$ originating from the hard tissues (Yone and Toshima, 1979). The fact that such a stomachless fish as carp do not secrete gastric juice (Ogino and Takeda, 1976) means the increase of phosphorus load into water by the fish fed diet containing higher level of fish meal. However, a study to establish a minimum level of dietary fish meal for both maximum growth and minimum phosphorus excretion of carp was not conducted.

Full-fat soybean contains low level of phosphorus and high amount of linoleic acid, which is not found in fish meal but essential for the growth of carp (NRC, 1993). It is, however, not typically used as an ingredient for fish feed formulation because of its low availability and a lack of nutritional knowledges. Kim et al. (1995) reported that the increase in replacing level of fish meal with roasted full-fat soybean in diet resulted in a concomitant decrease of weight gain and feed utilization with a linear increase in discharge of protein and phosphorus by carp. The purpose of this study was to investigate the effects of dietary full-fat soybean level on dry matter, protein, lipid, total carbohydrate and energy digestibilities by carp.

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Received November 18, 1994

Accepted July 7, 1995

Materials and Methods

Experimental Diet Preparation

Five experimental diets, Control, F₂₄S₁₃, F₁₆S₂₇, F₈S₄₀ and F₀S₅₆ 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 the dietary levels of two ingredients, fish meal (F) and roasted full-fat soybean (S). Chromic oxide was added to 1% level to a portion of each mixed diet as an inert tracer for the measurement of nutrient and energy digestibilities. Diets were prepared as spaghetti-like strands using the mincer-attached meat-grinder after mixing with 25% distilled water, and then the spaghetti was separated, dried in an oven at 60°C for 24 h. Formula and chemical composition were shown in table 1.

TABLE 1. FORMULA AND CHEMICAL COMPOSITION OF DIETS FOR DIGESTIBILITY TRIAL

Ingredients %	Diets				
	Con-trol	F ₂₄ S ₁₃	F ₁₆ S ₂₇	F ₈ S ₄₀	F ₀ S 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	2.00	2.00	2.00	2.00	2.00
Mineral mixture	0.50	0.50	0.50	0.50	0.50
Choline-HCl (50%)	0.50	0.50	0.50	0.50	0.50
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
Cr ₂ O ₃	1.00	1.00	1.00	1.00	1.00
Total	101.00	101.00	101.00	101.00	101.00
Chemical analysis (g or Kcal/100 g DM);					
C. protein	39.84	39.30	40.41	38.09	37.96
C. lipid	10.54	10.48	8.63	12.19	12.61
C. fiber	1.49	3.41	3.29	3.30	3.41
TCHO ^{b)}	40.87	41.54	42.00	41.26	41.12
C. ash	8.74	8.68	8.96	8.47	8.31
Ca	2.46	2.32	2.07	1.97	1.89
P	1.40	1.37	1.43	1.37	1.34
Gross energy	499.99	501.94	497.07	513.52	516.60

^{b)} Total carbohydrates = fiber + nitrogen - free extracts.

Experimental Animal and Fecal Collection

After feeding trial (Kim et al., 1995), a total of 300 carps with body weight of 200 ± 1.6 g (mean ± SD) were selected for the digestibility measurement. Fish were randomly allotted to 5 treatments with 2 replications each treatment (30 fishes/replication). They were adapted to a rearing facility for 10 days and fed diets eight times a day to satiety. And then, fecal collection was lasted for 7 days using a settling column (Kim and Woo, 1994) attached to each tank. Fecal matters, collected before first meal at 9 a.m., were oven-dried at 60°C for 48 h and then an aliquots of fully homogenized feces from 7 days-composited samples were prepared for the analysis.

Feeding Conditions

A recirculated rearing system consisted of 12 cylindrical tanks, settling basin, and filtering and decomposing tanks. Water volume in each rearing tank was maintained at 130 l with a flow rate of 10-12 l/min. The water temperature was in the range of 27 to 30°C during the experimental period (June 28-July 15, 1994). The photoperiod was under natural condition. Dissolved oxygen, pH and ammonia levels in water were measured once a week and the averaged values were 5.9 mg/L, 6.8 and 1.0 mg/L, respectively. Fish were fed to satiety eight times daily with an interval of one hour from 9 a.m.. All fish actively consumed the diets and no fish died in all the groups during the experimental periods.

Items Investigated

Digestibilities of dry matter, protein, lipid, total carbohydrates, ash, calcium, phosphorus and energy were measured to evaluate the nutritive value of experimental diets containing different levels of full-fat soybean. The apparent digestibility coefficients (ADCs) were calculated as follows (Maynard and Loosli, 1969):

$$\text{ADC of dry matter} = 100 \times (1 - \% \text{Cr}_2\text{O}_3 \text{ in feed} / \% \text{Cr}_2\text{O}_3 \text{ in feces}),$$

$$\text{ADCs of nutrients} = 100 \times (1 - \% \text{Cr}_2\text{O}_3 \text{ in feed} / \% \text{Cr}_2\text{O}_3 \text{ in feces} \times \% \text{nutrient in feces} / \% \text{nutrient in feed}).$$

Analytical Methods

Proximate analyses of both experimental diets and dried feces were made following the AOAC (1990) procedures. Energy contents were analyzed using an Automatic Adiabatic Bomb Calorimeter (Gallenkamp and Co. Ltd, England). Chromic oxide in the diets and feces was analyzed using a spectrophotometer (Shimadzu, UV-120-12) by the previously described method (Kim and Ahn, 1993). 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 and Discussion

Table 2 showed the chemical composition (g or kcal/100 g) of dried feces. Protein level in dried feces slightly increased from 20 g to 24 g depending upon the reduction of fish meal contents in diets. Lipid content increased from 2 g to 11 g as dietary full-fat soybean level increased from 0% to 56%. These trends accounted for the energy content of feces, which increased from 344 kcal to 451 kcal. However, total carbohydrates maintained relatively constant, which ranged from 51 g to 53 g. Ash content decreased from 27 g to 14 g according to the increase of dietary full-fat soybean contents, which, in turn, resulted in the decrease in the Ca and P levels, from 8 g to 3 g and from 5 g to 2 g, respectively.

From these data, apparent digestibility coefficient (ADCs) values of experimental diets were calculated (table 3). The ADCs of protein and lipid significantly ($p < 0.05$) decreased from 87% to 81% and from 94% to 74%,

respectively, with the increasing levels of dietary full-fat soybean. These resulted in a decrease in the ADC of energy from 82% to 74%, although the ADC of total carbohydrates (TCHO) was not greatly different in the range of 68% to 63%. On the other hand, the ADCs of ash, Ca and P significantly increased as the full-fat soybean content in diet increased ($p < 0.05$). And, the ADC of dry matter, ranging from 74% to 70%, not severely decreased, although significant ($p < 0.05$) differences were found among treatments.

TABLE 2. CHEMICAL COMPOSITION OF DRIED FECES (g or kcal /100g)¹⁾

Diets	Protein	Lipid	TCHO ²⁾	Energy	Ash	Ca	P
Control	19.8	2.4	50.6	343.7	27.3	7.5	4.5
F ₂₄ S ₁₃	20.6	3.4	53.3	369.8	22.7	6.8	4.3
F ₁₆ S ₂₇	23.7	5.4	50.7	395.4	20.1	5.0	3.4
F ₈ S ₄₀	23.9	8.3	51.2	425.2	16.7	4.3	2.5
F ₀ S ₅₆	24.0	11.1	50.9	450.6	14.1	3.2	2.1

¹⁾ Values are the means of two replicate groups.

²⁾ Total carbohydrates = fiber + nitrogen - free extracts.

TABLE 3. APPARENT DIGESTIBILITY COEFFICIENTS (ADCs, %) OF EXPERIMENTAL DIETS

Nutrient	Diets				
	Control	F ₂₄ S ₁₃	F ₁₆ S ₂₇	F ₈ S ₄₀	F ₀ S ₅₆
Dry matter	73.8 ± 0.17 ^{a1)}	73.7 ± 0.10 ^a	71.9 ± 0.17 ^b	71.0 ± 0.04 ^c	70.4 ± 0.13 ^d
Protein	87.0 ± 0.11 ^a	86.2 ± 0.35 ^a	83.5 ± 0.37 ^b	81.8 ± 0.04 ^c	81.3 ± 0.28 ^c
Lipid	94.1 ± 0.36 ^a	91.4 ± 0.22 ^a	82.4 ± 1.72 ^b	80.3 ± 2.07 ^b	74.1 ± 1.35 ^c
TCHO ²⁾	67.6 ± 0.21 ^a	66.2 ± 0.15 ^{ab}	66.1 ± 0.27 ^b	64.0 ± 0.33 ^c	63.4 ± 0.66 ^c
Ash	18.0 ± 0.08 ^d	31.2 ± 0.02 ^c	36.9 ± 2.69 ^{bc}	43.0 ± 3.96 ^{ab}	50.0 ± 1.56 ^a
Ca	19.5 ± 1.38 ^d	22.5 ± 0.32 ^{cd}	31.9 ± 3.33 ^{bc}	37.3 ± 4.06 ^b	49.7 ± 4.16 ^a
P	14.8 ± 0.88 ^d	17.6 ± 2.36 ^d	32.8 ± 1.25 ^c	46.4 ± 1.89 ^b	52.9 ± 1.03 ^a
Energy	82.0 ± 0.19 ^a	80.6 ± 0.15 ^a	77.7 ± 0.54 ^b	76.0 ± 0.56 ^c	74.2 ± 0.21 ^d

¹⁾ Values (means ± SE) in the same row not sharing a common superscript letter were significantly different ($p < 0.05$).

²⁾ Total carbohydrates = fiber + nitrogen - free extracts.

The reported ADC of protein in fish meal by carp was in the range of 80 to 89% (Kim, 1974; Atack et al., 1979; Ufodike and Matty, 1983; Hossain and Jauncey, 1989). Such a difference would be come from the origin and processing method of the fish meal employed (Ogino and Chen, 1973). The decrease in the ADC of protein with the increase of dietary full-fat soybean content suggested that protein utilization could be affected by the ingredient levels. Viola et al. (1982, 1983) indicated that certain vegetable protein meals had a reduced availability of

energy and lysine to carp, which may account for the inability of vegetable meals to replace fish meal completely. In the optimal rearing condition, fish digest dietary lipid well regardless of its origin (Takeuchi, 1979; Takeuchi et al., 1979). Schwarz et al. (1988) estimated the ADC of different fats added to diet at the level of 12% by carp having 221 g of body weight. They found that the digestibility of corn oil (95.9%), Linseed oil (93.4%) and fish oil (93.0%) was significantly higher than that of beef tallow (87.8%). Differently from the results, the ADC of

fat in the diet F₀S₅₆ containing 56% of full-fat soybean was lowest (74.1%) among treatments. However, that (94.1%) of the control in which fish oils were the greater part of fat was similar to that of fish oils reported by Schwarz et al. (1988).

In the previous study (Kim et al., 1995), we mentioned that reduced weight gain and feed utilization of fish fed the diet containing 56% of full-fat soybean might have been partly due to higher linoleic acid contents. Based on the present results, however, such the reduction in performance would partly result from a lower digestible energy intake due to the lower lipid digestibility. In addition to that, increasing levels of dietary full-fat soybean might have resulted in an unbalanced supply of the essential fatty acid (EFA). Carp need both linoleic and linolenic acids in their diet at the level of 1%, respectively (NRC, 1993). The principal sign of the EFA deficiency for carp was a reduced growth rate and feed efficiency or increased mortality (Takeuchi and Watanabe, 1977). Shimma et al. (1977) reported reduced reproductive performance in adult carp as the EFA deficiency. And the higher level of full-fat soybean in diets resulted in a concomitant decrease in protein digestibility, by which essential amino acid availability could be lowered. This may partially explain the observations of Viola et al. (1982, 1983). The ADC of total carbohydrates (TCHO) ranged from 67.6% to 63.4% among treatments, and the higher levels of full-fat soybean in diet had reverse relationship with ADC of total carbohydrates ($p < 0.05$). The highest ADC of TCHO by fish fed control diet could be explained by the lowest fiber contents (1.5%) among the experimental diets (Hilton et al., 1983). Although fiber and nitrogen-free extracts contents in the other four diets maintained nearly constant, difference in the ADC of TCHO was found among the diets (66% vs 64%) ($p < 0.05$).

In addition, relative decrease in crude ash contents according to the higher contents of full-fat soybean in diet resulted in linear increase of its digestibility from 18% to 50%. The same trend was found in the ADCs of Ca and P, which might be due to increasing levels of monocalcium phosphate which was highly available to carp (NRC, 1993). Kim et al. (1995) reported that fish fed the diet F₈S₄₀ excreted the lowest P (7.6 g) per kg of weight gain. Despite of the highest digestibility of P, P discharge by fish fed the diet F₀S₅₆ was highest (18 g) due to the lowest weight gain among the treatments.

These results indicated that the higher use of full-fat soybean would decrease the digestibility of energy-yielding nutrients.

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