

EFFECTS OF MONOCALCIUM PHOSPHATE SUPPLEMENTATION ON PHOSPHORUS DISCHARGE AND GROWTH OF CARP (*Cyprinus carpio*) GROWER

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Summary

Two percent of monocalcium phosphate (MCP) was added to control diet consisted of fish meal (18%), soybean meal (36%) and wheat flour (37%) in order to examine the effects on phosphorus (P) discharge and growth of carp (*Cyprinus carpio*). Growth trial, during which digestibility measurements were made over 7 days, was conducted for 4 weeks using a recirculated rearing system with a settling column for feces collection. Fishes (initial body weight of about 200 g) were fed five times a day upto satiation with tank controlled at 24-26°C. Fishes fed the diet containing 2% MCP (MCP-2) showed about two-fold improvement on both growth rate and feed utilization, compared to those of fishes fed the control diet; weight gain (129 g vs 62 g), feed conversion ratio (1.20 vs 2.46), protein efficiency ratio (2.09 vs 1.07) and daily growth index (3.70 vs 1.93). However, feed intakes were maintained at the same level (150 g/fish) between the two treatments. Dry matter digestibilities of two diets were relatively low, which were 58 and 60% for respective control and MCP-2 diets due to low digestibility of total carbohydrates. However, the digestibilities of both dietary protein (85%) and lipid (90%) of diets were relatively high. While all the P fed were observed to be discharged from fish fed control diet, the discharge from fish fed the MCP-2 diet was decreased up to less than the half (34.9 g/kg wt. gain) of the control. These present results revealed that the supplementation of dietary P requirement by MCP can not only promote growth performances but also reduce the level of P loading to water which is the primary water pollution indicator.

(Key Words: Carp, Diet, Monocalcium Phosphate, Phosphorus, Water Pollution)

Introduction

The phosphorus availability of inorganic salts by carp depends on their solubility, because carp do not secrete gastric juices. Ogino et al. (1979) reported that monobasic phosphate was utilized more efficiently than either dibasic or tribasic forms added to diet for carp. In general, fish meals are major animal protein source in carp diet and these contain a higher level (> 4%) of phosphorus (Kim, 1993). However, the phosphorus in fish meals exists mainly in the form of insoluble $\text{CaCO}_3 \cdot n\text{Ca}_3(\text{PO}_4)_2$ originating from the hard tissues, therefore, its availability is negligible

by carp (Yone and Toshima, 1979). This fact suggests that an increasing level of dietary fish meals would result in an increment of phosphorus loading into water environment.

Phosphorus (P) is not only an inorganic element essential for optimal growth of carp (NRC, 1983) but also the first limiting factor for algal growth which accelerates oxygen deficit in water (Auer et al., 1986). Considering the fact that a floating net-cage farming for carp occupies about 70% of total freshwater fish farming in Korea, the P in diet for carp feeding must be the most important factor both for optimal growth and for prevention of water pollution.

It is theoretically advisable that total inclusion level of dietary P should be kept at that of the requirement (0.6-0.7% in diet, Ogino and Takeda (1976)) in order to protect water quality and to obtain an expected growth of carp. Since a minimum level of dietary fish meals is not established yet, it is impossible to formulate diet to keep total dietary P at the recommended level due to higher content of P in fish meals available

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in Korea. That means that with fish meal only, an available P in diet could not be met up to the level it was recommended. Therefore, as a preliminary study to develop the low-pollution carp diet, the present experiment was conducted to investigate the effects of 2% monocalcium phosphate (MCP) supplementation in carp diet on growth and phosphorus discharge.

Materials and Methods

Experimental diet and feeding conditions

Two experimental diets, control and MCP-2, were formulated using conventional white fish meal, soybean meal and wheat flour (table 1). The diet MCP-2 contained 2% of monocalcium phosphate in place of wheat flour in control diet. For digestibility measurement of dietary nutrients, 1% of chromic oxide (Cr_2O_3) was added in each diet. Each ingredient of the diets was weighed, thoroughly mixed in a blender and then made into pellets of 4.8 mm diameter using a pellet mill (California, USA).

Carp (*Cyprinus carpio*) having mean initial weight of 207.8 ± 0.5 g per fish were used as experimental animal. In a recirculated rearing system, six groups of 20 fish each were randomly allotted in individual rearing tanks having a holding capacity of 150 L with a flow rate of 1.2 L/min. The water temperature was controlled at 24–26°C during the experimental periods (March 11–April 9, 1992). The photoperiod was regulated to 12 h light and 12 h dark. Dissolved oxygen, pH and ammonia levels in water were checked once a week and the values averaged, which were 6.4 mg/L, 6.2–6.8 and 1–3 mg/L, respectively.

Fish were fed to satiation five times daily with an interval of two hours from 9 a.m. except for the day before weighing when they were fasted. Daily growth index (DGI) was calculated using the following formula derived from Iwama and Tautz (1981):

$$\text{DGI} = (\text{FBW}^{1/3} - \text{IBW}^{1/3}) / \text{number of days} \times 100,$$

where FBW and IBW represent final and initial weights, respectively.

Fecal collection was made over 7 days using a settling column attached to each tank during the middle of the feeding trial. Daily feces collected before first meal at 9 a.m. were oven-dried at 50°C for 48 h and then aliquots of fully

homogenized feces from 7 days-composited samples were prepared for analysis. The apparent digestibility coefficients (ADCs) were calculated as follows (Maynard and Loosli, 1969):

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

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

All fish actively consumed the diets and no fish died in all the groups of the present experiment. Randomly selected 5 fishes from initial group and 5 fishes from each final tank were employed for determining phosphorus retention in whole body. The retention and discharge of P were calculated, respectively, as follows:

$$\text{P retention} = (\text{FBW} \times \% \text{P in whole body}) - (\text{IBW} \times \% \text{P in whole body}),$$

$$\text{P discharge (g/kg wt. gain)} = \text{P fed} - \text{P retained}.$$

Analytical methods

Proximate compositions of the experimental diets, dried feces and whole body were determined following the AOAC (1984) procedures. Chromic oxide in the diets and feces was analyzed using a spectrophotometer (Shimadzu, UV-120-12) at a wavelength of 440 nm after perchloric acid digestion (Bolin et al., 1952). Chemical compositions of diets and feces were shown in table 1.

Results and Discussion

Growth performances

Growth performances of carp fed two experimental diets for 4 weeks are presented in table 2. Fish fed the diet MCP-2 showed two-fold increase in weight gain (129 g) compared to that (62 g) of fish fed the control diet, though initial body weight and feed intake were not different between treatments. Such an increase resulted in about two-fold improvement on feed conversion ratio (1.20/2.46), protein efficiency ratio (2.09/1.07) and daily growth index (3.70/1.93) by the treatment or MCP-2.

Because ingredient composition of two diets was formulated identically except for monocalcium phosphate (MCP), it could be concluded that those improving effects on growth and feed utilization were resulted from the physiologically satisfactory supply of phosphorus requirement

PHOSPHORUS DISCHARGE BY CARP FEEDING

TABLE 1. COMPOSITION OF THE EXPERIMENTAL DIETS AND DRIED FECES

Ingredient (%) (as is basis)	Diet		Feces*	
	Control	MCP-2	Control	MCP-2
Fish meal 60%	18.00	18.00		
Soybean meal 44%	36.00	36.00		
Corn gluten meal	3.00	3.00		
Wheat flour	37.00	35.00		
Fish oil	3.00	3.00		
MCP	—	2.00		
Methionine	0.10	0.10		
Lysine	0.10	0.10		
Vit. mix**	1.00	1.00		
Min. mix**	0.50	0.50		
Antioxidant	0.03	0.03		
Salt	0.02	0.02		
Choline 50%	0.25	0.25		
Cr ₂ O ₃	1.00	1.00		
Chemical composition (g/100 g, dry matter basis)				
Crude protein	38.97	39.79	13.43	13.47
Crude lipid	5.39	6.13	1.13	1.00
Crude fiber	2.56	3.18	nd	nd
Crude ash	8.76	10.16	18.62	23.10
Ca	2.80	3.27	5.75	7.80
P	1.46	2.04	3.13	4.55

* Values are the means of 3 groups with 3 determinations of each group; nd = not determined.

** Provided by Korea Special Feed Mill Co., specifications unknown.

TABLE 2. GROWTH PERFORMANCES OF CARP FED TWO EXPERIMENTAL DIETS FOR 4 WEEKS*

Diet	Initial wt. (g/fish)	Wt. gain (g/fish)	Feed intake (g, DM/fish)	FCR	PER	DGI
Control	207.8±0.51	62.4±7.13	149.3±0.28	2.46	1.07	1.93
MCP-2	207.7±0.90	129.2±2.39	155.1±0.74	1.20	2.09	3.70

* Values are the means±s.e. of 3 groups; FCR = feed conversion ratio (feed intake, DM/wet weight gain); PER = protein efficiency ratio (wet wt. gain/protein intake); DGI = daily growth index (refer to text).

by the MCP in the diet. The control diet used in this present study was formulated using soybean meal and wheat flour, and the level of dietary fish meal was kept at only 18%. Therefore, it was generally expected that fish fed the diet do not grow well. However, it was extremely surprising that the addition of only 2% MCP exerted such an improving effects on growth and feed utilization. The present results suggest that the availability of P in commercial diet should be reconsidered for an economical point of view, though whether or not the similar results could

be obtained from the same experiment remains to be demonstrated.

Based on the phosphorus availabilities by carp (Ogino et al., 1979) of fish meals P (20%), phytate-P (20%) and MCP (94%), calculated available P level was 0.2 and 0.6% for control and MCP-2 diets, respectively. From these calculated data, the diet MCP 2 seemed to meet the P requirement by NRC (1983). Although the dietary P need (0.6-0.7%) for carp established by Ogino and Takeda (1976) was not demonstrated by any other investigators since then,

growth performances of fish fed the diet MCP-2 in this experiment showed a good reliability with their report.

In general, commercial diet for carp grower includes about 20 to 40% fish meals as an animal protein source, which, in turn, cause an increase in total P in the diet. While fish meals are good source of essential amino acids and fatty acids, the availability of their P in them is negligible by carp (Yone and Toshima, 1979). In a study on nutrient loading into water by carp feeding, Kim (1991) reported that the P availability was near to 0% for all the tested commercial carp diets. His result confirmed a lack of available P sources such as MCP in commercial diets.

Digestibility of nutrients

The apparent digestibility coefficients (ADCs) of dietary nutrients in two diets (table 3) were similar. The ADC of dry matter was relatively low, which were 58 and 60% for control and MCP-2 diets, respectively. This results would be due to the low ADC of total carbohydrates which was just around 37%. This value was even lower than that by Kirchgeßner et al. (1986) who reported that total carbohydrates fraction (nitrogen free extractions and crude fiber), rich in crude fiber, could be digested up to 65%. Although the diets were dry-pelleted, the ADC value of total carbohydrates in the present study seemed to be lower than it was expected, especially

considering the carp which were able to digest about 85% of the starch when it made up from 19 to 48% of diet (Chiou and Ogino, 1975). However, such low ADC value might be different when the value were separated into those of fiber and nitrogen-free extracts, because fibrous matter are the major component in dried feces (Kim, 1993). On the other hand, ash digestibility was higher (10%) for control diet than that (8%) for MCP-2 diet, suggesting a negative relation between dietary ash level and its digestibility (Kim, 1989).

The ADCs of dietary protein and lipid were up to 85 and 90%, respectively, for all treatments. Most animal protein sources appear to be highly digestible by carp (NRC, 1983) and also carp digest over 90% of dietary oils such as soybean oil and fish liver oil (Takeuchi, 1979). Kirchgeßner et al. (1986) reported about 83% protein digestibility by carp depending on the protein sources. Although carp can digest up to 95% of crude protein in fish meals, this value could be decreased to 80-85% due to their origin, processing method and the inclusion level in the diet (Ogino and Chen, 1973). Kim (1991) reported 86-89% protein digestibility of commercial carp diets according to the total collection method. In spite of differences in feed composition, ingredient level and/or feces collecting method, these data are in good accordance with the present result.

TABLE 3. APPARENT DIGESTIBILITY COEFFICIENTS (%) OF TWO EXPERIMENTAL DIETS*

Diet	Dry matter	Protein	Lipid	TCHO**	Ash
Control	57.68±0.76	85.40±0.59	91.09±1.34	36.20±0.62	10.02±1.12
MCP-2	59.46±0.95	86.29±0.15	93.32±1.31	37.70±2.01	7.90±1.42

* Values are the means±s.e. of 3 groups.

** Total carbohydrates calculated (fiber + nitrogen-free extracts).

Phosphorus discharge

Phosphorus discharge and availability based on retained P in whole body of carp fed the two diets are shown in table 4. Fish fed control diet recorded a zero gain of P in their body, while 9 g of P per kg weight gain were retained in fish fed the diet MCP-2. Although the level of P in control diet was lower than that in the other diet, the difference in weight gain between two treatments (table 2) resulted in more consumption

of P by fish fed control diet. From this result, it was calculated that all the consumed P (34.9 g/kg wt. gain) for control groups were discharged. However, the value for fish fed the diet MCP-2 was less than a half (15.5 g/kg wt. gain) of that for control group. The calculated availability of dietary P for the diet MCP-2 was 37%.

As mentioned earlier, carp have low digestibility of P in fish meals and phytate-P occurred in plant protein sources. Due to this fact, it could

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TABIF 4. PHOSPHORUS DISCHARGE BASED ON RETAINED P IN WHOLE BODY OF CARP FED TWO EXPERIMENTAL DIETS*

Diet	P in diet (g/100 g, DM)	P (g) per kg weight gain			Availability of dietary P (%)
		Fed	Retained	Discharged	
Control	1.46	34.93	0.00	34.93	0.0
MCP-2	2.04	24.53	9.08	15.45	37.0

* Values are the means of 3 groups.

be inferred that P discharge per unit production from feeding carp would exceed that from feeding carnivorous fish such as trout or eel, because the latter digest P in fish meals much more than carp. Wiesmann et al. (1988) reported that the amount of P discharge by feeding rainbow trout with different commercial diets was ranged from 3.9 to 18.8 g/kg wt. gain. These values directly related to dietary P level and feed conversion ratio.

On the other hand, P discharge from feeding carp reported by Watanabe et al. (1987) was ranged from 18.3 to 31.3 g for four experimental diets and 19.8 g/wt. gain for a commercial diet. These values did not show a consistent relationship with dietary P level or feed efficiency. Differently from the method used by the researchers who analyzed P retention in whole body, Kim (1991) determined P discharge by subtracting P output from P intake through total feces collection and reported almost all the P fed were discharged (18.3 g to 28.1 g/kg wt. gain) from four tested commercial diets. Since the growth rate was not significantly different among treatments in his experiment, the amount of P discharged was directly related to the dietary P level. Although P output was calculated by analyzing P gain in whole body in the present study, all the P fed were discharged in control groups. However, the P discharge by feeding diet MCP-2 was decreased to less than a half of the amount by control feeding. This result demonstrated that P discharge could be more reduced by improving feed efficiency (Matty, 1990; Lall, 1991; Ketola, 1991), suggesting the importance of a satisfying P requirement by MCP supplementation.

In the natural environment, the phosphorus content of freshwater and seawater varies widely from 0.02 to 0.6 mg/L (Almazov et al., 1967, cited from Lall, 1991). Recently, water pollution caused by phosphorus discharge from fish farming

are widely recognized (Enell, 1987; Folke and Kautsky, 1989; Persson, 1991). Phosphorus is required for the development and maintenance of the skeletal system and in several physiological processes (NRC, 1983). However, the unutilized release of P such as from uneaten feed and excreta in fish farms causes water pollution, as this element acts as the first limiting factor for algal growth (Aizaki et al., 1984; Auer et al., 1986). Therefore, fish feed should contain the least possible level of phosphorus with ingredients having high P availability in order to achieve optimum growth and reduce P output.

In this context, the present results suggested that P requirement can be satisfactorily met by MCP supplementation to diet for optimal growth and prevention of water pollution. Although the level of dietary total P should be reduced to the requirement level as close as possible, more considerations should be given to the improvement of feed efficiency. Today, the use of antipollution diet in fish farming practices is more and more recommended throughout the world (Matty, 1990). To keep up with this kind of step in Korea and to urgently develop low-pollution diet for carp, a numerous studies like present experiment should be more than conducted.

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