魚類における無機質の要求に関する研究2

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Mineral Requirements in Fish—II
Magnesium Requirement of Carp

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Magnesium deficiency in carp was found to produce a loss of appetite, poor growth, high mortality, sluggishness and convulsions. The minimal requirement of young carp for magnesium was 0.04 to 0.05% of a dry diet or 12 to 15 mg per kg body weight per day under the experimental conditions. The magnesium content of vertebrae from carp fed diets containing low magnesium decreased significantly while the calcium content increased slightly. Thus, the values for Ca/Mg of the vertebrae were changed by the dietary magnesium level.

The roles of magnesium in metabolism and nutrition of higher animals have been well established. Up to date, however, the requirement of magnesium in fish is not made clear.

The present studies were undertaken to elucidate the requirement and the deficiency symptoms of magnesium in carp, *Cyprinus carpio*. The results obtained demonstrated that magnesium is one of the essential dietary minerals and its dietary deficiency results in the development of a high mortality, loss of appetite, poor growth, sluggishness and convulsions.

Materials and Methods

First, the experiment designed to demonstrate the dietary indispensability and deficiency symptoms of magnesium in carp was carried out in duplicate feeding trials. Secondly, the experiment planed to determine the dietary requirement of magnesium was performed.

The composition of the test diet is shown in Table 1. The salt-mixture used was McCOLLUM no. 185[1] fortified with trace elements.[2] The content of magnesium in the diets was regulated by replacing magnesium sulfate in the salt-mixture with a mixture of equal weight of anhydrous sodium sulfate and potassium sulfate.

In the first experiment, the vitamin-free casein was washed with 1% acetic acid, distilled water and finally with alcohol to remove contaminated magnesium. In the second experiment, these treatments of casein were not carried out.

Carp averaging 2.8 g in body weight were used in the first experiment and 8.5 g in the second experiment. Fish were previously fed on the casein-diet containing 4% of

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Table 1. Composition of the test diet*2

Casein (vitamin-free)	45%
α-Starch	20
Dextrin	20
Cellulose	4
Soybean oil	2
Cod liver oil	3
Vitamin mixture	2
Salt mixture*1	4

*1 McCollum salt-mixture no. 185 fortified with trace elements.[2)]

*2 Dietary magnesium levels were adjusted by replacing magnesium sulfate in the salt-mixture with a mixture of sodium sulfate and potassium sulfate (1 : 1).

the salt-mixture[2)] and acclimatized to the experimental conditions. Feeding trials were conducted under conditions of aerated, running dechlorinated city water (15 *l*/h). Water temperature fluctuated 25 to 27°C in the first experiment and 18 to 25°C in the second experiment. Fish were fed 5 times daily, 6 days a week on a rigid schedule. Diets in dry pellet form were offered as long as the fish continued to feed.

Analyses of calcium and magnesium were made with a Hitachi model 208 atomic absorption spectrophotometer and that of phosphorus by the method of LOWRY and LOPEZ.[3)]

The experimental rearing water contained 15 ppm calcium and 3.5 ppm magnesium.

Results and Discussion

Results of the first experiment are shown in Table 2. The diets deficient in magnesium and of the control contained 5.2 mg and 63 mg of magnesium in 100 g, respectively. As shown in the table, the fish received the low magnesium diet showed a retarded growth and a high mortality as compared with those of the control fish. After 2 weeks of feeding, the fish fed on the magnesium-deficient diet lost appetite conspicuously and became sluggish. As a period of the feeding progressed, many of the magnesium-deficient fish showed convulsions occasionally and increased a number of dead fish. It is of interest that young

Table 2. Results of feeding trials with the magnesium-deficient and control diets*

Experimental group	Magnesium content in diet	No. of fish	Average weight		Growth rate	Mortality	Feed efficiency
			at start	at end			
	mg/100 g		g	g	%	%	
Mg-deficient	5.2	32	2.8	6.6	136	9.4	1.1
Mg-deficient	5.2	32	2.8	6.3	125	15.6	1.0
Control	63.0	32	2.9	7.3	152	0	1.3
Control	63.0	32	2.7	7.1	163	0	1.4

* Feeding trials were conducted from Aug. 9th to Sept. 5th, 1973, at a water temperature of 25 to 27°C.

carp exhibit characteristic deficiency symptoms of magnesium within a relatively short period of the feeding irrespective of the presence of magnesium in the environmental water. These results indicate that carp cannot absorb sufficient amount of magnesium from the rearing water to meet their requirement. Under the laboratory conditions, the most striking symptoms of the magnesium deficiency were a high mortality, loss of appetite, poor growth, sluggishness and convulsions.

In the second experiment, carp were fed on the diets containing graded amounts of magnesium during a period of 4 weeks. The results of the feeding trials are shown in Table 3.

Table 3. Results of feeding trials with diets containing different amounts of magnesium*

Magnesium content in diet	No. of fish	Average weight		Growth rate	Feed efficiency	Mortality
		at start	at end			
mg/100 g		g	g	%		%
8	10	8.4	16.2	93	0.98	0
21	10	8.2	17.8	117	1.1	0
37	10	8.7	20.8	139	1.3	0
51	10	8.4	19.7	135	1.3	0
83	10	8.9	19.0	113	1.1	0
99	10	9.0	20.1	123	1.2	0

* Feeding trials were conducted from Sept. 25th to Oct. 22th, 1973, at a water temperature of 18 to 25°C.

It has been reported that in higher animals the requirements for magnesium are influenced by the phosphorus, calcium and protein contents in the diet.[4-9] The composition of diets used in the present studies was 0.64% phosphorus, 0.34% calcium and 45% of casein. As shown in the table, the weight gain of the fish achieved the maximum at 0.037% of dietary magnesium. Tables 4 and 5 show the mineral composition of the whole body and the vertebrae, respectively. The relationship between dietary magnesium levels and the mineral composition of the vertebrae is shown in Fig. 1. Dietary magnesium levels affected significantly the magnesium contents of the whole body and the vertebrae. In the vertebrae, the calcium content was also affected by the dietary magnesium levels. At dietary magnesium levels below 0.037%, the magnesium content in the vertebrae decreased significantly and the calcium content increased slightly. These results postulate the possibility of calcification in the soft tissues. On the other hand, phosphorus content in the vertebrae was not affected by the dietary magnesium levels (Fig. 1).

As dietary magnesium levels affected the magnesium and calcium contents of the vertebrae, the values for Ca/Mg changed significantly by the dietary magnesium levels. The high values for Ca/Mg at low magnesium levels decreased with increasing the dietary magnesium levels and reached a constant value of around 50 at 0.037%. This

Table 4. Mineral composition of the whole body (% on dry basis)*

Magnesium content in diet	Ash	Ca	P	Mg	Ca/Mg
mg/100 g					
8	10.8	2.5	2.0	0.088	28
21	9.2	2.0	1.8	0.086	23
37	10.5	2.5	2.1	0.114	22
51	9.8	2.2	1.9	0.109	20
83	9.8	2.3	1.9	0.110	21
99	10.5	2.5	2.0	0.117	21

* Composition at start: Ash, 11.4; Ca, 2.8; P, 1.9; Mg, 0.127; Ca/Mg, 22.

Table 5. Mineral composition of the vertebrae from fish fed diets containing graded amounts of magnesium (% on dry basis)*

Magnesium content in diet	Ash	Ca	P	Mg	Ca/Mg
mg/100 g					
8	37.4	13.4	6.6	0.156	86
21	36.4	12.5	6.5	0.161	78
37	37.6	13.0	6.8	0.248	52
51	36.8	12.5	6.8	0.252	50
83	35.3	12.5	6.7	0.257	49
99	37.3	12.5	6.2	0.261	48

* Composition at start: Ash, 34.9; Ca, 11.8; P, 6.4; Mg, 0.225; Ca/Mg, 52.

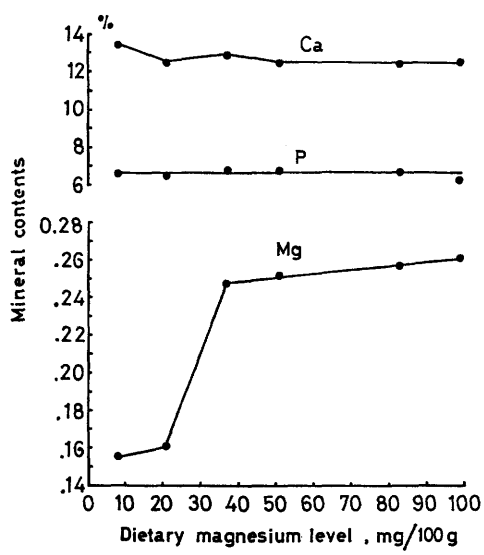

Fig. 1. Relationship between dietary magnesium levels and calcium, phosphorus, and magnesium contents of the vertebrae. Basal diet contains 0.34% calcium and 0.64% phosphorus. Values indicate % on dry basis.

magnesium level coincided well with that for the maximum growth of the fish.

Judging from the growth rate, values for Ca/Mg of the vertebrae and activities of the experimental fish, the minimal magnesium requirement of young carp is considered to be 0.04 to 0.05% of the dry diet under the present experimental conditions. It has been reported that the magnesium requirement of farm animals for growth is of the order of 0.06% of the dry ration, assuming that the calcium and phosphorus intakes are adequate but not excessive.[10] The phosphorus content of the diets used in the present studies is the adequate range for carp (unpublished data), thus there is no great difference in the magnesium requirements between carp and farm animals. In the present experiment, the amount of diet given to the fish was 3% of the total weight in average, hence the amount of magnesium required by carp is 12 to 15 mg per kg body weight per day. It remains still unknown, however, that whether magnesium content in the rearing water affects the requirement for this element of carp or not.

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