コイ稚魚による各種魚粉中Mnの利用性

誌名	日本水産學會誌
ISSN	00215392
著者	佐藤, 秀一 井爪, 一宏 竹内, 俊郎 渡辺, 武
巻/号	55巻2号
掲載ページ	p. 313-319
発行年月	1989年2月

Nippon Suisan Gakkaishi 55(2), 313-319 (1989)

Availability to Carp of Manganese Contained in Various Types of Fish Meals*1

Shuichi Satoh,*2 Kazuhiro Izume,*2 Toshio Takeuchi,*2 and Takeshi Watanabe*2

(Received July 22, 1988)

A feeding experiment was conducted to examine availability of manganese (Mn) contained in various types of fish meals (white fish meal, brown fish meal, and sardine meal with or without soluble). Fingerling carp weighing 4.3 g in average were fed diets containing one of four kinds of fish meals as a sole protein source with different levels of supplementary Mn for 11 or 24 weeks at water temperature of 15–25°C. Growth and feed efficiency were poor in fish receiving the diet without supplementation of Mn in every kind of fish meal diet groups, and were effectively imporved by addition of Mn and reached a plateau when supplementation of Mn together with Mn in each fish meal at a level met the Mn requirement of carp.

Thus the content of Mn in the diets derived from various types of fish meals is not sufficient without supplementary Mn for normal growth of carp, judging from the fact that feeding diets containing various fish meals as protein source without supplementary Mn induced poor growth, short body dwarfism and reduced Mn levels in vertebrae. The results have also shown that bioavailability to carp of Mn contained in different kinds of fish meals is very high, and is not affected by the content of tricalcium phosphate in diet.

In a previous study,[1,2] the lowest growth and the highest rate of appearance of dwarfism were observed in the fish receiving a diet without supplementary Mn (No-Mn diet) and were effectively improved by adding Mn at a level more than 10 μg/g diet in a form of $MnSO_4$ or $MnCl_2$. No-Mn diets used in these experiments contained 2–3 μg of Mn/g diet derived mostly from white fish meal, and addition of 10 μg of Mn to the diets, namely 12–13 μg of Mn in total which is equivalent to the Mn requirement of carp,[3] resulted in satisfactory performance. This result indicated a high availability of Mn in white fish meal to carp. Satoh *et al.*[4] also examined the availability of zinc (Zn) contained in various types of fish meals using rainbow trout. The availability of Zn in fish meal to rainbow trout was found to be affected by the content of tricalcium phosphate which reduced absorption of Zn in diet.[5,6]

Thus, following the previous experiments this study was conducted to examine availability of Mn to carp contained in various types of fish meals containing different levels of Mn and tricalcium phosphate. For this purpose four kinds of fish meals (white fish meal, brown fish meal and sardine meal with or without soluble (sardine whole meal, sardine ordinary meal)) were prepared. Carp were fed diets containing one of these fish meals as a sole protein source with or without supplementary Mn for 11 or 24 weeks.

This paper deals with these results.

Materials and Methods

Fish Meal and Experimental Diet

The availability of Mn in three kinds of fish meals (brown fish meal, sardine ordinary meal, and sardine whole meal) was compared with that of white fish meal. Proximate and mineral compositions as well as preparation of four kinds of fish meals were the same as those described in the previous paper.[4]

Composition of the experimental diets and the combination of fish meal and supplementary Mn levels are shown in Tables 1 and 2. White fish meal was used as a protein source for diets 1–3, brown fish meal for diets 4–6, sardine ordinary meal for diets 7–9, and sardine whole meal for diets 10–12, respectively. Diets 1, 4, 7 and 10

*1 Mineral Nutrition in Fish-XXIII.

*2 Fish Nutrition Laboratory, Tokyo University of Fisheries, Konan, Minato, Tokyo 108, Japan (佐藤秀一, 井爪一宏, 竹内俊郎, 渡辺　武: 東京水産大学水族栄養学研究室).

Table 1. Composition of the experimental diets used for carp (%)

Ingredient	Diet no.			
	1–3	4–6	7–9	10–12
White fish meal	55	—	—	—
Brown fish meal	—	52.5	—	—
Sardine meal without soluble	—	—	56.4	—
Sardine meal with soluble	—	—	—	50.7
α-Starch	20	20	20	20
Dextrin	10	10	10	10
Mineral mixture*1	5	5	5	5
Vitamin mixture	1.5	1.5	1.5	1.5
Choline chloride	0.5	0.5	0.5	0.5
Cellulose	3	7	2.4	8
Lipid*2	5	4.5	4.2	4.3

*1 Ogino salt mixture without Mn.[7]
*2 Soybean oil: pollock liver oil=3: 2, containing 1% of DL-α-tocopheryl acetate.

Table 2. Combination of the fish meal and supplementary levels of Mn

	Control*1	No-Mn*2	Min. Sup. Mn*3
White fish meal	diet 1	diet 2	diet 3
Brown fish meal	diet 4	diet 5	diet 6
Sardine meal without soluble	diet 7	diet 8	diet 9
Sardine meal with soluble	diet 10	diet 11	diet 12

*1 The diet with a complete mineral mixture.[7]
*2 The diet without supplementary Mn.
*3 The diet with supplementary Mn at a level which meets the Mn requirement of carp in total together with Mn derived from fish meal.[2]

with a supplementation of the mineral mixture at a level of 5% in diet[7] which satisfies mineral requirement of carp were arranged as the control diet for each fish meal group. Mn was deleted from the mineral mixture in diets 2, 5, 8 and 11. Mn in the form of $MnSO_4$ was added to diets 3, 6, 9 and 12 up to the levels which satisfy the Mn requirement of carp in total together with Mn derived from the respective fish meal, in order to determine the availability of Mn in each fish meal.

Proximate and mineral compositions of the experimental diets are shown in Table 3. There were no marked differences in crude protein (about 38%) and lipid (about 9%) contents in all experimental diets. Crude ash, calcium(Ca) and phosphorus(P) contents were affected with kind of fish meal used, highest in the white fish meal diets, medium in the brown fish meal diets or the serdine whole meal diets, lowest in the sardine ordinary meal diets. Zn content of these diets was highest in the sardine ordinary meal diets, and lowest in the white fish meal based diets. Mn content in the diets without supplementary Mn represented the Mn content in each fish meal, being lowest in the white fish meal diet, and highest in the sardine ordinary meal diet. Diets 3, 6, 9 and 12 contained about 15 μg of Mn per g diet in total which was derind from supplementary Mn and Mn in the meals and were enough to satisfy the Mn requirement of carp. Potassium(K) content was low in the white fish meal diet and sardine ordinary meal diets, and high in both brown fish mealdiets and sardine whole meal diets.

Feeding and Chemical Analyses

Fingerlings of carp (*Cyprinus carpio*) weighing 4.3 g in average were used as the experimental animals. Carp were obtained from Sankyo Suisan Co., Ltd. They were fed a commercial diet for 3 months and then divided into 12 lots of 30 fish each and fed the experimental diets shown in Tables 1 and 2 at water temperature of 15–25°C for 11 weeks. Feeding of the fish on diets 1 to 6 was extended unto 24 weeks in order to compare results with those of the previous study with carp.[2] Preparation of analytical samples and analytical conditions for minerals in the test diets and fish vertebrae were the same as those described previously.[2,8]

Results and Discussion

Growth

Results of the feeding experiment for 11 weeks and the effect of dietary Mn levels on grouth were

Table 3. Proximate and mineral compositions of the experimental diets used for carp

	Diet no.*											
	1	2	3	4	5	6	7	8	9	10	11	12
	White fish meal			Brown fish meal			Sardine meal without soluble			Sardine meal with soluble		
	Control	No-Mn	Min. sup. Mn	Control	No-Mn	Min. sup. Mn	Control	No-Mn	Min. sup. Mn	Control	No-Mn	Min. sup. Mn
Moisture (%)	5.0	4.6	6.2	7.2	8.6	7.3	8.8	8.6	7.4	8.8	8.4	7.9
Crude protein (%)	40.2	39.1	37.5	37.7	37.5	36.9	40.9	42.6	40.4	36.4	36.4	36.2
Crude lipid (%)	9.1	10.0	9.4	10.2	9.5	10.5	8.2	8.8	8.9	9.9	9.7	10.2
Crude ash (%)	15.5	15.3	15.0	12.2	12.7	11.7	11.7	12.2	11.4	10.8	11.5	10.9
K (mg/g)	7.6	7.0	7.0	11.0	11.5	12.2	6.1	6.1	6.5	9.3	10.1	9.5
Na (mg/g)	6.9	6.5	6.6	6.7	6.7	6.6	4.2	3.9	3.9	7.0	6.8	7.1
Ca (mg/g)	31.7	32.3	30.9	19.7	19.5	19.4	12.7	13.3	12.6	17.5	18.1	16.9
Mg (mg/g)	2.2	2.0	2.0	1.9	1.8	1.8	1.8	1.8	1.7	1.7	1.8	1.8
P (mg/g)	27.6	27.2	26.3	21.8	21.1	19.8	20.7	23.9	21.9	19.3	19.7	19.7
Zn (μg/g)	66.2	72.3	70.3	98.2	96.2	98.7	114.3	116.2	113.3	85.7	99.2	99.3
Mn (μg/g)	28.4	4.0	14.5	29.9	6.0	15.9	29.9	7.5	15.5	28.9	6.0	15.9
Cu (μg/g)	6.8	6.9	6.8	9.2	9.6	10.2	9.3	10.0	11.6	9.2	10.0	9.6
Fe (μg/g)	308.7	310.9	308.9	418.2	427.3	429.9	437.3	424.1	449.6	380.8	396.3	420.8

* See Table 2.

Table 4. Effect of supplementary Mn levels in four kinds of fish meal diets on growth, feed efficiency and appearance of dwafism in carp (11 weeks)

Diet no.	Kind of meal*1	Supple-mentary Mn*2	Av. body wt. (g)		Growth rate (%)	Feed effi-ciency*3	Dwar-fism (%)
			Initial	Final			
1	WFM	Control	4.3	41.2	857	1.11	0
2	WFM	No-sup. Mn	4.3	33.7	691	0.92	21
3	WFM	Min. sup. Mn	4.3	41.0	853	1.00	0
4	BFM	Control	4.3	38.0	796	1.00	0
5	BFM	No-sup. Mn	4.4	30.0	608	0.93	11
6	BFM	Min. sup. Mn	4.2	37.6	778	1.05	0
7	SM−Sb.	Control	4.4	34.4	682	0.87	0
8	SM−Sb.	No-sup. Mn	4.3	30.6	585	0.83	11
9	SM−Sb.	Min. sup. Mn	4.4	34.4	682	0.93	0
10	SM+Sb.	Control	4.2	36.0	765	1.04	0
11	SM+Sb.	No-sup. Mn	4.2	29.9	605	0.94	14
12	SM+Sb.	Min. sup. Mn	4.4	36.0	720	0.98	0

*1 Abbreviation: WFM, white fish meal; BFM, brown fish meal; SM-Sb., sardine meal without soluble; SM+Sb., sardine meal with soluble.
*2 See Table 2.
*3 g gain/g feed.

Table 5. Effect of supplementary Mn levels in two kinds of fish meal diets on growth, feed efficiency and appearance of dwarfism in carp (24 weeks)

Diet no.	Kind of meal*	Supple-mentary Mn*	Av. body wt (g)		Growth rate (%)	Feed effi-ciency*	Dwar-fism (%)
			Initial	Final			
1	WFM	Control	4.3	227.1	5194	1.15	0
2	WFM	No-sup. Mn	4.3	131.2	2979	0.94	61
3	WFM	Min. sup. Mn	4.3	215.8	5065	1.18	0
4	BFM	Control	4.4	189.2	4249	1.11	0
5	BFM	No-sup. Mn	4.3	126.5	2883	0.98	60
6	BFM	Min. sup. Mn	4.2	170.4	3880	1.09	0

* See Table 4.

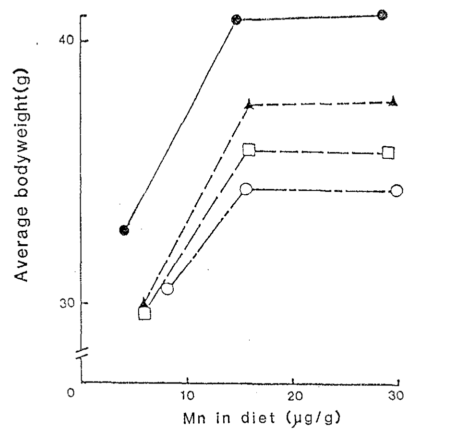

Fig. 1. Effect of supplementary Mn levels in four kinds of fish meal diets on growth of carp (11 weeks).

shown in Table 4 and Fig. 1, respectively. The low growth was obtained in fish receiving the diet without supplement of Mn in each fish meal diet group, and was effectively improved by addition of Mn and reached a plateau by supplement of Mn at a level to satisfy Mn requirement in total together with Mn in each fish meal. Among the control groups the growth of fish fed the white fish meal diet was highest and medium in fish fed the brown fish meal diet and the sardine whole meal diet, but lowest in fish fed the sardine ordinary meal diet. These results are in good agreement with the previous experiment with rainbow trout. The difference in growth response among different fish meal groups might be caused by the difference in protein quality of each fish meal in terms of net protein utilyzation.[9-11] Feed efficiency was also lowest in fish receiving the diet without supplementation of Mn in each fish meal diet group, and was effectively improved by sup-

Table 6. Effect of supplementary Mn levels in four kinds of fish meal diets on mineral compositions of vertebrae from carp at the 11th week

	Diet no.*											
	1	2	3	4	5	6	7	8	9	10	11	12
	White fish meal			Brown fish meal			Sardine meal whithout soluble			Sardine meal with soluble		
	Control	No-Mn	Min. sup. Mn	Control	No-Mn	Min. sup. Mn	Control	No-Mn	Mni. sup. Mn	Control	No-Mn	Min. sup. Mn
Crude ash (%)	53.1	53.8	53.0	52.2	53.2	53.8	51.6	52.2	50.0	52.2	51.5	52.3
K (mg/g)	3.9	4.2	4.1	4.3	4.2	4.1	4.0	4.1	4.7	4.3	4.6	4.7
Na (mg/g)	2.6	2.2	2.9	2.6	2.5	2.6	2.5	2.1	2.3	2.6	2.5	2.4
Ca (mg/g)	191.2	187.0	184.5	196.3	186.0	193.6	190.6	190.3	195.4	192.3	188.6	188.7
Mg (mg/g)	3.5	4.0	3.8	3.5	3.7	4.0	3.4	3.5	3.7	4.0	3.7	3.7
P (mg/g)	108.3	103.7	106.7	108.7	106.6	110.2	105.4	103.2	109.2	111.4	107.5	106.5
Zn (μg/g)	117.3	122.4	157.7	148.1	164.9	136.3	143.3	164.3	158.7	168.1	147.9	151.6
Mn (μg/g)	1.9	0.8	1.9	1.8	1.0	1.4	1.9	0.9	1.7	1.9	1.1	1.4
Cu (μg/g)	4.6	4.3	7.8	4.1	4.6	4.3	5.0	5.0	5.2	3.7	3.7	2.9
Fe (μg/g)	23.9	19.0	25.2	25.4	28.3	28.5	28.0	39.9	13.3	14.9	22.0	31.0

* See Table 2.

plementation of Mn.

Short body dwarfism was recognized in fish fed diets without supplementary Mn, as observed in the previous experiment with rainbow trout. The highest rate of appearance of dwarfism was observed in the fish receiving the white fish meal diet without supplementary Mn, and the symptom was also severest in this group due to the lowest content of Mn in the white fish meal. The symtom was found to be effectively prevented by addition of Mn up to the level which satisfies Mn requirement of carp together with Mn in the meal.

Results of 24-week feeding experiment for the white fish meal and brown fish meal groups are shown in Table 5. The same tendency as the 11-week feeding was observed in the results of 24 weeks feeding. The growth was lowest in fish receiving the diet without supplementation of Mn either the white fish meal or the brown fish meal group, and was improved by supplementing Mn up to the level of Mn requirement of carp. Feed efficiency was also tended to be the result of the 11th week. The rate of appearance of dwarfism in fish fed the diet without supplementation of Mn increased as extending feeding feeding period from 11 to 24 weeks. The appearance of dwarfism was also completely prevented by addition of the same amount of Mn mentioned above.

Mineral Composition of Vertebrae

Mineral composition and Mn content of vertebrae from carp after 11 weeks of feeding were shown in Table 6 and Fig. 2, respectively. Mn content was low in fish receiving the diet without

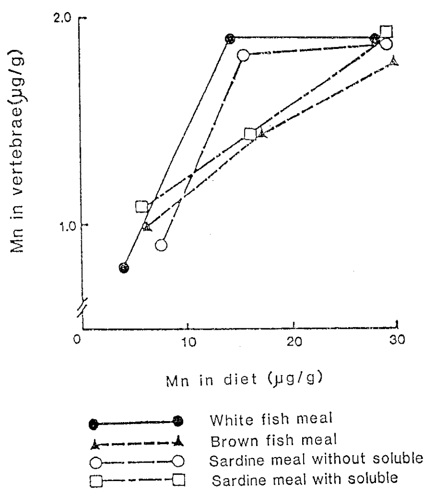

Fig. 2. Effect of supplementary Mn levels in four kinds of fish meal diets on Mn content in vertebrae of carp (11 weeks).

Table 7. Effect of supplementary Mn levels in two kinds of fish meal diets on mineral compositions of vertebrae from carp at the 24th week

	Diet no.*					
	1	2	3	4	5	6
	White fish meal			Brown fish meal		
	Control	No-Mn	Min. sup. Mn	Control	No-Mn	Min. sup. Mn
Crude ash (%)	56.1	54.8	55.4	55.8	53.9	56.4
K (mg/g)	4.1	3.8	4.4	3.8	3.1	3.2
Na (mg/g)	4.1	3.1	3.3	3.5	3.5	3.3
Ca (mg/g)	182.5	190.1	189.0	186.3	182.7	197.5
Mg (mg/g)	3.2	3.1	3.3	3.1	2.7	3.4
P (mg/g)	88.5	93.0	91.6	91.9	87.9	97.0
Zn (μg/g)	104.9	104.5	101.7	142.8	143.7	136.2
Mn (μg/g)	1.1	0.3	1.1	1.1	0.2	0.6
Cu (μg/g)	1.5	1.8	1.6	3.3	3.3	2.7
Fe (μg/g)	9.7	14.5	7.2	10.7	7.5	9.7

* See Table 2.

supplementary Mn in each fish meal diet group, especially lowest in the white fish meal diet group, reflecting the low dietery Mn content (Table 3). As increasing dietary Mn levels, the Mn content in vertebrae increased. The Mn content in the fish fed the white fish meal diet or the sardine ordinary meal diet reached a plateau by adding Mn (8–10 μg/g diet) to the level enough to satisy the Mn requirement of carp (13 μg/g diet) in total together with Mn derived from the meals. However, the content in the fish fed the brown fish meal diet or the sardine whole meal diet could not reach a plateau by adding the same amount of Mn mentioned above, and addition of 20 μg/g Mn was required to give the same level of Mn retention as the fish fed the white fish meal diet or the sardine ordinary meal diet. K content in the white fish meal diets and the sardine ordinary meal diets was lower than that of the brown fish meal diets or the sardine whole fish meal diets, suggesting a relationship between dietary K content and the Mn content of vertebrae as observed in rainbow trout.[4] There was no marked difference in the content of other minerals.

Mineral composition of vertebrae from carp after 24 weeks of feeding is shown in Table 7. In either the white or brown fish weal group, Mn conents of vertebrae in fish fed the diet without supplementary Mn were extermely low, the same as the result of the 11th week. When dietary Mn level was raised, the Mn content increased. The Mn level in the vertebrae in the fish fed the white fish meal diet reached a plateau by adding Mn to the level of the Mn requirement of carp. However, the level of fish fed the brown fish meal diet was lower than that of the white fish meal group at the same level of Mn to satisfy the requirement, and reached the same Mn level as the fish fed the white fish meal diet by supplementation of 20 μg/g of Mn.

These results obtained in this study clearly indicated that the content of Mn in the diets derived from various types of fish meals is not sufficient without supplementary Mn for normal growth of carp, judging from the fact that feeding diets containing various fish meals as protein source without supplementary Mn induced poor growth, short body dwarfism and reduced level of Mn in vertebrae. The poor growth response accompanied with dwarfism and the reduced Mn level in vertebrae was effectively improved by addition of Mn. The growth and the Mn level in the vertebrae reached a plateau when the Mn content in the diet reached the level to satisfy Mn requirement of carp by the sum of Mn from both supplementary Mn and Mn in the meals. These results have demonstrated that bioavailability to carp of Mn contained in the fish meals used in this experiment is very high. Gatlin and Wilson[12] reported that 2.4 μg of Mn/g diet supplied by the basal diet was apparently sufficient to sustain good growth and feed conversion efficiency in channel catfish, however bone Mn content increased almost linearly with increasing dietary Mn levels. Satoh *et al.*[13,14] and Knox *et al.*[15] also reported that the basal diet consisted of white fish meal or casein without supplementary Mn (3–4 or 1.3 μg/g) did not induce poor growth in rainbow trout, but resulted in a low level of Mn in vertebrae.

Thus bioavailability to carp of Mn contained in different kinds of fish meals was found to be very high, and was not affected by the content of tricalcium phosphate in diet, quite different from the case of Zn whose availability to rainbow trout[4-6] is greatly influenced by the tricalcium phosphate content in diet. This may be due to the absence of stomach in carp which can not dissolve tricalcium phosphate, leading to few interaction between Mn and calcium or phosphate.

Acknowledgements

We express here our sincere thanks to Professor emeritus Y. Yone, Kyushu Univ., who kindly read the manuscript and gave valuable suggestions. Thanks are also due to the Union of North Pacific Purse Seine Fishing for preparation of sardine meal.

References

1) S. Satoh, H. Yamamoto, T. Takeuchi, and T. Watanabe: *Nippon Suisan Gakkaishi*, **49**, 431–435 (1983).
2) S. Satoh, T. Takeuchi, and T. Watanabe: *Nippon Suisan Gakkaishi*, **53**, 825–832 (1987).
3) C. Ogino and G.-Y. Yang: *Nippon Suisan Gakkaishi*, **46**, 455–458 (1980).
4) S. Satoh, K. Izume, T. Takeuchi, and T. Watanabe: *Nippon Suisan Gakkaishi*, **53**, 1861–1866 (1987).
5) R. W. Hardy and K. D. Shearer: *Can. J. Fish. Aquat. Sci.*, **42**, 181–184 (1985).
6) S. Satoh, K. Tabata, K. Izume, T. Takeuchi, and T. Watanabe: *Nippon Suisan Gakkaishi*, **53**, 1199–1205 (1987).
7) C. Ogino, L. Takeuchi, H. Takeda, and T. Watanabe: *Nippon Suisan Gakkaishi*, **45**, 1527–1532 (1979).
8) S. Satoh, T. Takeuchi, and T. Watanabe: *Nippon Suisan Gakkaishi*, **53**, 595–599 (1987).
9) T. Watanabe, H. Nanri, S. Satoh, M. Takeuchi, and T. Nose: *Nippon Suisan Gakkaishi*, **49**, 1083–1087 (1983).
10) K. Toyama, M. Hoshi, Y. Takashima, S. Satoh, T. Takeuchi, and T. Watanabe: *Nippon Suisan Gakkaishi*. **50**, 2065–2075 (1984).
11) S. Satoh, T. Takeuchi, T. Watanabe, M. Hoshi, and K. Toyama: *Nippon Suisan Gakkaishi*, **50**, 2077–2083 (1984).
12) D. Gatlin III and R. P. Wilson: *Aquaculture*, **41**, 85–92 (1984).
13) S. Satoh, H. Yamamoto, T. Takeuchi, and T. Watanbe: *Nippon Suisan Gakkaishi*, **49**, 425–429 (1983).
14) S. Satoh, T. Takeuchi, Y. Narabe, and T. Watanabe: *Nippon Suisan Gakkaishi*, **49**, 1909–1916 (1983).
15) D. Knox, C. B. Cowey, and J. W. Adron: *Br. J. Nutr.*, **46**, 495–501 (1981).