Review on trace minerals Phosphorus and calcium requirements in the aquaculture fish food, intimately connected for growth and metabolism

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Abstract:

Aquaculture is one of the fastest growing food-producing systems in the world. The continuous increase of aquaculture production is expected to meet an increasing demand for fish products in both developing and developed countries. However, aquaculture is expanding in a period of environmental awareness and is, therefore, subject to regulations designed to limit its effect on the environment. In order for world aquaculture production to continue to increase, it will be necessary to reduce discharge of wastes, especially phosphorus (P), from fish farms to the aquatic environment.

Index terms: fish feed**,** Minerals, dietary phosphorus, dietary calcium.

Introduction:

The ultimate source of P in aquaculture effluent is feeds. Any excess P in diet above the minimum requirement for fish will be excreted by the fish. It is, therefore, critical to know precisely the dietary requirement of P in order to minimize excess P in diet without risking P deficiency in cultured fish. The dietary requirement of P has been studied for various fish and other animal species using fry or juveniles and indicators such as weight gain, feed efficiency, P levels in various tissues, bone density, bone-breaking strength and enzyme activities

[1]. Nutrient requirements in most animal species, however, decrease as they become older, because as they age, increasing portions of dietary nutrients including P are used for maintenance. In commercial aquaculture, large fish consume most of the feed used in the production cycle and correspondingly, excrete the largest proportion of waste into effluent. Consequently, knowing the dietary requirement of P specific for large fish is necessary to reduce P excretion from commercial aquaculture systems. Unfortunately, the various indicators listed above are not sensitive for large fish because of their slow growth rate. Feeding large fish with research diets for any extended period is also expensive.

Because of these difficulties, little is known about dietary requirements of P and other nutrients in fish especially those which are euryhaline.

Minerals are inorganic substances required in small amounts for normal growth, health and function. They are classified as macro- or trace minerals. Fish can obtain large quantities of some minerals (e.g., calcium) directly from the water, and a dietary source is usually unnecessary. In addition, many practical feedstuffs are rich in minerals, which reduce the need for synthetic dietary supplements. However, many plant feedstuffs contain minerals in unavailable forms. For example, soybean meal and other plant feedstuffs contain 60-70% of their phosphorus as phytate, which cannot be digested by fish. Phosphorus metabolism is closely tied to that of calcium, but phosphorus is not readily absorbed from the water. Therefore, phosphorus supplementation of diets is important for several reasons. First, commercial feeds contain mostly plant feedstuffs. Secondly, cyprinid fishes (including golden shiners, goldfish and fathead minnows) do not have true stomachs that secrete acid to enhance digestion. Mineral availability from common feedstuffs is known to be lower for some fishes that lack acidic digestion. The dietary phosphorus requirements of the main baitfish species are unknown. However, the requirement for common carp (another cyprinid) is 0.6-0.7% of the diet. These requirements are established using highly available forms of phosphorus (e.g., sodium phosphate monobasic). The phosphorus that is unavailable from plant feedstuffs in diets are excreted into the pond where it may stimulate undesirably heavy plankton blooms. Therefore, it is important to minimize the amount of unavailable phosphorus in the diet as it reduces both fish production and water quality.

Basic studies to determine mineral requirements for growth, survival, optimal health and reproduction are needed. Applied studies in outdoor systems are necessary also, due to the reliance of fish on natural foods. However, production and composition of natural foods varies between production units (e.g., ponds) and over time, and it is likely that mineral supplementation of commercial feeds will continue.

Phosphorus is a major mineral that must be supplied in the feed. However, much of the phosphorus in commercial fish diets may be released into the environment [2] and this is influenced both by the availability of dietary phosphorus and the high levels of phosphorus encountered in feeds because of the high levels found in animal proteins such as fish meal. The effects of phosphorus wastes from intensive cage and pen culture have been reviewed and recent studies of intensive pond systems have also demonstrated the importance of dietary phosphorus in determining algal density and water quality. Consequently, it is necessary to reduce phosphorus load in effluents and one way to achieve this is to reduce the levels in fish and shrimp diets.

Under practical farming conditions, mineral deficiency signs often arise from a dietary imbalance of calcium owing to the antagonistic effect of excess dietary calcium on the absorption of phosphorus [3] When there is an excess of calcium over phosphorus, the phosphorus is not absorbed by the intestine because it is combined with the calcium to form calcium phosphates that are not biologically available [4,5]

A phosphorus requirement has been determined for 10 species of fish including *Crysophrys major, Anguilla japonica, Salmo salar* I., 1758. *Cyprinus carpio* L. 1758, *Ictalurus punctatus* Rainesque 1818, *Oreochromis niloticus* L. 1758. *Oreochromis aureus*. Steindachner 1864. *Poecilia reticulata.* Peters 1859 and *Oncorhynchus mykiss*.[6,7.8.9,10,11,12,,13.14,15. 16.] Reported phosphorus requirements vary from about 0.25-1.00 g kg^{-1} of the diet although this rather wide range may be growth related.

There has been little reported investigation of the mineral requirements of fish species, especially the Ca requirement. A dietary Ca supplement may not be necessary for some fish [17, 18] since fish can easily absorb Ca from the surrounding water. [19,20,21,22,23] However, waterborne Ca has not satisfied the requirements of some species reared in low-Ca water [24a, 24b, 25a, 25b, 25c] It is generally accepted that sea water contains sufficient amounts of ionized Ca that are readily absorbed by marine fish and a Ca supplement to the diet may not be necessary for marine species. [26] Reported that a Ca supplement was unnecessary in a purified diet for red sea bream *Pagrus major*. In previous studies, however, we found that tiger puffer *Takifugu rubripes* could not absorb sufficient Ca from sea water. [27, 28] Ca from dietary tricalcium phosphate (TCP) was also unavailable to tiger puffer. [29] reported poor growth in redlip mullet when Ca was excluded from purified diets.

Study carried upon phosphorus and calcium requirements in the diet of the American cichlid *Cichlasoma urophthalmus* (Gunther). These studies have revealed that optimum level of phosphorus in the diet was 1.5g $kg^{-1,}$ the optimum calcium level was 1.8 g kg^{-1} and the optimum Ca-P ratio was 1:3. Carcass lipid levels were found to be inversely related to dietary phosphorus. [30]

Study carried upon the primary responses of rainbow trout to dietary phosphorus concentrations. The authors conducted a series of experiments and the fish were fed up to 24 days with semi purified diets that varied in phosphorus content. Concentrations of glucose-6-phosphate, ATP, creatine phosphate, glucose, total lipids and total cholesterol in blood or skeletal muscle were relatively unchanged by the 24 days of dietary phosphorus restriction. Inorganic phosphorus and ATP levels in the blood, however, correlated significantly and positively. Inorganic phosphorus levels in plasma and urine were significantly lower in fish fed phosphorus-deficient diets than phosphorus-supplemented diets. Urinary phosphorus excretion peaked 6-10h after feeding fish with diets containing potassium phosphate. Fish receiving either commercial feeds or experimental diets containing phosphorus as fish bone excreted trace amounts of phosphorus in the urine.

Faecal content of phosphorus significantly increased when the diet containing potassium phosphate was supplemented with calcium carbonate. Urinary phosphorus concentration was found to be a rapid and sensitive indicator for dietary intake of phosphorus and probably phosphorus status of the fish and had an advantage over conventional response variables in estimating dietary phosphorus requirement especially with large commercial-size fish. [31]

Hossain studied essentiality of dietary calcium supplement in redlip mullet *Liza haematocheila*. Studies have revealed that fish fed on a diet containing no calcium supplement grew significantly lower than the groups of fish fed on diet containing clacium supplements. From the studies the authors concluded that a dietary calcium supplement is necessary for the mullet. [32]

The effects of dietary phosphorus and lipid levels on utilization and excretion of phosphorus and nitrogen by rainbow trout (*Oncorhynchus mykiss*). Nutritional strategies to reduce both phosphorus and nitrogen excretion relative to growth of rainbow trout were tested in a 2×3 factorial experiment. The two factors were dietary P level and dietary lipid level. Reduction in dietary P from 14 to 8 g kg^{-1} dry diet was achieved by partial substitution of dietary fish meal with a combination of full-fat soyabean meal, corn gluten and spray-dried blood meal. A reduction in dietary fish meal from 500 to 200 g kg^{-1} dry diet, corresponding to a reduction in dietary P from 14 to 8 g kg^{-1} dry diet resulted in 50% reductions in both solid and dissolved P waste, but did not affect growth, feed efficiency ratio (FER) or sensory characteristics of rainbow trout. [33]

Aspects of mineral composition and growth rate of the hybrid African catfish fry fed inorganic phosphorus-supplemented diets. A 70-day feeding experiment involving sixteen 38% crude protein diet treatments of four inorganic phosphorus sources (monosodium phosphate, monopotassium phosphate, monocalcium phosphate (MCP), dicalcium phosphate (DCP), four levels of P (0.04%, 0.06%, 0.08%, 1.2%) and three replicates of each diet followed. A non-P supplemented diet and a purified diet (controls) were additionally fed. Gross efficiency of food conversion (GEFC), daily rate of growth (DRG), tissue ash, tissue phosphorus (TP), tissue calcium (TCa) and Ca:P ratio of the fish were measured weekly. These parameters varied significantly ($P<0.01$) among the (a) 18 test diets, (b) inorganic P sources and (c) duration. Monocalcium phosphate-supplemented diets resulted in better response to GEFC, DRG, TP and Ca than the P-supplemented diet while the Ca:P ratio was best exhibited by fish fed the DCP diet. The fish fed the control diets had better GEFC, DRG, TP and Ca than the P-supplemented diets probably because of nearer to optimum available P in these diets. In conclusion, supplementation with 0.6% MCP produced comparatively better growth, feed conversion and mineral deposition in the fry than other inorganic P sources [34] further the detail studies in this regards were shown in table 1

Conclusion:

In the present review, the requirements of calcium and phosphorus in various combinations and ratio are taken to assess the requirements of fishes maintained under laboratory conditions., further studies are needed on the mineral nutritional requirements in the fish to obtain better and quick growth during culture as the formulated feed should be such that it should lead to maximum utilization and should also contain sufficient amount of energy so that proteins are converted to fish flesh with high efficiency.

Table 1. Calcium and phosphorus requirements (g 100 g^{-1} in the diet) in different fish species Data expressed as percentages in the diet

Fish Species	Phosphorus (G 100 G^{-1} In The Diet)	Calcium (g 100 g^{-1} in the diet)	Ca In The Water	Reference
(a) Data expressed as percentages in the diet				
(b) Data recalculated as weight per unit weight of growth, where possible				
(a)				
Cichlasoma urophthalmus	1.5	1.8	84	Chavez-Sanchez *et al.* (2000)
Ciprinus carpio	0.6-0.7	0.10	5	Nakamura (1982)
C. carpio	0.6-0.7	NR	20	Ogino and Takeda (1976)
Ictalurus punctatus	0.45	0.05	14	Lovel (1978)
I. punctatus	0.8	1.5	56	Andrews *et al.* (1973)
Morone saxatilis	0.55	0.3	28-35	Dougall *et al.*

				(1996)
M. saxatilis	0.62	0.3	28-35	Dougall *et al.* (1996)
Oncorhynchus keta	0.5-0.6	0.36	20	Watanabe *et al.* (1980)
Oncorhynchus mykiss	0.25	-	40-50	Rodeshutscord (1996)
Oreochromis aureus	0.50	0.70	0	Robinson *et al.* (1987)
O. aureus	0.80	0.50	0	Robinson *et al.* (1987)
Salmo salar	0.6	-	-	Ketola (1975)
Liza haemotecheila	-	0.2	-	Hossain and Furuichi (2000)
Paecilia reticulata	-	0.4	-	Shim and Ho (1989)
Hamarus americanus	1.91	0.37	-	Gallagher *et al.* (1978)
Ictalurus punctatus	0.8	-	-	Deyoe and Tiemiur (1968)
Ictalurus punctatus	0.8-1.0	1.5	-	Andrew *et al.* (1973)
Red Sea bream	-	0.34	-	Sakamotos and Yone (1973)
Anguilla japonicus	29.0	-	-	Arai *et al.* (1974)
Oncorhynchus tshawgtscha	1.8	1.9	-	Richardson *et al.* (1985)

(b)

	P (g kg^{-1} of growth)	Ca (g kg^{-1} of growth)	Ca-P ratio in diet	
Cichlasoma urophthalmus	21.6	28.8	1.3	Chaverz-Sanchez *et al.* (2000)
Ictalurus punctatus	12.3	18.4	1.88	Andrews *et al.* (1973)

Morone saxatilis

M. saxatilis				
	16.3	16.3	2.0	Dougall *et al.* (1996)
	9.1	5.88	0.4	Dougall *et al.* (1996)
Oncorhynchus keta				
Oreochromis aureus	8.9	3.56	0.40	Watanabe *et al.* (1980)
O. aureus	0.80	11.2	0.5	Robinson *et al.* *(1987)*

[1]Determination of bone and scale mineralization with different phosphorus contents.

[2]Determination of weight gain, feed efficiency, serum phosphorus and calcium, and scale and bone mineralization
[3]Determination of calcium requirement with fixed dietary phosphorus of 0.50%
[4]Determination of phosphorus requirement with fixed dietary calcium of 0.80%

References:

[1] NRC, 1993. *Nutrient Requirements of Fish*. National Academy Press, Washington, DC.

[1b] NRC, 1994. *Nutrient Requirements of Poultry*. 9th rev. edn. National Academy Press, Washington, DC.

[1c] NRC, 1995. *Nutrient Requirements of Laboratory Animals*. 4th rev. edn.National Academy Press, Washington, DC.

[1d] NRC, 1998. *Nutrient Requirements of Swine*. 10th rev. edn. National Academy Press, Washington, DC.

[2] Wiesmann, D., Scheid, H. and Pfeffer, E. 1988. Water pollution with phosphorus of dietary origin by intensively fed rainbow trout (*Salmo gairdneri* Rich) *Aquaculture* **69** : 263-270

[3] Nakamura, Y. 1982. Effects of dietary phosphorus and calcium contents on the absorption of phosphorus in the digestive tract of carp. *Bull, Jpn. J. Sci. Fish.* **51** : 605-608.

[4] Andrews, J.W., Page, J.W. and Campbell, C. 1973. Effects of dietary calcium and phosphorus on growth, food conversion, bone ash and haematocrit levels of catfish. *J. Nutr.* **103**: 766-771.

[5] Cowey, C.B. 1976. The use of synthetic diets and biochemical criteria in the assessment of nutrient requirements of fish. *J. Fish Res. Bd. Canada* **33** : 1040-1045.

[6a] Sakamoto, S. and Yone, Y. 1973. Effect of dietary calcium-phosphorus ratio upon growth, feed efficiency and blood serum Ca and P level in red sea bream. *Bull. Jpn. J.Sci. Fish.* **39** : 343-348.

[6b] Sakamoto, S. and Yone, Y. 1976. Requirement of red sea bream for dietary calcium. *Rep. Fish Res. Lab. Kyushu Univ.,* **3** : 59-64.

[7a] Arai, S., Nose, T. and Hashimoto, Y. 1975a. Mineral requirements of eel I. Ca, Mg and P. *Proc. Meet. Jpn. Soc. Sci. Fish.* 1-6 April, 1975, p.48.

[7b] Arai, S., Nose, T. and Kawatsu, H. 1975b. Effect of calcium supplement to yeast grown on hydrocarbons as a feedstuff for rainbow trout. *Bull. Freshw. Fish. Res. Las Tokia* **25**: 33-40.

[8] Ketola, H.G. 1975. Requirement of Atlantic salmon for dietary phosphorus. *Trans. Am. Fish Soc.* **3** : 548-551.

[9] Ogino and Takeda, 1976; Ogino, C. and Takeda, H. 1976. Mineral requirements in fish III. Calcium and phosphorus requirement in carp. *Nippon Suisan Gakkaishi* **42** : 793-799.

[10] Lovel, 1978; Lovell, R.T. and Li, Y. 1978. Essentiality of vitamin D in diets of channel catfish (*Ictalurus punctatus*). *Trans. Am. Fish. Soc.* **107** : 809-811.

[11] Watanabe *et al.,* 1980; Watanabe, T., Murakami, A., Takeucni, L., Nose, T. and Ogino, C. 1980.Requirement of chum salmon held in freshwater for dietary phosphorus.*Nippon Suisan Gakkaishi*, **46** : 361-367.

[12] Wilson, R.P., Robinson, E.H., Gatlin, III. D.M. and Poe, W.E. 1982. Dietary phosphorus requirement of channel catfish. *J. Nutr.* **112** : 1197-1202

[13] Viola, S.G., Zohar and Arieli, Y. 1986. Phosphorus requirement and its availability from different soruces for intensive pond culture species in Israel. Part. Tilapia*,* Bamidgeh*,* **38** (1) : 3-12.

[14] Robinson, E.H., LaBomascus, D., Brown, P.B. and Lintop, T.L. 1987. Dietary calcium and phosphous requirements of *Oreochromis aureus* reared in calcium-free water. *Aquaculture* **64** : 267-276.

[15] Shim, K.F. and Ho, C.S. 1989. Calcium and phosphorus requirements of guppy *Poecilia reticulata. Nippon Suisan Gakkaishi.* **55** : 1943-1953.

[16] Rodeshutscord, M. 1996. Response of rainbow trout (*Oncorhynchus mykiss*) growing from 50 to 200g to supplements of dibasic sodium phosphate in a semipurified diet. *J. Nutr.* **126** : 324-331.

[17] Ogino, C. and Takeda, H. 1976. Mineral requirements in fish III. Calcium and phosphorus requirement in carp. *Nippon Suisan Gakkaishi* **42** : 793-799.

[18] Shim, K.F. and Ho, C.S. 1989. Calcium and phosphorus requirements of guppy *Poecilia reticulata. Nippon Suisan Gakkaishi.* **55** : 1943-1953.

[19] Lovelace, F.E. and Podolaik, H.A. 1952. Absorption of radioactive calcium by brook trout. *Prog. Fish Cult.* **14** : 154-158.

[20] Ichikawa, R. and Aguri, M. 1961. Metabolism of radionucleotides in fish. I. strontium calcium determination in gill absorption. *Nippon suisan Gakkaishi* **27***:* 351-357.

[21] Templeton, W.L. and Brown, V.M. 1963. Accumulation of calcium and strontium by brown trout from waters in the United Kingdom. *Nature*: 198-200.

[22] Love, R.M. 1980. *The Chemical Biology of Fishes.* Vol. 2. Academic Press, New York.

[23] Ichii, T. and Mugiya, Y. 1983. Effect of a dietary deficiency in calcium on growth and upake from the aquatic environment in the goldfish. *Carassius auratus. Comp. Biochem. Physiol.* **74A***:* 259-262.

[24a] Arai, S., Nose, T. and Hashimoto, Y. 1975a. Mineral requirements of eel I. Ca, Mg and P. *Proc. Meet. Jpn. Soc. Sci. Fish.* 1-6 April, 1975, p.48.

[24b] Arai, S., Nose, T. and Kawatsu, H. 1975b. Effect of calcium supplement to yeast grown on hydrocarbons as a feedstuff for rainbow trout. *Bull. Freshw. Fish. Res. Las Tokia* **25**: 33-40.

[25a] Robinson, E.H., Rawles, S.D., Yette, H.E. and Greene, L.W. 1984. An estimate of the dietary calcium requirement of fingerlings *Tilapia aurea* reared in calcium-free water. *Aquaculture* **41** : 389-393.

[25b] Robinson, E.H., Rawles, S.D., Brown, P.B., Yette, H.E. and Greene, I.W. 1986. Dietary calcium requirement of channel catfish *Ictalurus punctatus* reared in calcium-free water. *Aquaculture* **53** : 263-270.

[25c] Robinson, E.H., LaBomascus, D., Brown, P.B. and Lintop, T.L. 1987. Dietary calcium and phosphous requirements of *Oreochromis aureus* reared in calcium-free water. *Aquaculture* **64** : 267-276.

[26a] Sakamoto, S. and Yone, Y. 1976. Requirement of red sea bream for dietary calcium. *Rep. Fish Res. Lab. Kyushu Univ.,* **3** : 59-64.

[27] Furuichi, M., Furusho, Y., Hossain, M.A., Matsui, S. and Azuma, R. 1997. Essentiality of Ca supplement to white fish meal diet for tiger puffer. *J. Fac. Agr. Kyushu Univ.* **42**: 69-76.

[28] Hossain, M.A. and Furuichi, M. 1998. Availability of environmental and dietary calcium in tiger puffer. *Aquaculture International* **6**: 121-132.

[29] El-Zibdeh, H. 1996. *Studies on the utilization of minerals by marine fishes.* Ph. D. Dissertation. Kyushu University, Fukuoka, Japan.

[30] Chavez-Sanchez, C., Martinez-Palacios, C.A., Martinez-Perez, G. and Ross, L.G. 2000. Phosphorus and calcium requirements in the diet of the American Cichlid *Cichlasoma urophothalmus* (Gunther). *Aquacult. Nutr.* **6** : 1-9.

[31] Sugiura, S.H., Dong, F.M. and Hardy, R.W. 2000a. A new approach to estimating the minimum dietary requirement of phosphorus for large rainbow trout based on nonfaecal excretion of phosphorus and nitrogen.*J. Nutr.* **130** : 865-872.

[32] Hossain, M.A. and Furuichi, M. 2000. Essentiality of dietary calcium supplement in redlip mullet *Liza haematocheila. Aqualcult. Nutr.* **6** : 33-38.

[33] Green, J.A., Hardy, R.W. and Brannon, E.L. 2002. Effects of dietary phosphorus and lipid levels on utilization and excretion of phosphorus and nitrogen by rainbow trout (*Oncorhynchus mykiss*). I. Laboratory-scale study. *Aquacult. Nutr.* **8** : 279-290.

[34] Mgbenka, B.O. and Ugwu, L.L.C. 2005. Aspects of mineral composition and growth rate of the hybrid African catfish fry fed inorganic phosphorus-supplemented diets. *Aquacult. Res.* **36** (5) : 479-486.

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