ADVANCES IN TROPICAL AQUACULTURE. Tahiti, Feb. 20 - March 4, 1989.
AQUACOP IFREMER. Actes de Colloque 9 pp. 309-318.

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Mineral requirements of Penaeids

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Abstract. — *Marine shrimps absorb minerals from their aquatic environment aside from the minerals that come from the food they eat. Thus, the dietary requirement of shrimps for certain minerals will depend on the amounts and availability of these minerals in the aquatic environment. Dietary sources for growth may be necessary due to losses during moltings.*

Most of the dietary studies for mineral requirements have been done under laboratory conditions with purified or semi-purified diets and hardly any information is available under practical culture conditions. Most published data for mineral requirements are for juvenile ***Penaeus japonicus.*** *There are few data for* ***P. monodon, P. californiensis, P. merguiensis, P. aztecus.***

Calcium and phosphorus are the minerals that have been studied the most. These two have been found to be related to problems of soft-shelling in P. monodon. Apparently calcium and phosphorus requirements are within the range of 1 to 2 %. The ratio of calcium to phosphorus in the diet is also an important factor in the efficient utilization of both minerals. It seems that a 1 :1 ratio provides for good growth. Phosphorus deficiency results in reduced growth while lack of magnesium brings about decreased growth, poor survival and reduced feed efficiency in ***P. japonicus.*** *Iron toxicity has also been observed in* ***P. japonicus.***

It might not be necessary to include some minerals in the diet of penaeids.

INTRODUCTION

Food is of utmost importance in the culture of any organism and this includes penaeids. However, in order to properly feed the organism and be able to plan efficient, low cost diets it is necessary to know the nutrient requirement of the species. This includes protein, lipid, carbohydrates, vitamin and minerals. This review is limited to the report of existing literature on the dietary mineral requirements of penaeid/shrimps, including the methodologies, composition of basal diets, mineral deficiencies and toxicities.

PHYSIOLOGICAL SIGNIFICANCE OF MINERALS

Minerals are essential components of bones, teeth, and exoskeleton. These are necessary for maintenance of osmotic pressure, acid-base balance, thus the regulation of pH of blood, haemolymph, urine, and other body fluids. They are also components of soft tissues, enzymes, some vitamins, hormones and respiratory pigments and are essential for muscle contraction and transmission of nerve impulses.

The cuticle of most crustaceans contain minerals primarily CaCO3 with small amounts of magnesium, phosphorus and sulfur. About 99 % of the total inorganic composition of the exoskeleton widely varies among species, location on the body and stage of the molt cycle (Conklin, 1981).

Around twenty two minerals, both macro and micro, have been found essential to animals, fish and shrimp. However, unlike finfishes, there are relatively fewer information on the mineral needs of shrimps. Most of the information available for mineral requirements have been done under laboratory conditions using purified or semi-purified diets and scanty information is available on elemental requirements under practical culture conditions. (Tacon, 1987). The inorganic component of feedstuffs or ash is composed of minerals of which seven are needed in greater quantities compared to the other 15 which are required in trace amounts hence the distinction between macro, and trace minerals. Calcium, phosphorus, potassium, sodium, chloride, magnesium and sulfur are considered macro elements while iron, zinc, copper, manganese, nickel, cobalt, molybdenum, selenium, chromium, iodine, fluorine, tin, silicon, vanadium and arsenium are trace elements. Some minerals identified as essential to shrimps, are : calcium, phosphorus, magnesium, potassium, iron, zinc, copper, iodine and selenium. (Tacon, 1987).

Although minerals are very important, the study of mineral requirements of shrimps has been quite neglected. Perhaps this is due to the fact that shrimps live in an aquatic environment and can meet part of its requirement from the water they live in and the food they eat. Marine shrimps live in an environment that is hypertonic and continually drink small amounts of water, thus their mineral requirements like calcium are partly met (Tacon 1987). On the contrary, freshwater shrimps drink little or no water. Phosphorus, is not abundant in seawater and has to be taken from the food ingested. Therefore, dietary requirement of shrimps for some minerals will depend on the amounts present in the aquatic environment (Cowey and Sargent, 1979).

Penaeids may need dietary sources of minerals for growth because of repeated moltings wherein minerals are lost (Kanazawa, 1985). The availability of minerals to shrimp is dependent on the dietary source and form of the mineral that is ingested, amount stored in the body, interaction of other elements present in the gastrointestinal tract and body tissues and mineral interactions with other dietary ingredients or metabolites (Tacon, 1987).

Soluble monobasic, inorganic salts or bioavailable organic salts must be provided in the diet of stomachless shrimps. Phosphorus and calcium availability and absorption is dependent on the presence of an acid-secreting stomach. (Tacon, 1987).

Of the penaeids, the mineral requirement of *P. japonicus* is relatively the most studied. Hence data for mineral requirements for *P. japonicus* has often been extended to other species such as *P. monodon.* In order to define the nutrients required formulation of a basal diet is necessary.

DIETARY REQUIREMENT STUDIES

As a starting point a diet either similar to the diet of the shrimp in the wild or simulated from those fed to other species close to it such as insects and other finfishes is formulated. Kanazawa and co-workers (1970) formulated diets patterned after the diets fed to silk worm, chinook salmon, brine shrimp and components of short-necked clam. The salt mixture that was used is in Table 1. The composition of the purified diet is in Table 2.

Tab. 1a. — Trace minerals.

$AlCl_3.6H_2O$	0.024
$ZnSO_4.7H_2O$	0.476
$MnSO_4.4\text{-}6H_2O$	0.107
CuCl	0.015
KI	0.023
$CoCl_2.6H_20$	0.140
Cellulose powder	0.215

Likewise, Deshimaru and Kuroki (1974) tested 14 diets containing various levels of protein, fat, carbohydrates and minerals using semi-purified ingredients. From the results of the study they were able to formulate a basal diet for *P. japonicus* composed of 54 % casein, 6 % egg albumin, 3 % soybean oil, 3 % cod liver oil, 6 % glycogen a mineral mixture of 19.5 %, and 8.5 % of other ingredients. The mineral mixture is presented in Table 1. Their control diet is shown in Table 3 wherein 12.6 % of the mineral mix in Table 1 was used.

Tab. 1. — Percentage composition of mineral mix.

Salt	% *	% **
K_2HPO_4	30	10
NaH_2PO_4		21.5
$Ca\ (H_2PO_4)2.H_2O$		26.5
$CaCO_3$	16.8	10.5
Ca-lactate		16.5
KCl	9.4	2.8
$MgSO_4.7H_2O$	14.8	10.0
Ferric sulfate		1.4
$Ca_3(PO_4)_2$		27.4
$MnSO_4.7H_2O$		0.2
Fe-citrate		1.2
Trace metals		1.0***
Mineral mix/100 g diet	7.7 %	19.5 %

* Percentage composition of salt mixture used by Kanazawa and co-workers (1970)

** Percentage composition of the salt mixture used by Deshimaru and Kuroki (1974)

*** Trace minerals used are : $AlCl_3.6H_2O$, 0.024; $ZnSO_4.7H_20$, 0.476; $MnSO_4.4\text{-}6H_20$, 0.107; CuCl, 0.015; KI, 0.023; $CoCl_2.6H_20$, 0.140 and cellulose powder 0.215 g.

Further work on effects of Ca, P, K, Mg and Fe and mixed trace metals was reported by Deshimaru and Yone (1978). The diet reported in 1974 was used as basal diet and the mineral mixture was modified to contain :

	%
Ca	2
P	1 :1 Ca/P ratio
K	1
Mg	0.3
Fe	0.02
Trace metals	0.08

The above was added at 21 % of the basal diet.

The amounts of each major elements in percent of mineral mix in the diet are Ca 2.4 %, P 2.1 %, K, 1.2 %, Mg 0.2 %, Fe 0.02. The elements were provided as a single salt. The presence of 7.2 mg Ca and 249 mg P from casein and albumin were disregarded in the computations.

The mineral mixture defined by Kanazawa et *al.* (1970) was used by Sick et *al.* (1972) in a preliminary study with *Penaeus aztecus* and *P. setiferus.* The basal diet consisted of the following :

Casein	50.2
Methionine	1.0
Glycine	0.1
Na glutamate	0.2
Citric acid	0.3
Succinic acid	0.3
Mineral mix	5.0
Fat	8.0
CHO	20.5
Collagen	4.0
Vit. mix	2.5
Cellulose	7.9

Although the diet with added mineral mix produced shrimps with higher biomass, the increase was not very significant and the authors believe this was due to lack of cholesterol in the basal diet.

Sedgwick (1980) studied the mineral requirements of *P. merguiensis* using the mineral mixture defined by Deshimaru and Kuroki (1974) and compared the growth of shrimps to fresh mussel (*Mytilus edulis*). Freeze dried mussel, 79 % was the sole source of protein in the diet with 0, 7 and 14 % of the mineral mixture. The diet with 7 to 14 % mineral mix with 3.5 % vitamin mix gave the best growth. There was extensive mortality in shrimps fed the diets with minerals alone. In a preliminary study at the Aquaculture Department, SEAFDEC, poor growth was obtained with juvenile *P. monodon* when only minerals were added to a practical diet. Tables 4 and 5 give the composition of some premixes (New, 1976).

Calcium and phosphorus are the most commonly studied minerals. Although calcium is present in large amounts in seawater and is available to *P. japonicus* as shown by the study of Deshimaru and Yone (1978) it is still necessary to study the relationship of calcium to phosphorus. Results of studies by Deshimaru et *al.* (1978) and Deshimaru and Yone (1978) showed that adding calcium did not increase growth of *P. japonicus* compared to those fed the diet without calcium. Furthermore, they suggest 2 % phosphorus in the diet. The fact that calcium can be obtained from

Tab. 2. — Composition of diet for *P. japonicus* (Kanazawa et *al.* 1970).

Substances	%
Glucose	5.6
Sucrose	10.0
Starch	4.0
Chitin	4.0
Glucosamine	1.5
Cellulose powder	4.0
Purified soy-bean protein	50.0
Methionine	1.0
Tryptophan	0.2
Amino acid mixture	0.2
Glutamic acid	0.1
RNA	—
Citric acid	0.3
Succinic acid	0.3
Fatty acid mixture	—
Oil (Soy-bean oil, refined)	8.0
Salt mixture	7.7
Vitamin mixture	2.6
Cholesterol	0.5
Total	100.0

Tab. 3. — Composition of the control diet (Deshimaru and Kuroki, 1974).

Squid meal	43.2
Shrimp meal	13.8
Gluten	2.7
Active sludge	4.6
Yeast *1	18.4
Salt mixture *2	12.6
Vitamin mixture	2.7
Starch	1.0
Cholesterol	1.0
Total	100.0

*1 Saccharomyces sp.

*2 $AlCl_3.6H_20$, 0.024; $ZnS0_4.7H_20$, 0.476; $MnSO_4.4\text{-}6H_20$, 0.107; CuCl, 0.015; KI, 0.023; $CoC_{12}.6H_20$, 0.140 and cellulose powder 0.215 g.

*3 Thiamine-HCl, 5; Riboflavin, 16.4; Pyridoxine-HCl, 5; Nicotinic acid, 65.8; Ca-pantothenate, 24.7; Inositol, 328.8; Biotin, 0.5; Folic acid, 1.2; *p*-Aminobenzoic acid, 32.9 Choline Chloride, 657.7; Ascorbic acid, 822; — Tocopherol, 32.9; Menadione, 3.3; B-Carotene, 3.3; Calciferol, 0.5; Cyanocobalamin, 0.03 and cellulose powder 700 mg.

*4 This mixture was well-mixed with water and extruded from a mincing machine into a noodle-like shape (2 mm in diameter, 2 cm in length), then dried to less than 10 % moisture content.

the aquatic environment and is abundant in fish meal while phosphorus is lacking in the water makes phosphorus all the more necessary to provide for in the diet. On the other hand, Kanazawa et *al.* (1984) reported the need for 1 % calcium and 1 % phosphorus in the diet for *P. japonicus*. According to Shewbart et *al.* 1973), calcium, potassium and sodium chloride may not be needed by *P. aztecus* but phosphorus may be essential.

Due to the apparent discrepancy in the calcium requirements, which could be due to the type of calcium salts used-primary, secondary, or tertiary; Kanazawa (1985) suggests a reevaluation of the calcium requirements of *P. japonicus.*

Tab. 4. — Composition of some shrimp diet mineral premixes (g/100 g dry diet)*.

Composition	Premix number *			
	1	2	3	4
K_2HPO_4	2.310	0.500	1.500	0.600
$CaHPO_4.2H_2O$	—	—	1.370	0.548
$Ca_3(PO_4)_2$	2.110	0.750	—	—
KCl	0.724	—	0.470	0.188
$MgSO_4$	1.140	—	0.740	0.296
$CaCO_3$	1.293	—	0.840	0.336
$(C_3H_5O_3)_2Ca.5H_2O$	—	3.750	—	—
$FeCl_3$	—	—	0.070	0.028
$FeSO_4 7H_2O$	0.108	—	—	—
$MnSO_4 7H_2O$	0.015	—	0.010	0.004
Total premix inclusion in diet (%)	7.700	5.000	5.000	2.000

*1 Kanazawa et *al.* (1970); 2 Deshimaru and Shigueno (1972); 3 Sick et *al.* (1972); 4 Andrews and Sick (1972).
* After New (1976).

Tab. 5. — Mineral contribution to shrimp diets by premixes (News, 1976).

	Premix number*				
	1	2	3	4	5
g/100 g dry diet					
Calcium	1.336	0.679	0.655	0.264	1.06
Phosphorus	0.832	0.239	0.514	0.206	1.06
Potassium	1.417	0.244	0.919	0.368	0.90
Magnesium	0.230	—	0.150	0.060	0.30
Socium	—	—	—	—	
Choloride	0.344	—	0.270	0.107	
Sulphate	0.951	—	0.594	0.237	
mg/kg dry diet					
Iron	216.6	—	240.9	96.4	0
Copper	—	—	—	—	0
Manganese	30.5	—	19.8	7.9	0
Zinc	—	—	—	—	
Cobalt	—	—	—	—	
Iodine	—	—	—	—	
Calcium-phosphorus ratio	1.61	2.84	1.28	1.28	

*1 Kanazawa et *al.* (1970); 2 Deshimaru and Shigueno (1972); 3 Sick et *al.* (1972); 4 Andrews and Sick (1972); (1974b); 5 Kanazawa et *al.* (1984).

Additional dietary calcium might be necessary to maintain a 1 :1 calcium : phosphorus ratio. Kitabayashi et *al.* (1971) reported an optimum ratio of Ca :P of 1 :1 for *P. japonicus.* Bautista (personal communication) showed that a 1 :1 ratio was necessary to prevent soft-shell disease in *P.*

monodon while for juvenile *P. californiensis*, Huner and Colvin (1977) reported that a 2.1 :1 Ca :P ratio was optimum for growth.

Potassium at 1 % has been shown to be necessary in purified diets (Deshimaru et *al*, 1978). On the other hand Kanazawa et *al.* (1984) reported the need for 0.9 % potassium, and 0.3 % magnesium, in dry diets for *P. japonicus.*

Tab. 6. — Dietary mineral requirement of shrimp (Tacon, 1987).

Element/Species	Dietary requirement	References
Calcium		
P. japonicus	1-2 %	Kanazawa et *al.* (1984)
	1.24 %	Kitabayashi et *al.* (1971)
	1.00 %	Kanazawa (1985)
	<0.50 %	Deshimaru et *al.* (1978)
Phosphorus		
P. japonicus	1.04 %	Kitabayashi et *al.* (1971)
P. japonicus	2.00 %	Deshimaru and Yone (1978)
	1.00 %	
	1.2 %	Kanazawa et *al.* (1984)
Ca : P. ratio		
P. monodon	1:1	Bautista (Pers. comm.)
P. californiensis	2.42:1	Huner and Colvin (1977)
P. japonicus	1.2:1	Deshimaru and Shigueno (1972)
P. japonicus	1:1	Kanazawa et *al.* (1984)
P. merguiensis and *P. aztecus*	1.3:1	Sick et *al.* (1972)
	(0.66 %	and
	0.51 %)	
	ND[1]/	Shewbart et *al.* (1973)
Magnesium		
P. japonicus	0.30 %	Kanazawa (1984)
	ND[1]/	Deshimaru and Yone (1978)
P. merguiensis	.3 %	Aquacop (1978)
Iron		
P. japonicus	ND[1]/	Kanazawa et *al.* (1984)
	ND[1]/	Deshimaru et *al.* (1978)
Copper		
P. japonicus	ND[1]/	Kanazawa et *al.* (1984)
Potassium		
P. japonicus	0.9 %	Kanazawa et *al.* (1984)
	1.0 %	Deshimaru et *al.* (1978)
P. aztecus	ND[1]/	Shewbart et *al.* (1973)
Sodium chloride		
P. aztecus	ND[1]/	Shewbart et *al.* (1973)
Trace metals		
P. japonicus	0.2 % of the diet	Deshimaru et *al.* (1978)

[1]/ No dietary requirement demonstrated.

Most of the work done has been on juveniles and there is indeed a lack of information on mineral needs of larval and broodstock penaeids.

TRACE ELEMENTS

Except for the studies of Deshimaru and Kuroki (1974), Deshimaru and Yone (1978) and Kanazawa et *al.* (1970 and 1984) there is little information regarding trace element requirements. These are needed only in minute quantities, therefore, it is very difficult to study and demonstrate a mineral deficiency for trace elements such as copper, iron, and manganese. An amount of 0.2 % trace metals has been used in the diet by Deshimaru and Yone, (1978).

MINERAL DEFICIENCIES

Although minerals may be present in adequate quantities in feedstuffs for shrimp diets mineral deficiencies can occur under intensive culture conditions. The lack of certain specific minerals may be due to the presence of certain compounds that bind the elemental form of the mineral that is used in the feed, and antagonistic or synergistic reactions in the gastro-intestinal tract are factors that sometimes cause dietary mineral imbalances or deficiencies (Tacon, 1987). Kanazawa et *al.* (1984) reported reduced growth in *P. japonicus* when there is a deficiency in phosphorus and magnesium. Survival and feed efficiency are also decreased in magnesium deficiency.

Tab. 7. — Recommended mineral nutrient levels for carnivorous shrimp species. (Tacon, 1987).

Nutrient Level	Shrimp size class					
	Larval	PL1-25	PL25-1g	Juvenile	Grower	Broodstock
Major minerals, %						
Calcium, % max	3	3	2.5	2.5	2	2.5
Available phosphorus, % min	1.8	1.6	1.4	1.2	1.2	1.4
Potassium, % min	1.1	1.0	0.9	0.8	0.7	0.9
Magnesium, % min	0.18	0.15	0.13	0.10	0.08	0.13
Added dietary supplements						
Trace mineral, mg/kg	min					
Iron	100	90	80	70	60	100
Zinc	120	110	100	90	80	120
Manganese	60	55	50	45	40	60
Copper	12	11	10	9	8	12
Cobalt	1.2	1.1	1.0	0.9	0.8	1.2
Iodine	6	5.5	5	4.5	4	6
Chromium	1.0	0.9	0.8	0.7	0.6	1.0
Selenium	0.25	0.23	0.21	0.19	0.17	0.25

MINERAL TOXICITY

Studies done under laboratory conditions showed levels of iron above .006 to .012 % and manganese .01 to 0.1 % (Kanazawa et *al*, 1984)

retarded growth. Shown in Tables 6 and 7 is a summary of mineral requirements of shrimp (Tacon, 1987).

RECOMMENDATIONS

More work on mineral requirements of various penaeids species should be done using references diets and standardized methodologies such that results are comparable.

Acknowledgement. *I gratefully acknowledge IFREMER for inviting me and providing funds for my participation and to Dr. Enrique Avila for his suggestions on the manuscript.*

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