

Aquatic animal nutrition

Lecture VII: Mineral

Minerals

- Inorganic component of the feed
- Serve a wide variety of functions
 - Structural component of hard tissues
 - Component of soft tissues
 - Cofactors and/or activators of enzymes
 - Osmoregulation
 - Acid base balance
 - Production of membrane potentials

Minerals

Macro	Micro	
Calcium	Aluminum	Manganese
Chloride	Arsenic	Molybdenum
Potassium	Cobalt	Nickel
Magnesium	Chromium	Selenium
Sodium	Copper	Silicon
Phosphorus	Fluorine	Tin
Sulfur	Iron	Vanadium
	Iodine	Zinc

Minerals

Macro	Micro	
		Manganese
Magnesium		Selenium
Phosphorus	Copper	
	Iron	
	Iodine	Zinc

Requirement and source

- Similar to warm blooded animals for tissue formation and various metabolic functions
- Aquatic species, can absorb dissolved minerals from the water across gill, fins, oral epithelia (and other membranes) and via drinking (marine species).

Requirement and source

- Dietary requirements are influenced by the chemical make up of the water
 - Most Ca required comes from water
 - For marine species, seawater provides most iron, magnesium, cobalt, potassium, sodium and zinc
 - Phosphorus not typically available in water, hence it is required in the diet.

Practical diets generally require

- Phosphorus
- Magnesium - FW
- Zinc
- Iron
- Manganese
- Copper
- Selenium

Calcium and Phosphorus

- Calcium and phosphorus are two of the major inorganic constituents of feeds
 - Both are components of structural tissues
 - Calcium is essential for blood clotting, muscle function, proper nerve impulse transmission, osmoregulation
 - Phosphorus is a component of ADP, ATP, phospholipids, DNA, RNA and serve as pH buffer systems

Calcium and Phosphorus

- Dietary calcium can be absorbed from the intestine by active transport (dependent on physiological requirements)
- Mineral absorption depends upon whether the mineral is soluble at the pH of the gut
 - Minerals have a higher availability if water soluble
 - Presence of acidic stomach increases availability
 - calcium, for example, can be put in the diet as calcium lactate (58%), tribasic calcium phosphate (37%) or calcium carbonate (27% availability)

Calcium and Phosphorus

- In vertebrates
 - Blood levels of Ca and P are regulated by PTH and **cholecalciferol**
 - **Low levels of Ca** in blood trigger the release of PTH which facilitates the production of $1,25(\text{OH})\text{D}_3$
 - **Low levels of P** stimulate the production of $1,25(\text{OH})\text{D}_3$
 - Calcium binding protein (controls Ca and P absorption) in intestine
 - Cellular functions that control deposition/mobilization from structural tissues and kidney re-absorption
 - **Function** is similar in fish but the scales appear to have a higher exchange rate for Ca than bone.

Availability of Ca and P

1. Form in which it is included in the diet
2. Solubility at luminal pH (acidic stomach)
3. Level of lactose intake (lactose increases availability of Ca)
4. Vitamin D
5. Mineral interactions: iron, aluminum, manganese, potassium and magnesium
6. Fat intake (Ca forms insoluble soaps)
7. Nutrient status of the animal (compensatory response)

Calcium and Phosphorus

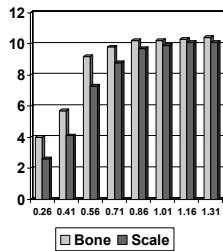
- A dietary source of calcium is not required for fish or shrimp grown in water with suitable levels of calcium!
 - Ca is absorbed from the water
- Phosphorus is generally low in most natural waters, there is a dietary requirement.
 - It has also been shown that supplementation of high levels of calcium to the diet inhibits phosphorus availability
 - thus, dietary ratios $\leq 2:1$ Ca:P are recommended

Phosphorus

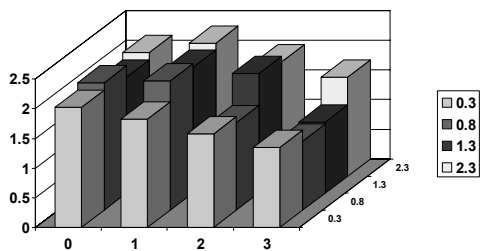
- Constitutes the primary expense for mineral supplement
- Environmental pollutant that is regulated in many countries (over supplementation and biological availability are critical issues)
- Dietary requirement (available P/100g diet)
 - Non-scaled fish 0.4
 - Scaled fish 0.6-0.8
- Mineral source dependant on availability
 - Dicalcium or defluorinated phosphates most common

Phosphorus requirement red drum

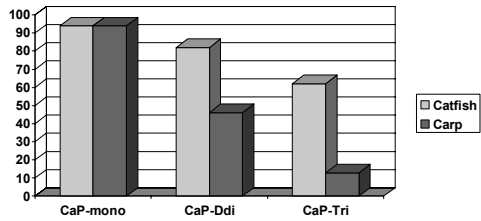
- Initial weight 1.2 g
- 11 week growth trial
- No significant differences
 - Weight gain
 - Feed efficiency
- Significant differences
 - Bone mineralization
 - Weight
 - Mineralization
 - Scale



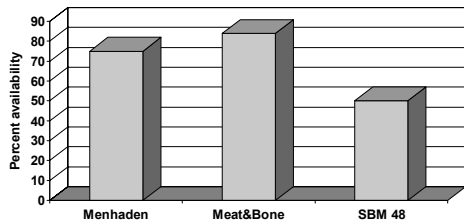
Response of *L. vannamei* to calcium and phosphorus supplement in a purified diet.



Phosphorus bioavailability



P bio-availability for catfish



Phytate

- Component of plants (corn, soybeans etc)
- It contains P which is normally not available to animals
- It binds minerals (P, Mn, Zn) making them unavailable

- Phytase is a naturally occurring enzyme that breaks down phytate
 - Demonstrated to release phytate bound P for a number of fish species

Magnesium

- 60% bodies Mg is located in bones
- Soft tissues: functions activator in carbohydrate metabolism and protein synthesis
- Freshwater (4–3 mg Mg/L) fish require 0.025 to 0.07% Mg in the diet
- Saltwater (1,350 mg Mg/L)
- Red sea bream- no requirement
 - Marine fish and shrimp excrete magnesium

Na, K, Cl

- Recognized as essential for a number of physiological processes (Osmoregulation, pH balance, Nerve impulse transmission)
- Dietary supplements are not required as most feeds and the water contain sufficient quantities
 - Exception K requirement of chinook salmon raised in FW
 - Positive effect of NaCl on growth of red drum raised in FW

Trace minerals

Micro	
Aluminum	Manganese
Arsenic	Molybdenum
Cobalt	Nickel
Chromium	Selenium
Copper	Silicon
Fluorine	Tin
Iron	Vanadium
Iodine	Zinc

Copper (Cu)

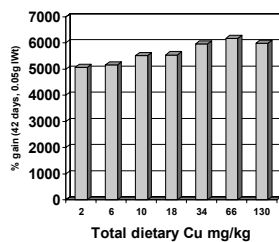
- Involved in iron absorption and formation of RBC, component of several enzyme systems (SOD, Cyt C and Lysyl oxidase).
- The improper linking of collagen (lysyl oxidase) results in structural failure resulting in bone fragility and structural changes in the heart (enlargement).
- Component of hemocyanin or cyanodin (respiratory pigment)
- Transported in a protein bound form

Dietary copper

- Fish 1.5 to 5 mg Cu/kg diet
- Shrimp 34-53 mg Cu/kg diet
- Commercial supplement - copper sulfate
- Copper toxicity
 - In the water 0.8 mg/L (FW)
 - 730 mg Cu/Kg feed

Dietary copper requirement of *P. vannamei*

- Reduced growth
- Depressed copper levels
 - hemolymph
 - carapace
 - hepatopancreas
- Enlargement of heart



Iodine

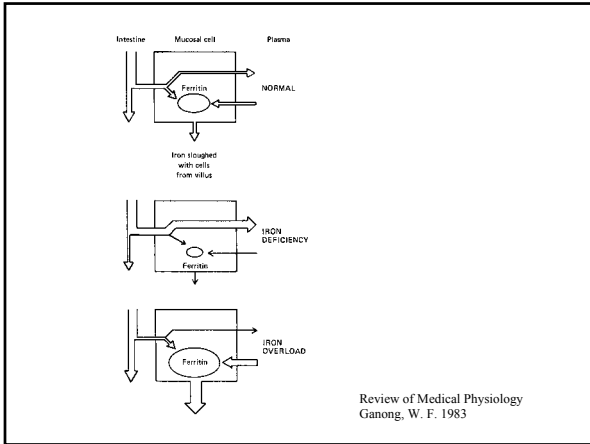
- Found in almost every cell of the body, Thyroid gland is the main reserve.
 - Thyroid hormones, which contain iodine, have a wide varieties of role is metabolism, growth, reproduction, neuromuscular function etc.
- Deficiencies have primarily been observed in wild populations
- Dietary requirements have not been well defined

Iron

- Functions
 - Component of various proteins: Hemoglobin (primary physiological requirement), myoglobin and cytochromes
 - Co factor in carious enzyme systems
 - Excreted with bile into intestine
 - Invertebrates removed with exoskeleton

Iron

- Transport/absorption
 - Intestine mucosal transferrin binds Fe^{2+} in the intestinal lumen and transports it across the mucosal brush border.
 - Within the cell Fe^{3+} is bound to apoferritin forming ferritin (ferritin stores are then regulated).
 - Iron is transferred to transferrin in the blood for transport to target tissues (eg liver)



Iron

● Excretion

- Fe and other minerals (Zn, Cu) are difficult to excrete. Some iron is excreted with bile
- Storage in the intestine allows removal of minerals when cells are sloughed.
- Invertebrates also store these minerals in the hepatopancreas and exoskeleton

Dietary iron

- Fish 30 mg/kg diet
- Shrimp- no deficiency has been observed
- Commercial supplements
 - Ferrous sulfate
 - Ferrous carbonate
- Problems
 - Toxic at high levels
 - Initiates formation hydrogen peroxides and free radical peroxides in the feed (lipids and vitamins)

Manganese

- Functions
 - Cofactor in AA metabolism, FA metabolism and glucose oxidation.
- Deficiencies
 - Poor growth, skeletal abnormalities, high embryo mortalities and poor hatch rate.

Dietary manganese

- Low levels in both fresh and marine water
- Freshwater fish require 2.4-12 mg/kg diet
- Due to poor availability from most foodstuffs, dietary supplementation is recommended
- Commercial supplement - Manganese oxide

Selenium

- Functions as component of enzyme glutathione peroxidase
 - Converts hydrogen peroxide and lipid hydroperoxides into water and lipid alcohols, respectively.
 - Acts along with vitamin E as a biological antioxidant. Protects cellular and sub-cellular membranes from peroxidative damage
- Protects from mercury toxicosis by forming a mercuric selenium complex. The protein bound complex is diverted to the kidney (where unbound mercury will accumulate) to the liver and spleen where the toxicity is reduced.

Dietary selenium

- Freshwater fish require 0.2 mg/kg diet
- Due to toxicity, maximum allowable supplement 0.1 mg/kg diet (US)
- Catfish
 - Selenomethionine 147% activity of sodium selenite
 - Selenoyeast 148% activity of sodium selenite

Zinc

- Functions
 - Cofactor in several enzyme systems
 - Component of metalloenzymes
 - carbonic anhydrase
 - carboxypeptidase A and B
 - alcohol dehydrogenase
 - glutamic dehydrogenase etc.

Dietary zinc

- Freshwater fish 15-30 mg/kg diet
- Practical diets will contain inhibitory substances
 - e.g. phytate hence 150 mg/kg is required
- Commercial supplement: Zinc oxide

Chelated minerals

- Agents which will bind a mineral
- Reduce bioavailability
 - phytate
- Increase bioavailability
 - Amino acids
 - Peptides
- Widely used in terrestrial animal nutrition
- Limited data with aquatic animals
- Catfish- Cu, Fe, Mn, Se and Zn proteinates

Generalized trace mineral premix (0.5% inclusion)

Ingredient	g/100g premix
Cobalt chloride	0.004
Cupric sulfate pentahydrate	0.250
Ferrous sulfate heptahydrate	4.000
Magnesium sulfate heptahydrate	28.398
Manganous sulfate monohydrate	0.650
Potassium iodide	0.067
Sodium selenite	0.010
Zinc sulfate heptahydrate	13.193
Filler	55.128
