

Nutrition and Feeding of fish

Nutrition and feeding

- ▶ Introduction
- ▶ Feed intake, digestion and nutrient absorption
- ▶ Nutritional requirements
- ▶ Types of feed
- ▶ **Selecting feed ingredients and formulation**
- ▶ Feed management
- ▶ Major feed-related issues confronting the aquaculture sector
- ▶ Conclusions

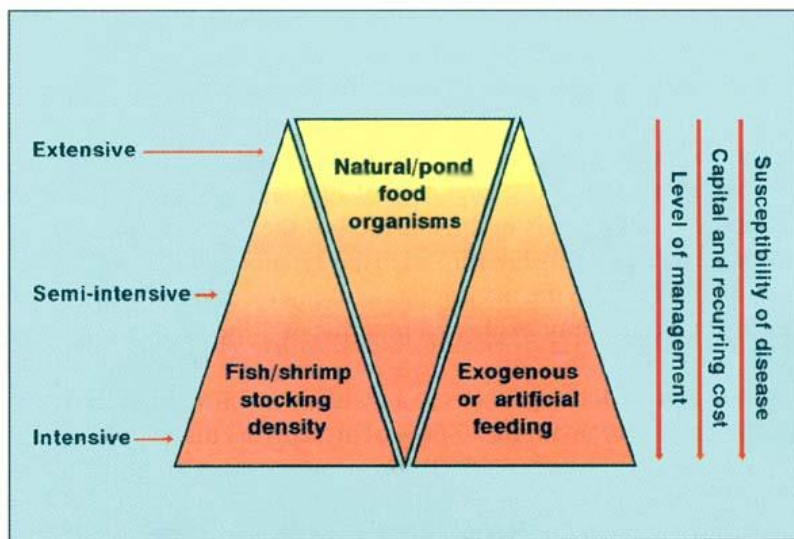
Fish Nutrition

- Important component for whole production system
 - Target species production
 - Growth, FCR, Water Quality, Disease
 - Economics
 - Overfeed and Underfeed
 - Species specific formulations available
 - Pond production
 - Closed recirculations systems (such as aquaponics)

Why feed fish

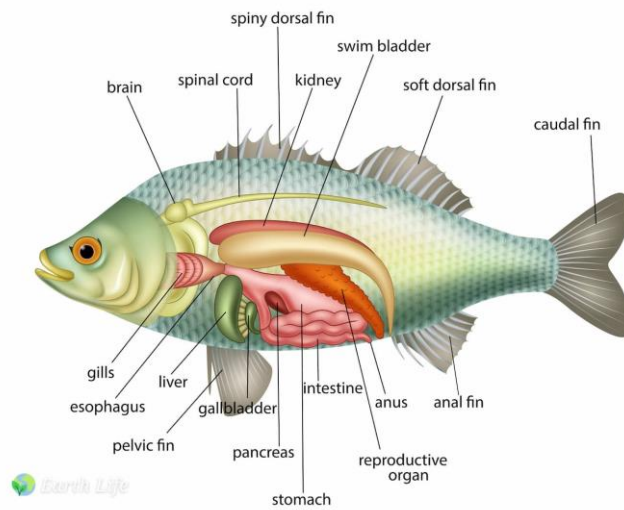
- Intensification reduces natural food organisms in pond
- Some culture methods have little chance of natural food sources
 - Aquaponics, cages, raceways
- Reduce reliance on natural foods
- Have control of what fish eats

- ▶ **Extensive**, where the cultured stock is entirely dependent on the food organisms naturally produced in the system, such as, for example, phytoplankton and zooplankton in a pond.
- ▶ **Semi-intensive**, where the cultured stock obtains a proportion of the nutrition from the food organisms naturally produced and the rest is provided by the farmer.
- ▶ **Intensive**, where the cultured stock is entirely dependent on externally provided food for its nutrition.



FEED INTAKE, DIGESTION AND NUTRIENT ABSORPTION

Digestive system structures and functions



| Structure | Functions |
|-----------------------|---|
| Teeth | Grasping, holding, crushing, depending on species |
| Pharynx | Opening to the gills |
| Esophagus | Short, simple passage to the stomach, lined with mucus secreting cells |
| Stomach | Walls lined with cells secreting hydrochloric acid and pepsinogen for initial stages of protein digestion, holding compartment for feed |
| Pyloric caecum | Secretes enzymes for digestion , increased surface area for digestion of nutrients |
| Intestine | Secretes enzymes for digestion, increased surface area for digestion of nutrients |
| Gall bladder | Stores and releases bile for digestion, absorption of fats |
| Liver | Synthesis and storage of some absorbed nutrients, production of bile, removal of some waste products from the blood |

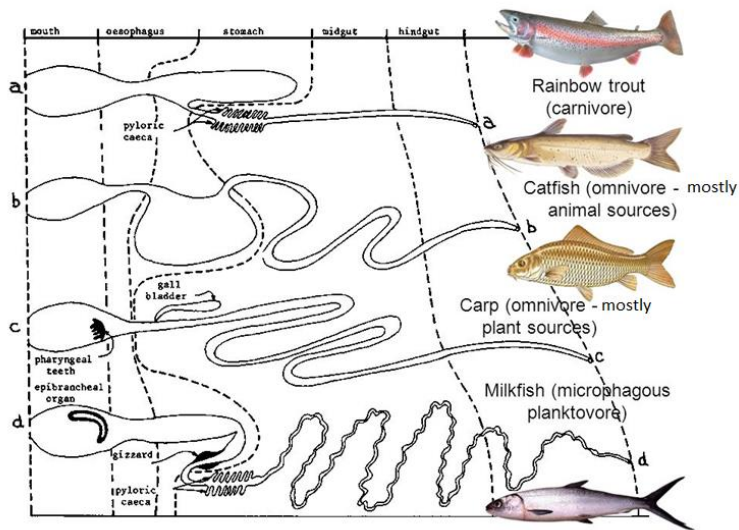
Feeding type and anatomy

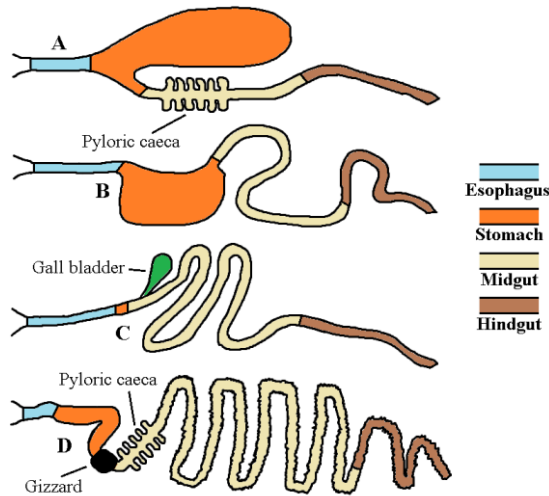
Fish can be divided into three types of eaters

- ▶ **Carnivores** - consume primarily animal material. Foods consumed by this type of fish may be as small as a microscopic crustacean or insect or as an amphibian or a small mammal.
- ▶ **Herbivores** - subsist primarily on vegetation and decayed organic material in the environment.
- ▶ **Omnivores** - consume almost any food source, either plant or animal origin.

Table 1. List of fish species of different feeding groups.

| Feeding group | Scientific name | English name | Local name | References |
|---------------|--|----------------------------|-----------------|-----------------------------|
| Herbivores | 1. <i>Hypophthalmichthys molitrix</i> | Silver carp | Silver carp | Kumar 1992 |
| | 2. <i>Catla catla</i> | Catla | Catla; Katal | Kumar 1992 |
| | 3. <i>Pangasius hypophthalmus</i> | Yellowtail Catfish | Thai pangus | Rahman 2005 |
| Carnivores | 1. <i>Channa striates</i> | Snakehead murrel | Shol | Shafi and Quddus 2001 |
| | 2. <i>Wallago attu</i> | Freshwater Shark | Boal | Shafi and Quddus 2001 |
| | 3. <i>Nandus nandus</i> | Mud Perch | Meni, Bheda | Mustafa <i>et al</i> , 1980 |
| Detritivores | 1. <i>Cirrhinus cirrhosus</i> | Mrigel | Mrigel, Mirka | Kumar 1992 |
| | 2. <i>Cyprinus carpio</i> Var <i>communis</i> | Common carp; Scale carp | Carpio | Shafi and Quddus 2001 |
| | 3. <i>Labeo rohita</i> | Rohu | Rui, Rohit, Rou | Kumar 1992 |
| Omnivores | 1. <i>Anabas testudineus</i> | Climbing perch | Koi | Nargis and Hossain 1987 |
| | 2. <i>Oreochromis mossambicus</i> | Tilapia | Tilapia | Shafi and Quddus 2001 |
| | 3. <i>Tenualosa ilisha</i> | Hilsha shad | Ilsha | Shafi and Quddus 2001 |





Comparative digestive anatomy of fish, own interpretation (NRC, 2011). The figure visualizes basic compartments in the digestive system, based on different food preferences. A: Carnivore. B & C: Omnivores with different strategies. D: Microphagous planktivore.

- ▶ The arrangement and **structure of the teeth** are related to the kind of food that the fish normally eat. There is a strong correlation among kind of teeth, feeding habits, and food eaten
- ▶ Generally, the **more active feeders have strong jaws with sharp teeth to bite and shred the food**. Some major kinds of jaw-teeth are the following: cardiform, villiform, canine, incisor and molariform
- ▶ Zooplankton feeders and most planktivores have **practically no teeth**.
- ▶ **Most fish have short, wide esophagus** that serves as a transitional area between the striated muscles of the mouth and the smooth muscles of the gut. Mucus producing cells are present in the esophagus.
- ▶ **Generally, fish that eat relatively small, soft particles have small stomach whereas fish that eat large food particles, e.g. whole fish, or eat at infrequent intervals have larger stomach.**
- ▶ absence of a stomach has been suggested to benefit fish adapted to freshwater (low chloride concentration) **where stomach acids impose added osmoregulatory pressure**. This is to avoid acidifying large amounts of alkaline food
- ▶ **In general, herbivores have longer intestines than carnivores**
- ▶ Gut length is directly more related to the amount of indigestible material in the food rather than whether the food source is of plant or animal origin.

Digestion and Absorption

- ▶ Dietary **proteins are broken down in stages to polypeptides, peptides and then amino acids** by several different proteases, including pepsin, trypsin and chymotrypsin, which are able to act on peptides and break bonds between specific amino acids.
- ▶ **Amylase, chitinase** and other various carbohydrate-digesting enzymes are responsible for the digestion of carbohydrates
- ▶ **Lipases, esterases and bile salts** are required for the emulsification and subsequent digestion of lipids.
- ▶ Products of digestion, mostly comprising basic molecules such as **amino acids, fatty acids and glucose**, are then absorbed into the bloodstream by passive diffusion or active transport.

Factors Affecting Digestion and Absorption

- ▶ Extrinsic and intrinsic factors
- ▶ Feed composition, digestibility, and preparation influence digestion and absorption
- ▶ Dietary fiber /Roughage
- ▶ Plant proteins are known to vary in their digestibility
- ▶ Presence of anti-nutritional factors
- ▶ **The condition of the digestive tract, pancreas, and the liver in fishes**
- ▶ Nutritional diseases and bacterial infections

Factors affecting the appetite of fish

Biotic and abiotic tend to affect the appetite of the fish and shrimp.

Biotic factors (living things within the ecosystem):

- ▶ Food availability and food distribution
- ▶ Competition; Generally, size differences of the stock and dominance cause increased variation in body sizes. Solution; periodic grading and feeding frequency
- ▶ presence of predators may inhibit feeding;
- ▶ Physiological condition such as starvation or motivation level, and **circadian rhythm** of the animal may dictate feeding time and amount of food ingested;
- ▶ Selection of prey; Choice of prey or food eaten, in terms of size and form, is limited by the mouth gape of the fish.
- ▶ Handling causes stress in fish. Brown trout refuse to feed for three days after handling while rainbow trout, milkfish, or sea bass resume feeding the next day.

Abiotic factors

- ▶ **Dissolved oxygen (DO)** is one of the most important abiotic factors affecting feeding behavior of fishes. Low DO levels lead to decreased feeding activity.
- ▶ Daily and **seasonal water temperature** fluctuation affect food intake.
- ▶ **Light intensity** also influences feeding activity of most fish, especially larval fish, which rely on vision to recognize food particles.
- ▶ **Unionized ammonia (NH₃)** levels of about 0.1 ppm inhibits growth in most species. However, appetite could be inhibited at ammonia levels high enough to cause serious physiological and morphological damage.

NUTRITIONAL REQUIREMENTS

Essential Ingredients

- Protein
- Fat
- Carbohydrate
- Minerals
- Vitamins

Protein

- Composed of amino acids
 - Ten can be synthesized by vertebrates, including fish
 - Essential: Must supply = protein quality
- Important component in diet
 - Expensive
 - Small quantity of good protein produces large amount of fingerlings
- Used for FISH GROWTH
 - A fish does not have a minimum protein requirement; it has a minimum amino acid requirement
 - Nutritionist should know AA composition and digestibility
 - Poor quality protein is burned for energy or deposited as fat

Factors that affect protein requirement

- Size of fish: Small fish require more protein than larger fish
- Protein quality: Protein needs to be of good quality (such as from grain amaranth or black soldier fly larvae)
- Natural foods: Some fish use natural foods effectively.
 - Depends on stocking density

- Protein: Energy Ratio:

- If energy level of diet low, you will waste protein to meet metabolic needs. Inefficient and expensive.
- If protein level low and energy moderate, then fish will get fat.
- If energy level too high, it suppresses food intake and fish don't meet protein requirement. Results in low growth rate over time and undersized fish.

Protein Requirement of tilapia

| | |
|--------------------------|---------------|
| First feeding fry | 45-50% |
| 0.02-2.0 g | 40% |
| 2.0-35.0 g | 35% |
| 35.0 g - Harvest | 30-32% |

Protein sources

- Animal protein
 - Fish meal
 - Balance of amino acids that approach requirements of most fish
 - Palatable and digestible
 - Not sustainable
 - Trash fish
 - By-catches
 - High water content, spoils
 - Anti-nutritional enzymes
 - Not sustainable
 - Poultry
 - Plenty of product due to chicken farming
 - Nutrition depends on part of chicken
 - Warrants more experiments
 - Insects
 - High in protein (e.g. Black soldier fly larvae)
 - High in water content
 - Availability, production cost
 - Diet supplement
 - Crustaceans
 - High in protein
 - High in chitin
 - Zooplankton
 - Fed in combination with commercial diet
 - Usually not sole source of feed because readily take dry feed

- Plant Protein
 - Usually lacks in AA content
 - Must add additional AA
 - Many contain anti-nutritional factors and/or toxins
 - Deactivated or destroyed by soaking or heat
- Soybean (30-50%)
 - Farmed all over
 - Amino acid imbalance
 - Inclusion of other ingredients
 - Palatability
 - Attractants
 - Trypsin inhibitor
 - Heated during processing
 - Partial replacement probable

Protein Sources

- Cottonseed Meal (20%)
 - Contains toxin gossypol
 - Direct and indirect effects of gossypol
 - Direct
 - Liver
 - Indirect
 - Binding to AA
 - Binds to lysine making it neutral, supplemental lysine needed
 - Palatable, economical in areas of US that produce cotton
 - Glandless cotton contains no gossypol. Difficult to find in US
- Rice (<75% inclusion)
 - Nutrient value limiting
- Algae (10-20%)
 - Production expensive
 - Dry meals are expensive
 - Best 'in situ'
 - Some are toxic
 - High in carotenoids
- Duckweed (<20%)
 - Very common in ponds
 - High in water
 - Dietary supplement

LIPIDS

- Source of energy and essential fatty acids
 - One gram of lipid contains 2x the energy of 1 gram carbohydrates or 1 gram protein
 - Spare the protein for growth
- Maintain cell fluidity
 - Globular proteins transport things in and out of the cell membrane

Types of Lipids

- ▶ **Fats or triglycerides** are formed by the reaction of **glycerol with fatty acid molecules and hence called glycerides**.
- ▶ **Phospholipids** are esters of fatty acids and phosphoric acid (H_3PO_4) and a nitrogenous base. They are the main components of biological membranes.
- ▶ **Waxes** are esters of long-chain fatty acids and of high molecular weight monohydric alcohols. **Like triglycerides, they are sources of energy stored in plants and animals and serve as protective coating**
- ▶ **Steroids** are usually polycyclic long-chain alcohols. They are precursor of sex or other **hormones in fish and shrimp** and are biologically important in the reproductive processes. **Cholesterol is a physiologically important sterol and is widespread in biological membranes, especially in animals.**
- ▶ **Sphingomyelins** do not contain glycerol, but are fatty acid esters of long-chain amino alcohol sphingosine. They are lipid components of the brain and nerve tissue of plants and animals.

CARBOHYDRATES

- ▶ Organic compounds - common in plants which include simple **sugars, starches, celluloses, gums, and related substances**.
- ▶ Fish do not utilize feed with a lot of carbohydrate but mostly need protein and fats.
- ▶ Cheap source of energy and can spare the more expensive protein as an energy source.

Utilization of Carbohydrates

- ▶ **Aquatic animals do not have a specific dietary requirement for carbohydrates but their presence in diets may provide an inexpensive source of energy.**
- ▶ Warmwater freshwater species generally can use dietary carbohydrates more efficiently than coldwater and marine species.
- ▶ **Fish can survive, grow, and display normal reproductive physiology if maintained on a carbohydrate-free diet**
- ▶ **However, carbohydrates are a cheap source of energy.**
- ▶ If carbohydrates are **not provided** within the diet, other compounds (mainly the expensive proteins and lipids) are utilized for energy production and for the synthesis of various biologically important compounds that are normally derived from carbohydrates
- ▶ Thus, in aquafeed formulation it is important to provide the appropriate concentration of carbohydrates to spare other dietary components
- ▶ Further to this, carbohydrates have very important physical roles in aquafeed: **acting as binders, constituting the basic pellet structure** and being essential for holding feed pellets together in dry and semi-moist diets

- ▶ **Starch**, flour, alginates, agar, carrageenan, and guar gum used as **feed binders** to improve the water stability of fish and shrimp diets.
- ▶ **Fibre**, such as cellulose and lignin, is commonly present in many plant-derived raw materials. **Fibre is an indigestible carbohydrate and therefore does not play an important role in fish nutrition.**
- ▶ However, fibre provides physical bulk to the feed and improves gastric evacuation.
- ▶ **A minimum amount of fibre in feed is beneficial, but if it exceeds 8% it can significantly decrease growth and feed efficiency.**

VITAMINS

- ▶ Vitamins are organic compounds that are required in the diet in small amounts
- ▶ They have specific **regulatory functions** and are **necessary for normal growth, maintenance of health, and reproduction.**
- ▶ They do not give energy but are **needed in enzyme systems** to hasten or catalyze reactions in energy utilization
- ▶ Vitamins are essential for the **regulation of metabolism** in the cells and for the transformation of energy. Without vitamins, respiration, growth, muscle contraction, and other physical activities cannot occur. Many are used to form coenzymes or as part of an enzyme system. About 15 vitamins are known to be needed by fish.
- ▶ Insufficient amounts in fish diets may result in nutritional deficiency diseases, poor growth, and increased susceptibility to diseases and infections

Classification of Vitamins

Vitamins are classified according to their solubility: water-soluble and lipid-soluble.

- ▶ Water-soluble vitamins include **B vitamins** (thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, folic acid, and cobalamins), **inositol, choline, and vitamin C** (ascorbic acid). **Of these, vitamin C probably is the most important because it is a powerful antioxidant and it enhances the immune system of fish and shrimp.**
- ▶ Fat-soluble vitamins include vitamins A (retinol, beta-carotene), D (cholecalciferol), E (tocopherols), and K (phylloquinone).

FUNCTIONS OF WATER SOLUBLE VITAMINS

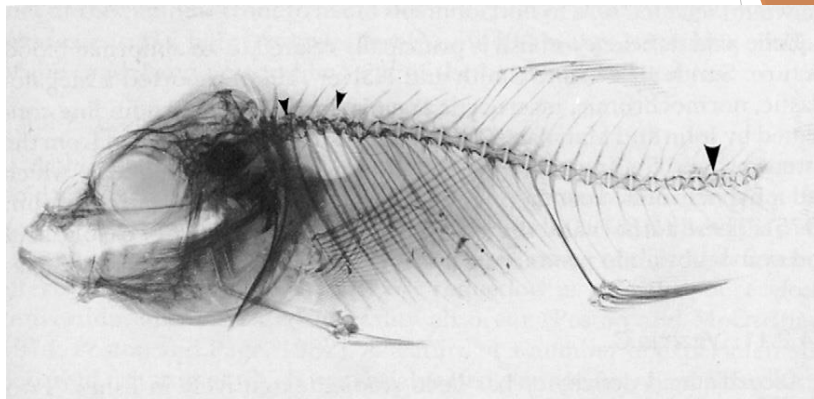
- ▶ **Choline** –✓ Component of membranes ✓ Precursor of acetylcholine, a chemical for nerve transmission ✓ Provider of methyl groups for chemical reactions
- ▶ **Myoinositol** - component of membranes and is involved in sending signals during several body processes.
- ▶ **Vitamin C** - formation of connective tissue, bone matrix and wound repair. It also facilitates the absorption of iron from the intestine and helps prevent the peroxidation of fats in tissues.
- ▶ **Most water-soluble vitamins** serve as **coenzymes** in the body's biochemical reactions. Enzymes are biological catalysts. Most enzymes are proteins and they are unique for each biochemical reaction. Coenzymes then work with or become part of an enzyme.



Atlantic salmon with screamer disease. There is a deformed jaw due to fusion of the articulation and a permanently open mouth. The disease is associated with vitamin C and phosphate marginal deficiency in fast-growing fish. Courtesy of Dr. Patricia Salas.



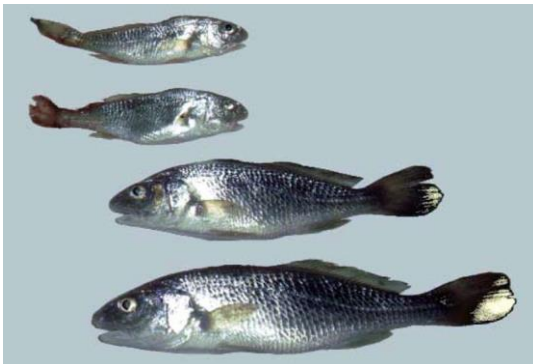
Scurvy in ascorbic acid deficient salmon



X-Ray of osteoid deformation and fracture (arrowheads) in thoracic vertebrae of a vitamin C-deficient *Oreochromis niloticus* and associated deformation of the body and articulation of posterior vertebrae (arrowhead).

FUNCTIONS OF FAT SOLUBLE VITAMINS

- ▶ **Vitamin A** is **necessary for sight**, proper growth, reproduction, resistance to infection and maintenance of body coverings. As many land animals, fish can use beta-carotene as a Vitamin A precursor.
- ▶ **Vitamin D** **helps the body mobilize, transport, absorb and use calcium and phosphorous**. It works with two hormones from an endocrine gland, the parathyroid.
- ▶ **Vitamin E** working with selenium, protects cells against adverse effects of oxidation.
- ▶ **Vitamin K** is required for the normal blood clotting process. Many animals can synthesize vitamin K in their intestines.



Vitamin deficiency can lead to a range of growth and health problems. The red drum at the top received no vitamin C in their diets.
<https://www.globalseafood.org/advocate/vitamins-varied-factors-affect-health-disease-resistance-effects-in-fish/>



These channel catfish suffer from nutritional muscular dystrophy and other ailments due to a vitamin E and selenium deficiency. Photo courtesy of Delbert Gatlin III.

MINERALS

- ▶ Required to **maintain many metabolic processes** and to **provide material for major structures** (e.g. bones, teeth, exoskeleton of crustaceans) of aquatic animals.
- ▶ They are also required for **maintenance of osmotic pressure, acid-base balance** (e.g., the regulation of blood pH, hemolymph, urine and other body fluids) and the proper functioning of muscles and nerves.
- ▶ Unlike carbohydrates, fats, and proteins, they do not provide energy but they may serve as components of enzymes, vitamins, and hormones.
- ▶ **Fish, especially marine fish species, live in an environment that contains many of the minerals that they need for growth and survival.**

Mineral requirements

- ▶ **Fish can absorb a number of minerals directly from the water:** calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), iron (Fe), zinc (Zn), copper (Cu) and selenium (Se). This reduces the mineral requirement in the diet.
- ▶ **Macrominerals** are present in the body in relatively large quantities. The macrominerals include: Calcium (Ca), Chlorine (Cl), Magnesium (Mg), Phosphorous (P), Potassium (K), Sodium (Na)
- ▶ **Microminerals include:** Copper (Cu), Iodine (I), Iron (Fe), Manganese (Mn), Selenium (Se), Zinc (Zn)

FUNCTIONS OF MACROMINERALS

- ▶ **Calcium and phosphorous- development and growth of the skeleton** and they act in several other biochemical reactions. Fish absorb calcium directly from the water by the gills and skin. The requirement for calcium is determined by the water chemistry.
- ▶ **Dietary phosphorus is more critical.** Phosphorous deficiency signs include poor growth, reduced feed efficiency and bone deformities.
- ▶ **Magnesium functions with many enzymes as a cofactor.** The dietary requirement can be met from either the water or the feed. Deficiencies of magnesium cause anorexia, reduced growth, lethargy, vertebrae deformity, cell degeneration and convulsions.
- ▶ **Sodium potassium and chlorine are electrolytes.** Sodium and chlorine reside in the fluid outside the cells. Potassium resides inside the cells- an intracellular cation. Because of the abundance of these elements in the environment, deficiency signs are difficult to produce.

Bulletin of the Japanese Society of Scientific Fisheries 42 (7) 793-799 (1976)

Mineral Requirements in Fish—III Calcium and Phosphorus Requirements in Carp

Chinkichi OGINO* and Hiroshi TAKEDA*

(Received February 23, 1976)

Carp were fed on diets containing different levels of calcium and phosphorus. The rearing water contained 20 ppm calcium and 0.002 ppm phosphorus. The growth rate correlated positively with dietary phosphorus levels but not with calcium levels. Feeding with a low-phosphorus diet resulted in reduced growth, low feed efficiency and deformity of the head. Dietary phosphorus levels affected greatly the ash, calcium and phosphorus contents of the vertebrae. Radiography of the fish receiving a low-phosphorus diet showed an insufficient development of the bones. The available phosphorus level in a diet producing the maximal growth was found to be 0.6 to 0.7%.

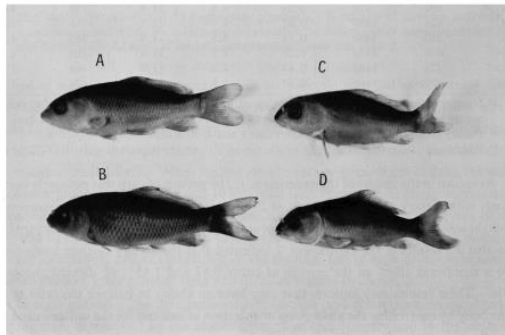


Fig. 1. Carp fed on diets containing different levels of calcium and phosphorus. Note the deformity of the head resulting from phosphorus deficiency. Signs A, B, C and D indicate fish fed diets 4, 8, 1 and 5 (Table 2), respectively.

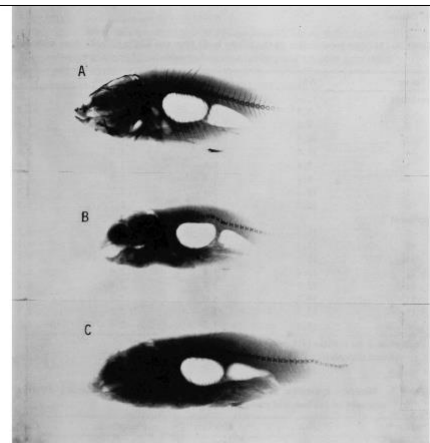


Fig. 2. Radiograph for the experimental fish. Note the abnormal development of the bones resulting from phosphorus deficiency. Signs A, B and C indicate fish fed diets 4, 1 and 5 (Table 2), respectively.

FUNCTIONS OF MICROMINERALS

- ▶ **Copper is a part of many enzymes** and it is required for their activity. Fish are more tolerant of copper in feed than in water.
- ▶ **Iodine is necessary for the formation of hormones from the thyroid gland.** Fish can obtain iodine from either water or feed. Similar to land animals, a deficiency causes the thyroid gland to grow, a condition similar to goitre.
- ▶ **Iron is necessary for the formation of heme compounds.** These compounds carry oxygen. **Because natural waters are low in iron**, feed is considered the major source of iron. Iron deficiency causes a form of anaemia. At high levels, iron can be toxic and cause reduced growth, diarrhoea, liver damage and death.

- ▶ **Manganese functions as a part of enzymes or as a cofactor.** Although it can be absorbed from the water, it is more efficiently absorbed from the feed. **A deficiency causes reduced growth and skeletal abnormalities.**
- ▶ **Selenium protects cells and membranes against peroxide danger.** Selenium deficiencies cause reduced growth. **Both selenium and vitamin E are required to prevent muscular dystrophy in some species.** When dietary selenium exceeds 13 – 15 mg per kg of dry feed, it becomes toxic resulting in reduced growth, poor feed efficiency and death.
- ▶ **Zinc is also a part of numerous enzymes.** **Dietary zinc is more efficiently absorbed than that dissolved in water.** Dietary calcium and phosphorous, phytic acid protein type, all affect zinc absorption and use. A zinc deficiency causes suppressed growth, cataracts, fin and skin erosion, dwarfism or death.



Advanced thyroid "tumors" (actually iodine deficient) in a rainbow trout (*Salmo gairdneri* Richardson). From Halver (1972).



Zinc deficiency cataract in a salmon showing the delicate gray translucent lens (arrowhead).

Energy – Why does fish need it?

- Energy is not a food stuff
 - Formed from breakdown of feed
 - Protein, lipids and carbohydrates
- Activity
- Chemical reactions
- Nervous system
- Osmoregulation
- Growth
- Energy reserves
- Excretion of wastes
- Reproduction

ENERGY

- Fish eat to satisfy their energy demands
 - Too much energy
 - Get fat or do not satisfy their protein requirement = don't grow
 - Too little energy
 - Utilize protein as energy source = \$ costly
- Require less energy than land mammals
 - Cold-blooded
 - Live in water
 - Waste excretion

Factors affecting the energy requirement of fish

- Species
 - Warmwater/Coldwater
 - Herbivores/Carnivores
- Water Temperature
 - Fish are poikilothermic
 - Metabolic rate directly related to water temperature
 - Rise of ten degrees doubles rate of metabolism
- Fish Size
 - Smaller fish
 - Developing muscle, bones, organs, growth
 - Larger fish
 - Slower growth and basal metabolism

Factors affecting the energy requirement of fish

- Fish Age
 - Energy requirement decreases as age increases
- Physiological Activity
 - Spawning activity and formation of reproductive systems
- Environmental Factors
 - Water current
 - Swimming and positioning
 - Water quality
- Diet Composition
 - Fry/broodfish
 - High protein and fats

Types of feed

FORMULATION OF AQUAFEEDS

- ▶ Aquafeed development started when **natural food sources in culture** systems became inadequate and had to be supplemented with prepared feed
- ▶ As fish stocking densities in culture increase, **supplemental feeding is no longer sufficient.**
- ▶ A **complete feed** that contains all the necessary nutrients in sufficient amounts to bring about good growth, survival, and reproduction is needed.
- ▶ Feed ingredients generally come from animal or plant sources and some are by-products of the food industry.
- ▶ There is no single feed ingredient or feedstuff that contains all the nutrients in adequate amounts. Thus, different feed ingredients are combined to make a feed that has the desired composition and nutrient levels

Feed Ingredients for Aquaculture

- ▶ The **choice** of a feed ingredient in aquafeed formulation depends on: content of **essential nutrients**; **digestibility** and **bioavailability**; **absence of anti-nutritional factors** and **toxic substances**; commercial availability; and cost
- ▶ Some feed ingredients for aquaculture feeds are listed below

| Protein | Lipid | Carbohydrate |
|-----------------------|-------------------|------------------|
| Blood meal | Beef tallow | Bread flour |
| Copra meal | Corn oil | Cassava starch |
| Defatted soybean meal | Cod liver oil | Corn meal |
| Fish meal | Coconut oil | Corn starch |
| Meat and bone meal | Cottonseed oil | Fine rice bran |
| Shrimp head meal | Menhaden oil | Sago palm starch |
| Shrimp meal | Pollack liver oil | Seaweeds |
| Squid meal | Tuna liver oil | |
| Trash fish | Squid liver oil | |
| Yeast | Soybean oil | |

Some sources of protein, lipid, and carbohydrate in aquaculture feeds

- ▶ Feedstuffs of animal origin usually contain high amounts of protein with good amino acid profile
- ▶ A protein source is considered good if the amino acid profile is close to that of the species being feed
- ▶ Some plant protein sources have high protein content but they often have inferior amino acid profiles compared with protein from animal sources.
- ▶ Feedstuffs from plants are good sources of carbohydrate, and some are of good protein quality such as soybean meal.
- ▶ Generally, carbohydrates are cheaper sources of energy than lipid or fat sources

Amino acid composition of some fish meals (FM), leaf meals (LM) and other protein sources

| Amino acid | Amount (g/100 g protein) | | | | | | | | | | | | | |
|---------------|--------------------------|-------------|-----------|---------|------------|-------------|------------|--------------|-------------|-----------|--------------|-----------|-------------|--|
| | White FM | Peruvian FM | Sapsap FM | Tuna FM | Tabagak FM | Shrimp meal | Squid meal | Soybean meal | Kangkong LM | Camote LM | Ipil-ipil LM | Acacia LM | Tamarind LM | |
| Alanine | 6.0 | 6.1 | 6.7 | 5.0 | 5.5 | 5.5 | 5.8 | 4.0 | 5.0 | 5.2 | 6.2 | 3.2 | 3.6 | |
| Arginine | 6.2 | 5.5 | 4.0 | 5.4 | 4.7 | 7.1 | 7.5 | 6.0 | 3.3 | 3.7 | 5.2 | 2.2 | 2.4 | |
| Aspartic acid | 9.4 | 8.7 | 9.5 | 8.5 | 8.1 | 8.3 | 10.1 | 11.1 | 8.7 | 10.2 | 11.4 | 6.3 | 7.6 | |
| Cystine | 0.7 | 0.9 | 0.8 | 0.7 | 0.9 | 0.6 | 0.9 | 1.2 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | |
| Glutamic acid | 13.8 | 13.2 | 14.9 | 11.2 | 11.3 | 12.4 | 15.8 | 18.7 | 8.8 | 10.2 | 11.2 | 6.6 | 7.6 | |
| Glycine | 7.0 | 5.4 | 6.4 | 5.2 | 5.3 | 4.9 | 5.7 | 4.0 | 4.3 | 4.7 | 6.0 | 3.2 | 4.0 | |
| Histidine | 2.2 | 1.8 | 3.9 | 5.6 | 2.3 | 2.1 | 2.2 | 3.2 | 2.7 | 2.8 | 1.4 | 3.9 | 4.0 | |
| Isoleucine | 3.9 | 4.1 | 4.5 | 3.9 | 4.2 | 3.8 | 4.2 | 4.5 | 3.4 | 3.7 | 6.6 | 2.4 | 3.0 | |
| Leucine | 7.4 | 7.1 | 7.5 | 6.5 | 6.6 | 6.7 | 7.7 | 7.2 | 6.5 | 7.9 | 6.6 | 4.8 | 5.7 | |
| Lysine | 7.7 | 7.4 | 7.3 | 6.2 | 7.3 | 6.3 | 7.8 | 5.8 | 4.6 | 4.4 | 6.1 | 2.9 | 3.4 | |
| Methionine | 3.0 | 2.8 | 2.9 | 2.3 | 2.8 | 2.4 | 2.8 | 1.4 | 1.5 | 1.8 | 1.2 | 0.9 | 0.9 | |
| Phenylalanine | 4.3 | 3.8 | 3.8 | 3.8 | 3.5 | 3.8 | 3.4 | 5.2 | 5.7 | 6.5 | 3.9 | 3.8 | 4.2 | |
| Proline | 4.3 | 4.2 | 3.5 | 3.7 | 3.0 | 3.2 | 3.8 | 5.5 | 3.9 | 3.8 | 5.5 | 3.6 | 3.8 | |
| Serine | 4.4 | 3.6 | 3.4 | 3.3 | 3.1 | 3.1 | 3.9 | 5.2 | 3.7 | 4.3 | 4.4 | 3.2 | 3.8 | |
| Threonine | 4.2 | 3.9 | 3.9 | 3.6 | 3.7 | 3.6 | 4.1 | 3.8 | 3.9 | 4.4 | 5.1 | 2.7 | 3.6 | |
| Tryptophan | 1.0 | 0.7 | 1.2 | 0.8 | 0.8 | 1.1 | 1.0 | 0.4 | NA | NA | NA | NA | NA | |
| Tyrosine | 3.8 | 3.2 | 4.4 | 2.6 | 3.3 | 3.3 | 3.1 | 2.7 | 4.1 | 6.5 | 3.4 | 3.5 | 3.0 | |
| Valine | 5.1 | 5.2 | 5.2 | 4.5 | 4.9 | 4.3 | 4.3 | 4.4 | 5.3 | 5.8 | 6.3 | 3.5 | 3.9 | |
| % Protein | 70.5 | 70.5 | 66.0 | 77.2 | 78.4 | 71.8 | 78.7 | 43.8 | 31.9 | 30.8 | 27.8 | 25.3 | 15.1 | |

- ▶ Aside from carbohydrates, lipids are also used as sources of energy. They also provide essential fatty acids in fish diets. Examples of commonly used dietary lipid sources are **fish liver oils** and plant oils such as soybean oil and com oil, palm oil etc
- ▶ The choice of a feed ingredient is mainly dependent on the amount of essential nutrients that it contains
- ▶ In complete feed formulations, micronutrients are added in small amounts in the form of **vitamin and mineral mixtures**. Examples of these mixes for crustaceans and fishes are shown in Tables

| | Moisture | Crude Protein | Crude Fat | Crude Fiber | NFE' ** | Ash |
|-------------------------------------|----------|---------------|-----------|-------------|---------|------|
| Animal: | | | | | | |
| Fish meal (FM, local) (6) | 10.3 | 64.1 | 6.5 | 0.8 | 8.5 | 20.1 |
| FM, Chilean (27) | 8.4 | 70.1 | 8.5 | 0.5 | 4.1 | 16.8 |
| FM, Danish (2) | 9.5 | 73.9 | 9.4 | 0.3 | 2.4 | 14.0 |
| FM, Peruvian (30) | 8.3 | 68.3 | 5.9 | 0.8 | 7.7 | 17.3 |
| FM, Peruvian (26) | 7.1 | 67.9 | 10.0 | 1.3 | 4.1 | 16.7 |
| FM, tuna (9) | 9.4 | 65.4 | 8.0 | 0.8 | 8.8 | 17.0 |
| FM, white (11) | 7.2 | 69.0 | 7.6 | 0.6 | 4.8 | 18.0 |
| Prawn head meal (35) | 6.5 | 51.2 | 5.2 | 13.3 | 5.3 | 25.0 |
| Shrimp meal, <i>Acetes</i> sp. (60) | 8.2 | 68.6 | 3.9 | 3.6 | 7.6 | 16.3 |
| Squid meal (60) | 6.9 | 78.5 | 5.5 | 1.3 | 6.7 | 8.0 |
| Squid meal, scrap (4) | 5.5 | 74.1 | 7.1 | 0.9 | 8.1 | 9.8 |
| Frog meal (2) | 7.6 | 62.5 | 1.7 | 1.2 | 4.7 | 29.9 |
| Blood meal (2) | 6.3 | 87.7 | 3.0 | 0.4 | 3.3 | 5.6 |
| Meat and bone meal (19) | 5.6 | 46.8 | 9.6 | 2.0 | 7.5 | 34.1 |



| | Amount (% dry matter) | | | | | |
|------------------------------|-----------------------|---------------|-----------|-------------|---------------------|------|
| | Moisture | Crude Protein | Crude Fat | Crude Fiber | NFE ¹ ** | Ash |
| Plant: | | | | | | |
| Acacia Leaf Meal (LM) (2) | 4.4 | 25.7 | 5.6 | 21.2 | 41.7 | 5.8 |
| Alfalfa LM | 7.2 | 17.2 | 3.0 | 27.7 | 42.9 | 9.2 |
| Camote LM, (7) | 4.5 | 29.7 | 4.9 | 10.0 | 43.2 | 12.2 |
| Cassava LM, (8) | 5.9 | 22.1 | 9.3 | 12.4 | 49.2 | 7.0 |
| Ipil-ipil LM, giant (14) | 7.8 | 25.1 | 6.8 | 10.6 | 44.0 | 13.5 |
| Ipil-ipil LM, native (6) | 10.3 | 29.3 | 8.8 | 11.5 | 43.5 | 6.9 |
| Kang-kong LM (6) | 5.7 | 28.5 | 5.4 | 10.5 | 43.6 | 12.0 |
| Malunggay LM (7) | 3.5 | 30.4 | 8.4 | 8.3 | 43.7 | 9.2 |
| Papaya LM (10) | 5.4 | 20.7 | 11.6 | 11.2 | 42.6 | 13.9 |
| Copra meal (10) | 7.9 | 22.0 | 6.7 | 17.3 | 44.3 | 9.7 |
| Cowpea (7) | 8.0 | 23.0 | 1.3 | 4.1 | 67.5 | 4.1 |
| Cowpea, dehulled (2) | 7.7 | 25.4 | 0.9 | 1.4 | 68.3 | 4.0 |
| Mungbean, green (5) | 7.1 | 23.2 | 1.2 | 3.1 | 68.7 | 3.8 |
| Mungbean, yellow (5) | 7.7 | 24.1 | 1.1 | 3.8 | 67.1 | 3.9 |
| Rice bean (2) | 5.0 | 26.5 | 0.8 | 4.0 | 64.6 | 4.1 |
| Corn meal (10) | 8.4 | 7.8 | 4.7 | 2.6 | 83.1 | 1.8 |
| Cornstarch (5) | 11.9 | 0.4 | 0.2 | 1.1 | 98.2 | 0.1 |
| Flour, bread (40) | 12.1 | 12.9 | 1.2 | 0.3 | 84.9 | 0.7 |
| Flour, whole wheat (15) | 11.3 | 15.3 | 1.7 | 0.8 | 81.1 | 1.1 |
| Wheat, Pollard (4) | 9.5 | 15.4 | 4.5 | 10.3 | 64.0 | 5.8 |
| Germ, wheat (2) | 6.0 | 27.8 | 4.3 | 3.4 | 59.6 | 4.9 |
| Gluten, corn (5) | 7.3 | 62.6 | 7.7 | 2.2 | 25.9 | 1.6 |
| Gluten, wheat (6) | 8.9 | 80.7 | 1.4 | 0.4 | 16.4 | 1.1 |
| Rice bran (78) | 9.2 | 13.3 | 14.1 | 8.5 | 53.4 | 10.7 |
| Rice bran, tiki-tiki (5) | 10.7 | 18.0 | 2.0 | 8.0 | 62.4 | 9.6 |
| Rice hull (7) | 7.0 | 3.3 | 2.0 | 32.4 | 41.6 | 20.7 |
| Soybean meal, as is (21) | 5.6 | 35.8 | 19.8 | 4.9 | 33.9 | 5.6 |
| Soybean meal, defatted (108) | 8.4 | 43.6 | 1.5 | 5.5 | 41.7 | 7.7 |



Amount (% dry matter)

| | Moisture | Crude Protein | Crude Fat | Crude Fiber | NFE** | Ash |
|-------------------------|----------|---------------|-----------|-------------|-------|------|
| Other sources: | | | | | | |
| Casein (11) | 7.2 | 89.7 | 0.1 | 0.3 | 8.9 | 1.0 |
| Crab meal (2) | 4.2 | 37.9 | 4.1 | 10.7 | 8.9 | 38.4 |
| Gelatin (6) | 7.9 | 94.4 | 0.0 | 0.1 | 5.1 | 0.4 |
| Mussel meal, green (30) | 5.9 | 64.6 | 8.6 | 3.0 | 12.5 | 11.8 |
| Oyster meal (6) | 4.4 | 54.6 | 9.4 | 4.0 | 20.1 | 11.9 |
| Scallop meal (2) | 7.3 | 65.2 | 10.9 | 1.4 | 8.8 | 13.7 |
| Snail meal, kuhol (5) | 4.0 | 52.1 | 1.8 | 2.1 | 15.7 | 28.3 |
| Yeast, Brewers (2) | 7.2 | 49.4 | 1.6 | 2.4 | 34.5 | 12.1 |

| | Amount (% dry matter) | | | | | |
|-----------------------------------|-----------------------|---------------|-----------|-------------|--------|------|
| | Moisture | Crude Protein | Crude Fat | Crude Fiber | NFE ** | Ash |
| Yeast, <i>Candida</i> (3) | 8.3 | 55.2 | 0.8 | 1.7 | 35.1 | 7.4 |
| Natural Food: | | | | | | |
| <i>Acartia</i> sp. (copepods) | 7.8 | 71.2 | 8.3 | 5.4 | 9.9 | 5.2 |
| <i>Artemia</i> (37) | 8.0 | 55.5 | 6.8 | 11.3 | 15.0 | 11.4 |
| <i>Azolla</i> (2) | 8.0 | 27.2 | 3.4 | 12.9 | 36.5 | 20.0 |
| <i>Brachionus</i> sp.(5) | 8.1 | 51.9 | 10.4 | 3.5 | 15.3 | 18.9 |
| <i>Chaetoceros calcitrans</i> (7) | 7.6 | 24.4 | 7.1 | 2.5 | 26.7 | 39.3 |
| <i>Chlorella</i> , marine (3) | 10.1 | 35.1 | 4.2 | 5.6 | 27.7 | 27.4 |
| <i>Isochrysis galbana</i> (2) | 10.4 | 33.6 | 18.1 | 4.4 | 23.0 | 20.9 |
| <i>Moina macrocopa</i> (3) | 8.5 | 57.8 | 7.6 | 8.4 | 17.2 | 9.0 |
| <i>Sargassum</i> (2) | 10.4 | 9.0 | 0.8 | 9.6 | 46.4 | 34.2 |
| <i>Skeletonema</i> sp. (4) | 10.4 | 24.7 | 2.6 | 0.7 | 20.2 | 51.8 |
| <i>Spirulina</i> (2) | 8.0 | 56.7 | 2.8 | 0.6 | 28.1 | 11.8 |
| <i>Tetraselmis</i> sp. (4) | 5.5 | 49.1 | 10.7 | 2.1 | 19.0 | 19.1 |
| Digman (4) | 9.8 | 20.6 | 3.3 | 16.4 | 35.9 | 23.8 |
| <i>Enteromorpha</i> (lumot) (15) | 15.2 | 13.8 | 1.9 | 9.3 | 36.9 | 38.1 |
| <i>Gracilaria</i> sp. (18) | 7.0 | 10.2 | 0.4 | 5.8 | 44.8 | 38.8 |
| <i>Kappaphycus</i> sp. (10) | 6.1 | 5.4 | 0.8 | 6.1 | 57.3 | 30.4 |

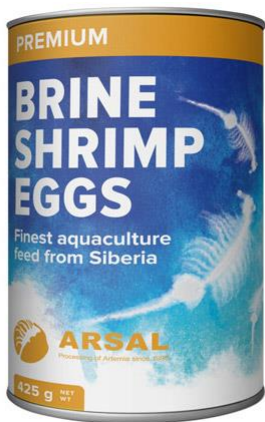


Table 4.6 Recommended vitamin mixture for warmwater fishes such as milkfish, sea bass, and catfish *

| Vitamin | Amount (per kg) in dry diet ^a | |
|---------------------------------|--|------------------------|
| | Supplemental | Complete |
| Vitamin A activity | 2,000 IU | 5,500 IU |
| Vitamin D ₃ activity | 220 IU | 1,000 IU |
| Vitamin E | 11 IU | 50 IU |
| Vitamin K | 5 mg | 10 mg |
| Choline | 440 mg | 550 mg |
| Niacin | 17-28 ^b mg | 100 mg |
| Riboflavin | 2-7 ^b mg | 20 mg |
| Pyridoxine | 11 mg | 20 mg |
| Thiamin | 0 | 20 mg |
| Calcium pantothenate | 7-11 ^b mg | 50 mg |
| Biotin | 0 | 0.1 mg |
| Folacin | 0 | 5 mg |
| Vitamin B ₁₂ | 2-10 mg | 20 mg |
| Ascorbic acid | 0-100 ^b mg | 30-100 ^b mg |
| Inositol | 0 | 100 mg |

^a These amounts do not allow for processing or storage losses.
^b Highest amounts are appropriate when "standing crop" of fish exceeds 500 kg/hectare.
^c Source: NRC 1977.

Table 4.7 Mineral mixtures for purified and practical warmwater fish diets*

| Mineral | Dry Diet (g/100g) |
|---------------------------------------|-------------------|
| <i>Practical Diets</i> | |
| CaCO ₃ | 0.750 |
| MnSO ₄ ·H ₂ O | 0.030 |
| ZnSO ₄ ·7H ₂ O | 0.070 |
| CuSO ₄ ·5H ₂ O | 0.006 |
| FeSO ₄ ·7H ₂ O | 0.050 |
| NaCl | 0.750 |
| KIO ₃ | 0.0002 |
| CaHPO ₄ ·2H ₂ O | 2.00 |
| <i>Purified Diets</i> | |
| CaHPO ₄ ·2H ₂ O | 2.07 |
| CaCO ₃ | 1.48 |
| KH ₂ PO ₄ | 1.00 |
| KCl | 0.10 |
| NaCl | 0.60 |
| MnSO ₄ ·H ₂ O | 0.035 |
| FeSO ₄ ·7H ₂ O | 0.05 |
| MgSO ₄ | 0.30 |
| KIO ₃ | 0.001 |
| CuSO ₄ ·5H ₂ O | 0.003 |
| ZnCO ₃ | 0.015 |
| CoCl ₂ | 0.00017 |
| NaMoO ₄ ·2H ₂ O | 0.00083 |
| Na ₂ SeO ₃ | 0.00002 |

FISH PREMIX

Cat No. 770701900

0.5% Vitamins and Trace Minerals Premix for Fish

MIXING INSTRUCTION
5kg Per 1 ton of Final Feed

GUARANTEED ANALYSIS FOR 5KG

| | | | | | |
|-------------|---------------|------------------|-----------|------------|-------------|
| Vitamin A | 20,000,000 IU | Folic Acid | 5,000 mgr | Iron | 40 gr |
| Vitamin D3 | 4,000,000 IU | Panith Acid | 50,000mgr | Copper | 4 gr |
| Vitamin E | 200,000 IU | Biotin | 400 mgr | Iodine | 5 gr |
| Vitamin K | 1,200 mgr | Antioxidant | 125 gr | Selenium | 0.2 mgr |
| Vitamin B1 | 10,000 mgr | Vitamin C | 150 gr | Cobalt | 0.2 mgr |
| Vitamin B2 | 30,000 mgr | Choline Chloride | 400 gr | Calcium | 600 gr |
| Vitamin B6 | 19,000 mgr | Manganese | 30 gr | Lysine | 100,000 mgr |
| Vitamin B12 | 1,000 mgr | Zinc | 40 gr | Phosphorus | 4,000 gr |
| Niacin | 200,000 mgr | | | Methionine | 100 gr |

VETERINARY USE ONLY
NOT FOR HUMAN CONSUMPTION

Batch No.....
 Manufacturing Date.....
 Expiry Date.....
 NAFDAC Reg. Number.....

Store in a cool and dry place away from sunlight

Produced by:
AGRO BAR-MAGEN NIG. LTD.

OFFICE: ABMN House, BCGA Compound behind Conoil Filling Station,
Gbekeba Road, Off Apata Road, Ibadan, Oyo State.
Tel: 07031228564, 08033136621, 08065865062.
E-mail: abmn@bar-magen.com

5kg

AQUA GROW-UP

EACH 1KG CONTAINS :

| | | | |
|-------------------------|-----------|------------------------|----------|
| MULTI VITAMINS : | | TRACE MINERALS: | |
| Vitamin A | 5000 IU | Calcium | 225 mg |
| Vitamin D3 | 1000 IU | Cobalt | 20.00 mg |
| Vitamin B1 | 10.00 mg | Magnesium | 60.00 mg |
| Vitamin B2 | 10.00 mg | Iron | 30.00 mg |
| Vitamin B6 | 5.00 mg | Copper | 2.00 mg |
| Vitamin B12 | 15.00 mcg | Zinc | 2.00 mg |
| Vitamin B3 | 75.00 mcg | Potassium | 20.00 mg |
| Vitamin B5 | 15.00 mg | Manganese | 2.00 mg |
| Vitamin C | 10.00 mg | Choline Chloride | 50.00 mg |
| Vitamin E | 150.00 mg | | |
| Vitamin H | 25.00 mg | | |
| Vitamin B9 | 5.00 mg | | |

STORAGE & DRY PLACE
PROTECT FROM DIRECT SUNLIGHT
USE FOR MEDICAL USE
IMMEDIATELY FEED SUPPLEMENT

BENEFITS

1. Prevents Vitamin & Mineral Deficiency
2. Gives Quick Relief From The Stress Caused Due to Transportation/handling
3. Clinical Disturbances and other Stress Factors
3. Reduce Mortality Ratio
4. Aids in Maintaining Immunity
5. Enhances Body Weight & Growth
6. Helps to Give Better FCR

USAGE AND ADMINISTRATION

Fish, Prawns & Shrimps
10-20 gm/kg of feed

Mfg. by
ANPOTAL NUTRITIONS
P.O. Box 2000, Ibadan, Oyo State

Batch No: AGP-
Mfg Date:
Use Before:
M.S.P. Rate:
(incl of all taxes)

Feed Formulation

- ▶ Feed formulation is a process that involves combining various feed ingredients, which contain different amounts of nutrients, so that the resulting composition would meet the specific requirement of the cultured species.
- ▶ The nutrient levels of feed ingredients to be used are balanced mathematically in order to come up with the desired final composition.
- ▶ The two most important factors to consider in formulating a feed for any aquaculture species are **nutrient requirements** and **feeding behavior**.
- ▶ Other factors to consider are the stages in the life cycle (larval, grow-out or broodstock) and the type of culture system.

- ▶ Feedstuffs should first be analyzed for their **proximate composition**, but if this is not possible, **feed composition tables (FCT)** can be used as guide in formulating feeds.
- ▶ There is no **definite feed formula** for any species because of the many **environmental and physiological factors** involved as well as differences in the availability of feed ingredients from one locality to another
- ▶ Substitution of a feedstuff or feedstuffs in the formula is possible provided that the **final formulation is similar** in nutrient content and there are **no negative effects** on growth and survival and increase in feed cost.
- ▶ Feeding experiments have shown that favorable results are obtained as long as the amounts of nutrients **present do not exceed the recommended nutrient levels**. **Excess of nutrients can be expensive**, and can cause deterioration of the culture system.
- ▶ Maximum levels of incorporation of some feedstuffs in the formula for carnivores, omnivores, and herbivores are listed in Table BELOW

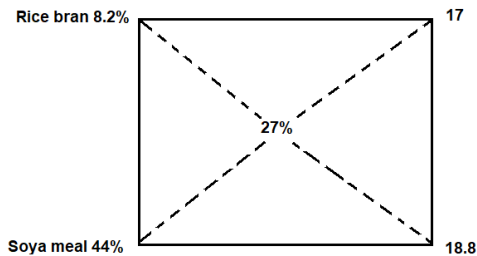
| Feedstuffs | Fish | | Shrimp | |
|------------------------------------|-----------|------------------------|-----------|------------------------|
| | Carnivore | Omnivore/ Herbivore | Carnivore | Omnivore/ Herbivore |
| Alfalfa meal | 5 | 10 | 5 | 10 |
| Blood meal, spray dried | 10 | 10 | 10 | 10 |
| Cassava/Tapioca meal | 15 | 35 | 15 | 25 |
| Coconut meal | 15 | 25 | 15 | 25 |
| Corn grain meal | 20 | 35 | 15 | |
| Corn gluten meal | 15 | 20 | 15 | 20 |
| Cottonseed meal, solvent extracted | 15 | 20 | 10 | 15 |
| Corn distillers | 10 | 15 | 10 | 15 |
| Dicalcium phosphate | 3 | 3 | 3 | 3 |
| Hydrolyzed feather meal | 10 | 10 | 10 | 10 |
| Fish meal | no limit | no limit | 20 | 35 |
| Fish protein concentrate | 15 | 10 | 15 | 15 |
| Ground meal, solvent extracted | 15 | 25 | 15 | 25 |
| Liver meal | 50 | 50 | 25 | 20 |
| Meat and bone meal, | 20 | 25 | 15 | 20 |
| Poultry by-product meal | 15 | 20 | 15 | 20 |
| Rapeseed meal, solvent extracted | 20 | 25 | 15 | 20 |
| Rice bran, solvent extracted | 15 | 35 | 15 | 35 |
| Shrimp meal | 25 | 25 | no limit | no limit |
| Squid meal | no limit | no limit | no limit | no limit |
| Sorghum meal | 20 | 35 | 15 | 35 |
| Soybean meal, solvent extracted | 25 | 35 | 20 | 30 |
| Soybean meal, full fat | 35 | 40 | 20 | 30 |
| Wheat grain meal | 20 | 35 | 20 | 35 |
| Wheat bran | 15 | 30 | 15 | 30 |
| Wheat gluten meal | 15 | 15 | 20 | 20 |
| Wheat middlings | 25 | 40 | 20 | 35 |
| Whey | 10 | 10 | 10 | 10 |
| Yeast (Brewers), dried | 15 | 15 | 15 | 15 |

Recommended maximum inclusion levels (%) of some major feed ingredients in a practical diet for fish and shrimp

- ▶ There are several methods of formulating feeds. These are **Pearson's Square Method, Algebraic Equation, Trial and Error, and Linear Programming**.
- ▶ The Pearson's Square method is recommended in formulating a **supplemental feed** with only **two to four** ingredients
- ▶ The Trial and Error method is generally used in calculating a formula for a complete diet with many ingredients.
- ▶ In **commercial feed production** where cost is a principal consideration, a computer program (Linear Programming) is used to combine feed ingredients that will give an effective formulation with the lowest cost.

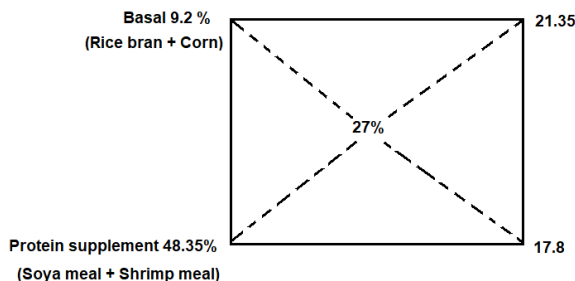
Pearson square method

- ▶ For example, suppose rice bran and soybean meal were available as feedstuffs to prepare a diet for carp that was 25 % crude protein
- ▶ The desired protein level of the feed is placed in the middle of the square. Next, the protein level of the feed is subtracted from that of the feedstuffs, placing the answer in the opposite corner from the feedstuff. Ignore positive or negative signs.



- To make the 27 percent crude protein carp feed, we must mix 17/35.8 of rice bran with 18.8/35.8 soybean meal.
- Rice Bran $17/35.8 = 47.5\%$
Soybean meal $18.8/35.8 = 52.5\%$
- So to make 100 kg of this feed we must mix **47.5 kg** of rich bran with **52.5 kg** of soybean meal.

- ▶ If more than two feedstuffs are used in a feed, they may be grouped into basal feeds (CP < 20 percent) and protein supplements (CP > 20 percent), averaged within each group, and plugged into the square method.
- ▶ For example, suppose shrimp meal and corn were also available for the carp feed mentioned above. The crude protein levels of the shrimp meal (52.7 percent) and of corn (10.2 percent) are averaged with soybean meal and rice bran, respectively.



- Basal feed = $21.35/39.15 = 54.53\%$
- Protein supplement = $17.8/39.15 = 45.47\%$
- Thus, to make 100 kg of this feed one would mix the following;
- Rice bran = 27.265%
- Corn = 27.265%
- Soya meal = 22.735%
- Shrimp meal = 22.735%

Linear Program for Least-Cost Formulation

- ▶ Linear programming is used when many ingredients are to be combined for a least cost feed formula. This method is especially useful in commercial feed manufacture wherein large quantities of feed ingredients are used
- ▶ A computer is necessary in this type of formulation. When one or more ingredients are not available, other feed ingredients are utilized as substitutes in order to come up with the same feed quality
- ▶ The quantities of substitute ingredients are determined using the linear programming method
- ▶ Information on the amounts of nutrients in each of the feed ingredients to be used is essential in this method. This can be obtained from a feed composition table or chemical analysis
- ▶ A computer program will list several combinations to come up with almost similar feed quality at a lesser cost.
- ▶ Examples of computer program for least cost formulation are **WUFFDA** EXCEL based program and **feedCalculator** and Android based program

Feed formulation software

WUFFDA

- ▶ WUFFDA is a Microsoft Excel Workbook for least-cost feed formulation.
- ▶ To use it, you must have Microsoft Excel on your computer. The Instructions file explains how to use the program and requires Microsoft Word. The PowerPoint file shows how to use the program and requires Microsoft PowerPoint.
- ▶ <https://secure.caes.uga.edu/extension/publications/files/html/RB438/WUFFDA-English.html>

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SysnovaFeed is a revolutionary free/open-source least-cost feed formulation software by Sysnova Information Systems Limited.

SysnovaFeed software is a comprehensive free/open-source tool designed to meet the formulation needs of professional nutritionists and feed producers.

- The free/open-source nature of SysnovaFeed also makes it ideal for use in academic institutions and universities.
- SysnovaFeed is user-friendly and simple to download and set up on any desktop or laptop computer.
- SysnovaFeed is customizable and easily allows any nutritionist to enter unlimited numbers of ingredients and formulations.

SysnovaFeed aims to bring benefits of the free/open-source software movement to the global livestock industry.

<https://www.sysnova.com/SysnovaFeed>

THE FEEDCALCULATOR APP
Your partner in feed optimization, training & technical support of farms and feedmills

> 83.000 app downloads worldwide
4.9 star Google review rating!

GET IT ON Google Play



The FREE FeedCalculator generates least-cost & high quality feed recipes based on locally available ingredients.

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For farmers & Feed Mills

Be in charge of your own feed! This app can formulate feed recipes for **broilers, layers, pigs, catfish & tilapia**. Dairy will be available soon!

Least cost feed recipes

The smart algorithm in the app always calculates recipes for the **lowest possible price** based on locally available ingredients and prices.

Quality guaranteed!

All recipes formulated by the Feedcalculator are meeting the animal specific feed requirements and are based on **international feed standards**.

TYPES OF FEEDS

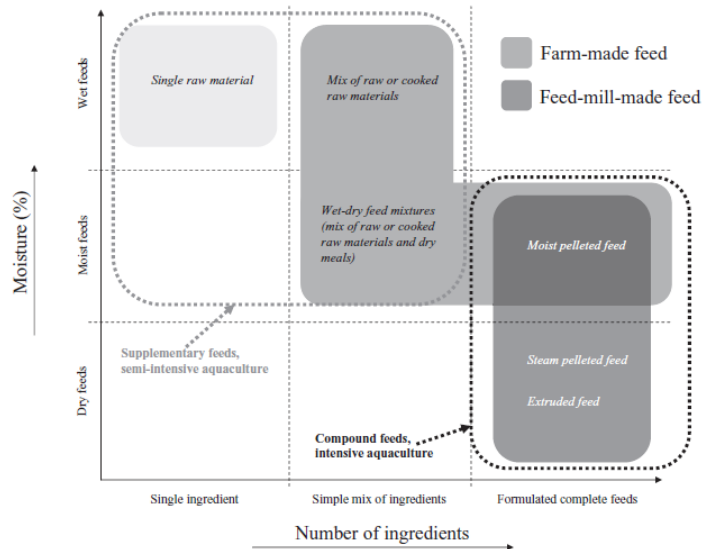
- ▶ The feed types range from single ingredients to a mix of ingredients, cooked or raw, to moist and dry formulated feeds, and essentially reflect the type of practice.

1. Single-ingredient:

- ▶ mostly used in semi-intensive aquaculture of omnivorous fish species such as carp.
- ▶ These types of feed, including single ingredients, a mix of ingredients, cooked or raw, are generally referred to as supplementary feeds as these augment the food produced within the culture system and contribute to the nutrition of the stock

2. Formulated feed

- Farm-made feed – mostly wet and moist feeds
- Industrial feed - dry pelleted feed.
- ▶ Dry pelleted feed can be further classified into steam-pelleted or extruded feeds, according to the technology used,



Schematic representation of different types of feed grouped relative to the number of ingredients used and the moisture content of the final product.

a. Wet, moist and semi-moist feeds

- ▶ commonly includes the utilisation of a mix of different fresh or frozen raw materials, such as fish- or seafood derived by-products, meat and poultry offal or other agricultural-derived by-products, and these feeds usually contain more than 60% moisture.
- ▶ Addition of silage combined with dry meals, including for example plant-derived meals, fish meal and animal by-product-derived meals to reduce the moisture content.
- ▶ Likewise, oils and/or vitamin and mineral mixtures are included to increase the overall water stability and nutritional value of the feed.
- ▶ These feeds are nutritionally wholesome, with the formulations including different dry and wet ingredients, plus vitamins and minerals, as required.
- ▶ The ingredients are ground and mixed and the dough is passed through a spaghetti/noodle type machine and cut to specific lengths; the resulting pellets have a relatively high moisture content (30–35%) and need to be utilised rapidly.



▶ **Compounded/commercial dry pelleted feeds**

- ▶ Dry feeds are currently the most commonly used feeds in intensive aquaculture such feeds are conveniently transported for distribution, easily stored and handled, have a longer shelf-life and are generally consistent in quality
- ▶ Dry feeds commonly have less than 10% moisture, can be produced in a wide range of pellet shapes and sizes and are commonly produced by two different methods: steam or extrusion pelleting



▶ **Extrusion**

- ▶ Extrusion technology the mixture of ingredients is processed at a higher pressure and temperature.
- ▶ Pellets obtained by the extrusion process are tougher (as the starch will be fully gelatinized), and, via the modification of the extrusion parameters, sinking or floating feeds can be produced.
- ▶ A further advantage of extruded pellets is the fact that very large quantities of oil can be added to the feed, up to 40% in weight, producing the high-energy diet (HED)

Types of fish pellets

- Sinking
 - Must be fed slower
 - Hard to observe fish behavior
- Floating
 - Has air pockets
 - Easier to observe fish behavior

Feed Rates

- Dependent on:
 - Management strategy
 - Feed type and size
 - Species size and density
 - Water temperature and quality
 - Weather

FORMS/TYPES OF FEEDS

- ▶ **Mash or powder form:** This is given to fish weighing < 0.2g. to 5.0g./pc. This is known as the fry mash
- ▶ **Crumbles:** This is given to fish weighing 5.1g. to 30.0g./pc. This is also known as the starter crumbles
- ▶ **Pellets:** This is given as soon as the mouth of fish is big enough to swallow the smallest size of pellet
- ▶ **A. Juvenile Pellet.** This is known as the grower pellet. It is given to fish weighing 30.1 to 90.0g./pc.
- ▶ **B. Adult Pellet.** This is known as the finisher pellet. It is given to fish weighing greater than 90.0g./pc.

Example of Novatek fish feed

| Aquaculture (Extruded / Floating feeds) | | Fish age, weight gain over period - Culture system | | |
|---|---------------------------------------|--|----|-------|
| 181AQ002 | Fish Broodstock (5mm Extruded) | >250gr Fish size | 25 | K 371 |
| 179AQ000 | Fish Post Hatch 45% MT (0.2mm Powder) | 0-3wks, 0 to 0.2gr - Cage/Pond | 3 | K 96 |
| 179AQ000 | Fish Fry 45% (0.2 Powder / 0.5 Mash) | 0 - 1wks, 2-5gr - Cage/Pond | 15 | K 275 |
| 179AQ000 | Fish Juvenile 45% (1mm Crumble) | 2 - 4wks, 5-20gr - Cage/Pond | 15 | K 275 |
| 179AQ000 | Fish Juvenile 45% (2mm Crumble) | 5 - 7wks, 20-40gr - Cage/Pond | 15 | K 275 |
| 180AQ001 | Fish Pre-Starter 40% (2mm Extruded) | 5 - 8wks, 20-50gr - Cage/Pond | 25 | K 399 |
| 180AQ001 | Fish Pre-Starter 40% (3mm Extruded) | 8 - 12wks, 50-90gr - Cage/Pond | 25 | K 399 |
| 181AQ002 | Fish Starter 38% (4mm Extruded) | 13-18wks, 90-250gr - Cage/Pond | 25 | K 371 |
| 182AQ003 | Fish Grower 32% (5mm Extruded) | 19-24wks, 250-450gr - Cage/Pond | 25 | K 333 |
| 183AQ004 | Fish Finisher 24% (5mm Extruded) | 22-24wks, 350-500gr - Cage/Pond | 25 | K 321 |
| 184AQ005 | Pond Fish 18% (5mm Extruded) | >180gram fish size - Clear Pond | 25 | K 175 |
| 185AQ006 | Fish Green Pond (5mm Extruded) | >180gram fish size - Fertilised Ponds | 25 | K 151 |
| 187AQ280 | Catfish Weaner 48% | Catfish Weaner 48% | 15 | K 322 |
| 188AQ300 | Catfish Starter 42% | Catfish Starter 42% | 15 | K 517 |
| 189AQ310 | Catfish Hatchery | Catfish Hatchery | 15 | K 386 |
| 190AQ310 | Catfish Pre-Gower 36% | Catfish Pre-Gower 36% | 25 | K 437 |
| 191AQ320 | Catfish Grower 32% | Catfish Grower 32% | 25 | K 403 |

Feeding Strategies

- Ad libitum or Satiation
 - Feed all fish will eat during timed period
 - 2-4x/day
 - Farmer understands his/her 'fish personalities'
- Percent Body Weight/Day
 - Based on growth rate, FCR, and survival
 - Requires frequent sampling
 - Divide daily ration; fed 2-4x/day

FEEDING RATIO

- ▶ It is the amount of feed being fed daily to the fish. It is also expressed as percentage of fish biomass

| Feeding Strategies | Size of Fish | Feeding |
|--------------------------------------|----------------------|------------|
| Fertilization + Supplemental Feeding | Fry | 10-5 % BW |
| | Fingerlings | 5-3 |
| | Juvenile | 3-2 |
| | Market Size/ Breeder | 3-2 |
| Complete Feeding | Fry | 30-15 % BW |
| | Fingerlings | 10-15 |
| | Juvenile | 10-5 |
| | Market Size/ Breeder | 5-2 |

- ▶ Feeding rates are affected by water temperature. Fish of all size eat less and stop taking feed as water decreases or increases beyond their optimum range.

Feeding chart

Suggested feeding chart for tilapia

| ESTIMATED WEIGHT | FEED RATE | FEEDING FREQUENCY | FEED TYPE | FEEDING TIME AND ALLOCATION OF FEED | | | | |
|------------------|-----------|-------------------|-----------|-------------------------------------|--------|--------|-------|-------|
| | | | | 8hrs | 10 hrs | 12 hrs | 14hrs | 16hrs |
| Grams | % | Per day | | | | | | |
| <0.5 | 20 | 5X | Fry mash | 5% | 15% | 30% | 30% | 20% |
| 0.5 - 5 | 15 | 4X | Fry mash | | 20% | 30% | 30% | 20% |
| 5 - 22 | 10 | 4X | Juvenile | | 20% | 30% | 30% | 20% |
| 22 - 75 | 5 | 3X | Starter | | 20% | 40% | 40% | |
| 75 - 150 | 3 | 3X | grower | | 20% | 40% | 40% | |
| 150 - 250 | 2 | 3X | finisher | | 20% | 40% | 40% | |
| >250 | 1.5 | 2X | finisher | | 40% | | 60% | |

How to use the feeding table:

| Explanation | Calculation |
|---|---|
| Data from your records | Average body weight sampling of fish: 123 g Number of fish: 750 Pieces |
| Total weight of fish in the pond: Weight x number of fish | $123\text{g} \times 750\text{ pieces} = 92,250\text{ g} / 1,000 = 92,25\text{ Kg}$ rounded is 92 Kg. |
| Lookup in the table the size of the pellets: | A fish weighing 123g, best pellet size is 3 mm , daily feeding rate is 3.2% of the body weight |
| Total amount to feed daily to your fish: Weight of fish in the pond x daily feeding rate | $3.2\% = 0.032$ (if you use your phone to calculate) $92\text{ Kg} \times 0.032 = 2.944\text{ Kg} \approx 2.9\text{ Kg}$ |
| Feeding portions (for this example 2 portions): | Morning feed : $2.9 / 2 = 1.45\text{ Kg}$ Afternoon feed : $2.9 / 2 = 1.45\text{ Kg}$ |

Feed Presentation

- Hand feeding
 - Advantages
 - Fish behavior observation by feeders detecting problems at source
 - Healthy, vigorous feeding and only just enough fed at any one time since humans can detect when fish have had enough
 - Disadvantages
 - Labor intensive
- Demand feeder
 - Advantages
 - Ad libitum, less labor
 - Disadvantages
 - Nature, higher FCR, fish bullies eat more than others, frequently breaks and fouls water causing mass fish die-off, capital costs

Feed Storage

- Inadequate storage leads to nutrient loss
 - Sunlight = vitamin loss
 - Heat = rancid fats
 - Damp = molds
- Cool, dry place
 - Air-conditioned room
 - Use before expiration date (3 months)
 - Don't stack higher than 10 on pallet
 - First in, first out strategy
- Rodent resistant
 - Rodents eat feed and defecate on it, introducing pathogens.

DETERMINATION OF AVERAGE BODY WEIGHT (ABW), DAILY FEED RATION (DFR), TOTAL FEED REQUIREMENT (TFR) AND FEED CONVERSION RATIO (FCR)

- a. **ABW (g)**
= $\frac{\text{total wt. of fish randomly sampled}}{\text{No. of fish sampled}}$
- b. **DFR**
= ABW x stocking density x feeding rate
- c. **TFR**
= DFR x feeding duration
- d. **FCR**
= $\frac{\text{Amount of feeds consumed (kgs.)}}{\text{Wet weight gain of fish (kgs.)}}$

The closer the FCR to 1.0 kg, the better is the feed. Good feeds have FCR's of between 1.5 to 2.0 kg.

END OF TOPIC