Lecture Notes on Fish Nutrition

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Semester - IV
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A. Nutritional Requirement of Fish

Good nutrition in animal production systems is essential to economically produce a healthy, high quality product. In fish farming, nutrition is critical because feed represents 40-50% of the production costs. Fish nutrition has advanced dramatically in recent years with the development of new, balanced commercial diets that promote optimal fish growth and health. The development of new species-specific diet formulations supports the aquaculture (fish farming) industry as it expands to satisfy increasing demand for affordable, safe, and high-quality fish and seafood products.

Digestive system structures and functions in fish –

Structure	Functions
Teeth	Grasping, holding, crushing, depending on species
Pharynx	Opening to the gills
Esophagus	Short, Simple passage to 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 cecum	Secretes enzymes for digestion; Increased surface area for absorption of nutrients
Intestine	Secretes enzymes for digestion; Increased surface area for absorption of nutrients
Gall bladder	Stores and releases bile for digestion and absorption of fats
Liver	Synthesis or storage from absorbed nutrients, production of bile, removal of some waste products from blood

Feeding type and anatomy –

Fish can be divided into three types of eaters

1. 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
1. small mammal.
2. Herbivores subsist primarily on vegetation and decayed organic material in the environment.
3. Omnivores consume almost any food source, either plant or animal origin.

Certain anatomic changes in the mouth of fish occurred through evolutionary development. Fish can be classified according to their feeding habits into the following categories:

1. Predators: Trout are an example of fish that feed on animals generally large enough to be seen with the naked eye. Teeth are well developed and act as a means of grasping and holding the prey. Some predator relies primarily on sight to hunt, whereas others rely on the senses of taste and touch or on lateral line sense organs.
2. Grazers: The mullet is an example of a fish that grazes in the same sense as mammalian grazers. Generally, mullets graze continuously on the bottom of the water habitat for either plants or small animal organisms. Food is taken in well-defined bites.

3. Strainers: The menhaden is an example of a fish that selects food primarily by size rather than type. An adult menhaden can strain in excess of 6 gal of water per minute through its gill rakers. Through this process of rapid straining, the menhaden able to concentrate a relatively large mass of plankton and other organisms.
4. Suckers: The buffalo fish is an example of a fish that feed primarily on the bottom of its habitat, sucking in mud and filtering and extracting digestible material.
5. Parasites: Some fish, like the lamprey, attach themselves to other animals and exist on the host's body fluids.

Requirements of protein –

Different fish with different feeding habits require different percentage of protein in their diet for optimum growth performance in aquaculture. Proteins are long chains of amino acids linked by bonds called peptide bonds. All amino acids contain nitrogen, so all proteins contain nitrogen. In fact, measuring nitrogen content is a method of calculating protein content. Metabolism of protein for energy produces nitrogen end products. Fish eliminate these through gills, faeces and urine. These nitrogen end products can cause problems in fish ponds. Protein is the major concern during formulation of fish feed. It is the most expensive for fish feed and the most important factors that contributing to the growth performance of cultured species.

Protein serves three purposes in the nutrition of fish:

1. Provide energy
2. Supply amino acids
3. Meet requirements for functional proteins- enzymes and hormones and structural proteins.

The requirement for protein in fish diets is essentially a requirement for the amino acids in the dietary proteins. Some amino acids the fish cannot synthesis are called indispensable or essential amino acids –

1. Arginine
2. Valine
3. Histidine
4. Isoleucine
5. Leucine
6. Lysine
7. Methionine
8. Threonine
9. Tryptophan
10. Phenylalanine

Protein levels in aquaculture feeds generally average 18-20% for marine shrimp, 28-32% for catfish, 32-38% for tilapia, 25-30% in Indian Major Carps (under ideal pond condition).

Requirements of carbohydrates –

In fish, carbohydrates are stored as glycogen that can be mobilized to satisfy energy demands. They are a major energy source for mammals, but are not used efficiently by fish. For example, mammals can extract about 4 kcal of energy from 1 gram of carbohydrate, whereas fish can

only extract about 1.6 kcal from the same amount of carbohydrate. Up to about 20% of dietary carbohydrates can be used by fish.

Since carps in general, and IMC in particular, are generally herbivorous, carbohydrates can be used as a cheap energy source. It has been reported for rohu fingerlings that a minimum level of 40 percent dietary carbohydrate is required (at a protein level of 35 percent) for optimum growth, feed conversion and nutrient utilization.

Requirements of Lipid –

Each gram of fat contains 2.5 times the energy in a gram of carbohydrates or proteins. The digestibility of fat varies, depending on –

1. Amount in the diet
2. Type of fat
3. Water temperature
4. Degree of unsaturation
5. Length of carbon chain

The optimum lipid requirement for IMC fingerlings was found to be in the range of 12-15 percent. However, lipid requirement has been shown to be temperature dependent. For adult fishes' dietary fat requirement varies between 1-8% in different pond condition and temperature.

Requirements of vitamins –

Vitamins are organic compounds necessary in the diet for normal fish growth and health. They often are not synthesized by fish, and must be supplied in the diet.

The two groups of vitamins are water-soluble and fat-soluble.

Water-soluble vitamins include:

1. Thiamine
2. Riboflavin
3. Pyridoxine
4. Pantothenic
5. Niacin
6. Biotin
7. Folate
8. Vitamin B12
9. Choline
10. Myoinositol
11. Vitamin C

Functions -

a. Choline function as a –
    - ✓ Component of membranes
    - ✓ Precursor of acetylcholine, a chemical for nerve transmission
    - ✓ Provider of methyl groups for chemical reactions

b. Myoinositol is also a component of membranes and is involved in sending signals during several body processes.
c. Vitamin C is involved in the 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.
d. 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.

The fat-soluble vitamins are -

1. Vitamin A
2. Vitamin D
3. Vitamin E
4. Vitamin K

Functions -

Fat soluble vitamins are absorbed in the intestine along with fats in the diet. Unlike water soluble vitamins, fat soluble vitamins can be stored in body tissues. Excessive amounts in the diet can cause a toxic condition called hypervitaminosis.

Functions of the fat-soluble vitamins are quite specific.

a. 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.
b. Vitamin D helps the body mobilize, transport, absorb and use calcium and phosphorous. It works with two hormones from an endocrine gland, the parathyroid.
c. Vitamin E is the name given to all substances that act like alpha tocopherol. Vitamin E working with selenium, protects cells against adverse effects of oxidation.
d. Vitamin K is required for the normal blood clotting process. Many animals can syntheses vitamin K in their intestines.

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:

1. Calcium (Ca)
2. Chlorine (Cl)
3. Magnesium (Mg)
4. Phosphorous (P)
5. Potassium (K)
6. Sodium (Na)

Functions -

a. Calcium and phosphorous are most directly involved in the 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.
b. Dietary phosphorus is more critical. Phosphorous is derived from dietary phosphate. Phosphorous deficiency sings include poor growth, reduced feed efficiency and bone deformities. The availability of phosphorous in feedstuffs varies widely.
c. 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.
d. 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.
e. Microminerals are present in very small amounts in the bodies of fish, but they are still important to fish health.

The microminerals include:

1. Copper (Cu)
2. Iodine (I)
3. Iron (Fe)
4. Manganese (Mn)
5. Selenium (Se)
6. Zinc (Zn)

Functions -

a. Copper is a part of many enzymes and it is required for their activity. Although it is necessary for fish health, copper can be toxic at concentrations of 0.8 to 1.0 m per litre of water. Fish are more tolerant of copper in feed than in water.
b. 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.
c. 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.
d. 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.
e. 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.
f. 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.

Other dietary components –

Many fish diets contain other ingredients that can affect them. Some of these ingredients are natural, others are added. These ingredients include substances such as water, fibre, hormones, antibiotics, antioxidants, pigments, binders and feeding stimulants.

1. Water - All diets contain water. The water may be a part of the feedstuff, come from the air or be added. The less water in a diet, the easier the storage and handling. When moisture in a diet exceeds 12 percent, the feed is more susceptible to spoilage. Some commercial diets contain high moisture levels because fish seems to prefer moist feed.
2. Fibre - Fibre refers to plant material such as cellulose, hemicellulose, lignin, pentosums and other complex carbohydrates. These are indigestible and they do not play an important role in nutrition. Fibre adds bulk to a feed but increases the amount of faecal material produced. The goal in commercial aquaculture is to limit the diets fibre content and use highly digestible feeds.
3. Hormones - Researchers have evaluated the use of various natural and synthetic hormones of fish. These hormones include growth hormone, thyroid hormones, gonadotropin, prolactin, insulin and various steroids like androgens and oestrogens. Hormones are used for two purposes: (1) Induced or synchronized spawning and (2) Sex reversal.
4. Antibiotics - With the arsenal of antibiotic available for humans and other livestock, only two have received FDA approval for use in fish that are sulfadimethoxine / ormetoprim and oxytetracycline. When these antibiotics are used in the, the quantity fed, the feeding rate and the withdrawal time must be strictly controlled. Unlike livestock, fish do not demonstrate any benefit from sub therapeutic levels of antibiotics in their feed.
5. Antioxidants - Fish feeds containing high levels of fats often use antioxidants. Oxidation of the fats affects the nutritional values of the fat and some vitamins. Synthetic vitamin E in diets usually less little antioxidant activity, so synthetic antioxidants like ethoxyquin, BHT, BHA and propyl gallate are used.
6. Pigments - Pigmentation of the skin and flesh in fish comes from carotenoids. Fish cannot make these carotenoids, so they must be present in the diet. In salmonids, the carotenoids astaxanthin and canthaxanthin are responsible for the red to orange colour of their flesh. In the wild, these carotenoids come mainly from zooplankton. Some of the natural materials used to pigment the flesh of salmonids include crab, brill, shrimp and yeast. Yellow pigmentation of the flesh of catfish is undesirable. It is caused by the carotenoid's lutein and zeaxanthin from plant material in the diet.
7. Pellet Binders - Binders improve stability in the water, firmness and reduce fines during processing and handling. Widely used binders are sodium and calcium bentonites, lignosulfates, carboxymethylcellulose, hemicellulose, guar gum alginate and some new inert polymers.
8. Feeding stimulants - The acceptance of the fish feed is determined by the smell and attractants of the feed. Many researchers are focusing on increasing the palatability and

acceptance of feed for increasing the feed utilization. This is especially important in starter and larval feeds. In general, carnivorous fish respond to alkaline and neutral substances. Herbivorous fishes respond to acid substances. Besides increasing feed consumption, some compounds act as deterrents.

B. Preparation of Fish Feed -

Commercial fish diets are manufactured as either extruded (floating or buoyant) or pressure-pelleted (sinking) feeds. Both floating and sinking feed can produce satisfactory growth, but some fish species prefer floating, others sinking. Shrimp, for example, will not accept a floating feed, but most fish species can be trained to accept a floating pellet.

Extruded feeds are more expensive due to the higher manufacturing costs. Usually, it is advantageous to feed a floating (extruded) feed, because the farmer can directly observe the feeding intensity of his fish and adjust feeding rates accordingly. Determining whether feeding rates are too low or too high is important in maximizing fish growth and feed use efficiency.

Feed is available in a variety of sizes ranging from fine crumbles for small fish to large (1/2 inch or larger) pellets. The pellet size should be approximately 20-30% of the size of the fish species mouth gape. Feeding too small a pellet results in inefficient feeding because more energy is used in finding and eating more pellets. Conversely, pellets that are too large will depress feeding and, in the extreme, cause choking. Select the largest sized feed the fish will actively eat.

Feed formulation is essentially applied nutrition. A number of terms and expressions are introduced that will be put to practical use as information is presented on the nature and qualities of various feedstuffs and the information presented on the nutrient requirements of fish. Precise understanding of these terms is essential to their correct application. One must recognize that some of these terms have a built-in error that cannot be escaped. This does not eliminate their usefulness in feed formulation. However, one must appreciate the fact that some are useful approximations of the values and not true values.

Steps in feed formulation -

Step – 1: The first step in diet formulation is balancing the crude protein and energy levels. This can be accomplished by trial and error, by the square method for either crude protein level or energy level and then adjusting, or by solving simultaneous equations.

Step – 2: The second step in diet formulation is to check the levels of indispensable amino acids in the formulation to be sure the dietary levels meet the requirements of the animal to be fed. The requirements of fish for indispensable amino acids is expressed as the dietary level (as a percent of the diet) or as a percent of the dietary protein level. If the diet formulation is low in any amino acid, a feedstuff that contains high levels of that amino acid must be added to the diet at the expense of another ingredient. Once the amino acid requirements are met, the dietary protein and energy levels must be rechecked to, see if any substitution of ingredients has imbalanced the formulation.

In practical feed formulation, pellet quality and acceptability must be considered in addition to nutrient levels and cost. These considerations will vary from species to species and with the type of pellet being made.

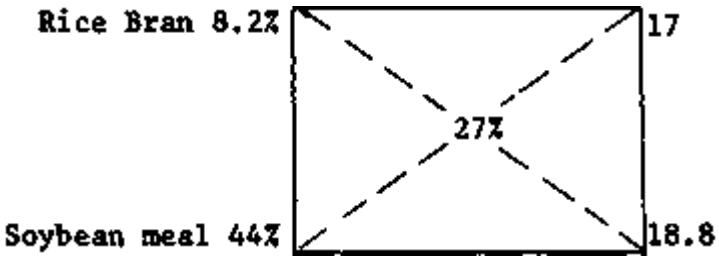
Methods of feed formulation –

1. Pearson square method –

In most fish diets, protein is the most expensive portion and is usually the first nutrient that is computed in diet formulation. The energy level of the diet is then adjusted to the desired level by addition of high energy supplements which are less expensive than protein supplements.

The Pearson square method is an easy way to determine the probable ratios of mixing different protein ingredient and to formulate a feed with desired dietary protein level.

For example, suppose rice bran and soybean meal were available as feedstuffs to prepare a diet for carp that was 25 percent crude protein. A square is constructed and the two feedstuffs are put on the two left corners along with the protein content of each. 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.

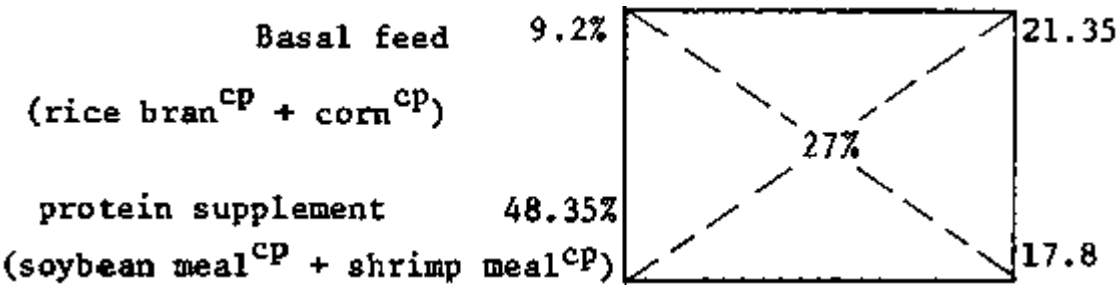


To make the 27 percent crude protein carp feed, we must mix 17/35.8 of rice bran with 18.8/35.8 soybean meal.

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 kg
Corn	27.265 kg
Soybean meal	22.735 kg
Shrimp meal	22.735 kg

2. Best buy technique –

The price of the feedstuffs used in diet formulations must be considered to formulate a cost-efficient diet. Feedstuffs can be compared with one another on the basis cost per unit of protein, energy, or amino acid. For example, suppose one has wheat middling and wheat millrun available for a fish diet, which feedstuff would be the least expensive source of energy?

Wheat millrun costs Rs. 10/kg, and contains about 1200 kcal ME/kg.

Cost/Kcal = 10/1200 = 0.0083 Rs. /Kcal.

Wheat middling cost 15/kg and contain 1663 kcal ME/kg.

Cost/Kcal = 15/1633 = 0.0090 Rs. /Kcal.

Thus, the wheat millrun which has a lower ME value for fish is the better buy because it costs less per kcal.

3. Pelleting –

The process flow chart of pelleting is as follows –

Grinding → Mixing → Pelleting → Drying → Coating → Cooling

Pelleting is the process to compress small particles into larger solid with given shape and texture, which involves the combination of moisture, heat and pressure. Thus larger homogenous particles agglomerating from small ingredients are also called dense pellets than sink rapidly in water. A pellet mill shapes the pellets by compression through long land dies

thus the pellet is dense. In most cases, a pellet binder is need in the formula to facilitate the cohesion of the pellet.

4. Extrusion –

The process flow chart of extrusion is as follows –

Grinding → Mixing → extrusion → Drying → Coating → Cooling

Extrusion is a high temperature short time heating process; it minimizes the degradation of food nutrients while improving the digestibility of protein and starches. The feed extruder is an ideal machine that designed for processing floating or sinking aquafeed just by adjusting the formula. An extruder will expand the pellet through substantial gelatinization of the starch, expansion and increased porosity thus the reduction of the density. No need for the addition of a pellet binder in most cases.

5. Automatic Feeders

Fish can be fed by hand, by automatic feeders, and by demand feeders. Many fish farmers like to hand feed their fish each day to assure that the fish are healthy, feeding vigorously, and exhibiting no problems. Large catfish farms often drive feed trucks with compressed air blowers to distribute (toss) feed uniformly throughout the pond.

There are a variety of automatic (timed) feeders ranging in design from belt feeders that work on wind-up springs, to electric vibrating feeders, to timed feeders that can be programmed to feed hourly and for extended periods. Demand feeders do not require electricity or batteries. They usually are suspended above fish tanks and raceways and work by allowing the fish to trigger feed release by striking a moving rod that extends into the water. Whenever a fish strikes the trigger, a small amount of feed is released into the tank. Automatic and demand feeders save time, labour and money, but at the expense of the vigilance that comes with hand feeding. Some growers use night lights and bug zappers to attract and kill flying insects and bugs to provide a supplemental source of natural food for their fish.