Fish Nutrition and Feed Technology

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Introduction

Fish is poikilothermic animal, extrinsic and intrinsic factor play an important role in the fish nutrition. Aquaculture sector is a major industry in many countries, and it will continue to grow as the demand for fisheries products increases, mainly due to the health beneficial effects. The fish is perishable commodity; it is known for its well-balanced nutrient composition. Good nutrition is of paramount importance for economic production of healthy and high quality product. In aqua farming, nutrition plays a key role mainly due to cost of feed which represents about 40-60% of the production costs. Fish nutrition research has advanced in recent years with the development of commercial diets that promote fish growth and health. Development of species-specific feed formulations support the aquaculture industry as it expands to satisfy increasing demand for affordable, safe, and high-quality fish and seafood products. The in the field of aquaculture, growth of the fish / shell is of prime importance, the growth is affected either due to less intake of feed or under-utilization of feeds. Undernourished animal cannot maintain its health and be productive, regardless of the quality of its environment. The production of nutritionally balanced feed for fish requires efforts in research, quality control, and biological evaluation. Faulty nutrition obviously impairs fish productivity and result in a deterioration of health until recognizable diseases ensues. At present, information on fish feed is based on nutritional and diet development work carried out on temperate fish species of fish in advanced countries. Hence, the focus of the fish nutritionist should be on preparation of economically viable fish feed by utilizing locally available inexpensive fish feed ingredients.

Major Nutrient Groups

Energy-yielding Nutrients

Proteins, carbohydrates and lipids are distinct nutrient groups that the body metabolizes to produce the energy it needs for numerous physiological processes and physical activities. There is considerable variation in the ability of fish species to use the energy-yielding nutrients. This variation is associated with their natural feeding habits, which are classified as herbivorous, omnivorous or carnivorous. Thus, there is a relationship between natural feeding habits and dietary protein requirements. Herbivorous and omnivorous species require less dietary protein than some carnivorous species (NRC, 1993). Carnivorous species are very efficient at using dietary protein and lipid for energy but less efficient at using dietary carbohydrates. The efficient use of protein for energy is largely attributed to the way in which ammonia from deaminated protein is excreted via the gills with limited energy expenditure. The foods carnivorous species eat contain little carbohydrate, so they use this nutrient less efficiently.

In terms of energy density, proteins, carbohydrates and lipids have average caloric values of 5.65, 4.15 and 9.45 kilocalories per gram (kcal/g), respectively. These gross energy values are obtained by fully oxidizing the nutrients and measuring their heat of combustion in a calorimeter, with the energy released expressed as kcal/g or kiloJoule (kJ)/g (1 kcal = 4.185 kJ). Not all of the gross energy from nutrients is utilized because some of it is not digested and absorbed for further metabolism. Thus, the amount of digestible energy (DE) provided by a feed or feed ingredient is commonly expressed as a percentage of gross energy. A smaller fraction of the DE absorbed by the fish will be lost in metabolic wastes, including urinary and gill excretions, but these losses are relatively minor compared to the dietary energy excreted in the feces. Because it is hard to collect fish urinary and gill excretions, it is much more difficult to determine metabolizable energy (ME) values for aquatic organisms than for terrestrial animals. Therefore, ME values are not commonly reported for fish feeds or ingredients.

Proteins and amino acids. Proteins consist of various amino acids, the composition of which gives individual proteins their unique characteristics. Many of the biochemicals required for normal bodily functions are proteins, such as enzymes, hormones and immunoglobulins. Fish, like other animals, synthesize body proteins from amino acids in the diet and from some other sources. Amino acids that must be provided in the diet are called “essential” or “indispensable” amino acids. Quantitative dietary requirements for the ten indispensable amino acids have been determined for several fish species (Wilson, 2002). There are also ten “nonessential” or “dispensable” amino acids that the body can synthesize from other sources. These dispensable amino acids also may be found in dietary protein and used for synthesizing body proteins. Table 1 lists indispensable and dispensable amino acids. A deficiency of any one of the indispensable amino acids can limit protein synthesis, which often causes reduced weight gain and other specific symptoms.

Table 1: Two Major Classes of Amino Acids.

Indispensable (essential)	Dispensable (nonessential)
Arginine	Alanine
Histidine	Asparagine
Isoleucine	Aspartic acid
Leucine	Cystine
Lysine	Glutamic acid
Methionine	Glutamine
Phenylalanine	Glycine
Threonine	Proline
Tryptophan	Serine
Valine	Tyrosine

Meeting a fish’s minimum dietary requirement for protein, or a balanced mixture of amino acids, is critical for adequate growth and health. However, providing excessive levels of dietary protein is both economically and environmentally unsound because protein is the most expensive dietary component and excess protein increases the excretion of nitrogenous waste. Most herbivorous and omnivorous fish evaluated to date require a diet with 25 to 35 percent crude protein; carnivorous species may require 40 to 50 percent crude protein (Wilson, 2002). Commercial feeds are carefully formulated to ensure that protein and amino acid requirements are met.

Carbohydrates:

Carbohydrates are the least expensive form of dietary energy for man and domestic animals, but their utilization by fish varies and remains somewhat obscure. Warm water fish are able to utilize much higher levels of dietary carbohydrates coldwater or marine fish (Wilson, 1994). Fish do not have a specific dietary requirement for carbohydrates, but including these compounds in diets is an inexpensive source of energy. The ability of fish to utilize dietary carbohydrate for energy varies considerably; many carnivorous species use it less efficiently than do herbivorous and omnivorous species (Wilson, 1994). Some carbohydrate is deposited in the form of glycogen in tissues such as liver and muscle, where it is a ready source of energy. Some dietary carbohydrate is converted to lipid and deposited in the body for energy. The enzymes for the major carbohydrate metabolic pathways, such as glycolysis, tricarboxylic acid cycle, pentose phosphate shunt, gluconeogenesis, and glycogen synthesis, have been demonstrated (Shimeno, 1974; Cowey and Walton, 1989). The optimal requirement of dietary level of digestible carbohydrate varies among species as well within the species. In general, less than 20%digestible carbohydrate appears optimal for marine or cold water fish.

Carbohydrates of various size (carbon chain length) and complexity (one to several units bonded together) are synthesized by plants via photosynthesis. Cellulose and other fibrous carbohydrates are found in the structural components of plants and are indigestible to monogastric (simple-stomach) animals, including fish. In fact, the amount of crude fiber in fish feeds is usually less than 7 percent of the diet to limit the amount of undigested material entering the culture system.

Soluble carbohydrates such as starch are primary energy reserves found in seeds, tubers and other plant structures. Animal tissues such as liver and muscle contain small concentrations of soluble carbohydrate in the form of glycogen, which is structurally similar to starch. This glycogen reserve can be rapidly mobilized when the body needs glucose. Prepared feeds for carnivorous fish usually contain less than 20 percent soluble carbohydrate, while feeds for omnivorous species usually contain 25 to 45 percent. In addition to being a source of energy, soluble carbohydrate in fish feed also gives pellets integrity and stability and makes them less dense.

Lipids. This nutrient group consists of several different compounds. Neutral lipids (fats and oils), in the form of triglycerides, provide a concentrated source of energy for aquatic species. Dietary lipid also supplies essential fatty acids that cannot be synthesized by the organism (Sargent et al., 1999). Fatty acids of the linoleic acid (n-3) family are generally more essential to fish than those of the linoleic acid (n-6) family. Many freshwater fish can elongate and desaturate 18-carbon linolenic acid with one double bond to longer chains (20 and 22 carbons) of more highly unsaturated fatty acids (HUFAs) with five or six double bonds. In contrast, most marine fish must have HUFA in the diet.

In the body, HUFAs are components of cell membranes (in the form of phosphoglycerides, or phospholipids), especially in neural tissues of the brain and eye. They also serve as precursors of steroid hormones and the highly active eicosanoids produced from 20-carbon HUFAs (Sargent et al., 1995). Eicosanoid compounds include cyclic molecules such as prostaglandins, prostacyclins and thromboxanes produced by the action of cyclo-oxygenase, as well as linear compounds such as leukotrienes and lipoxins initially formed by lipoxygenase enzymes. Eicosanoids are responsible for blood clotting, immunological and inflammatory responses, renal function, cardiovascular tone, neural function, and other functions. A diet deficient in essential fatty acids reduces weight gain, but usually after an extended period. This is due to mobilization of essential fatty acids from endogenous tissue lipids.

Micronutrients

Minerals

This nutrient group consists of inorganic elements the body requires for various purposes. Fish require the same minerals as terrestrial animals for tissue formation, osmoregulation and other metabolic functions (Lall, 2002). However, dissolved minerals in the water may satisfy some of the metabolic requirements of fish.

Minerals are typically classified as either macro- or microminerals, based on the quantities required in the diet and stored in the body. Macrominerals are calcium, phosphorus, magnesium, chloride, sodium, potassium and sulfur. Dietary deficiencies of most macrominerals have been difficult to produce in fish because of the uptake of waterborne ions by the gills. However, it is known that phosphorus is the most critical macromineral in fish diets because there is little phosphorus in water. Because excreted phosphorus influences the eutrophication of water, much research has been focused on phosphorus nutrition with the aim of minimizing phosphorus excretion. Phosphorus is a major constituent of hard tissues such as bone and scales and is also present in various biochemicals. Impaired growth and feed efficiency, as well as reduced tissue mineralization and impaired skeletal formation in juvenile fish, are common symptoms when fish have diets deficient in phosphorus (Lall, 2002).

Chloride, sodium and potassium are important electrolytes involved in osmoregulation and the acid–base balance in the body (Lall, 2002). These minerals are usually abundant in water and practical feedstuffs. Magnesium is involved in intra- and extracellular homeostasis and in cellular respiration. It also is abundant in most feedstuffs.

The microminerals (also known as trace minerals) include cobalt, chromium, copper, iodine, iron, manganese, selenium and zinc. Impaired growth and poor feed efficiency are not readily induced with micromineral deficiencies, but may occur after an extended period of feeding deficient diets (Lall, 2002). The trace minerals and their metabolic functions in fish are shown in Table 2. The quantitative dietary requirements for some fish species have been established (Lall, 2002).Copper, iron, manganese, selenium and zinc are the most important to supplement in diets because practical feedstuffs contain low levels of these microminerals and because interactions with other dietary components may reduce their bioavailability. Although it is not usually necessary to supplement practical diets with other microminerals, an inexpensive trace mineral premix can be added to nutritionally complete diets to ensure an adequate trace mineral content.

Table 2: Trace Minerals and some of their Prominent Functions.

Trace mineral	Function
Copper	metalloenzymes
Cobalt	vitamin B_{12}
Chromium	carbohydrate metabolism
Iodine	thyroid hormones
Iron	hemoglobin
Manganese	organic matrix of bone
Molybdenum	xanthine oxidase
Selenium	glutathione peroxidase
Zinc	metalloenzymes

Vitamins

Fifteen vitamins are essential for terrestrial animals and for several fish species that have been examined to date (Halver, 2002) (Table 3). Vitamins are organic compounds required in relatively small concentrations to support specific structural or metabolic functions. Vitamins are divided into two groups based on solubility.

Fat-soluble vitamins include vitamin A (retinol), vitamin D (cholecalciferol), vitamin E (alpha-tocopherol) and vitamin K. These fat-soluble vitamins are metabolized and deposited in association with body lipids, so fish can go for long periods without having these vitamins in the diet before they show signs of deficiency.

Water-soluble vitamins include ascorbic acid (vitamin C), biotin, choline, folic acid, inositol, niacin, pantothenic acid, pyridoxine, riboflavin, thiamin and vitamin B12. They are not stored in appreciable amounts in the body, so signs of deficiency usually appear within weeks in young, rapidly growing fish. Most of these water-soluble vitamins are components of coenzymes that have specific metabolic functions. Detailed information about the functions of these vitamins and the amounts fish need have been established for many cultured fish species (Halver, 2002).

Vitamin premixes are now available to add to prepared diets so that fish receive adequate levels of each vitamin independent of levels in dietary ingredients. This gives producers a margin of safety for losses associated with processing and storage. The stability of vitamins during feed manufacture and storage has been improved over the years with protective coatings and/or chemical modifications. This is particularly evident in the development of various stabilized forms of the very labile ascorbic acid (Halver, 2002). Therefore, vitamin deficiencies are rarely observed in commercial production.

Table 3: Vitamins and some of their Major Functions as Established in Fish

Fat-soluble vitamins	Function
vitamin A, retinol	epithelial tissue maintenance, vision
vitamin D, cholecalciferol	bone calcification, parathyroid hormone
vitamin E, tocopherol	biological antioxidant
vitamin K	blood clotting
Water-soluble vitamins	
thiamin, B_1	carbohydrate metabolism
riboflavin, B_2	hydrogen transfer
pyridoxine, B_6	protein metabolism
pantothenic acid	lipid & carbohydrate metabolism
niacin	hydrogen transfer
biotin	carboxylation & decarboxylation
choline	lipotrophic factor, component of cell membranes
folic acid	single-carbon metabolism
cyanocobalamin, B_{12}	red blood cell formation
ascorbic acid, vitamin C	blood clotting, collagen synthesis
inositol	component of cell membranes

What to know about fish or shrimp to be able to increase production through proper feeding:

- Biology of the species to be cultured.
- Nutrient requirements.
- Feeding habits of the fish, what food it prefers, how it takes in food, what time of the day it eats, what parts of the body are involved in the ingestion of food.
- Proper pond management.

Ways of developing feeds

- Imitation of natural diets which is possible when stocking density is low.
- Trial and error with existing cheap diets. This is attractive because development costs may be less.
- Controlled feeding with nutritionally defined diets. This method appears costly, time-consuming, and likely to lead to many problems. However, it is the best approach. Experience with other animals such as chicken and swine has shown that formulating cheap reliable feed is not possible until the nutrient requirements of the species and the interaction of these nutrients are known for the various life stages.

To achieve increased production through proper feeding, one has to:

- Study nutritional requirements
- Understand the digestive processes
- Evaluate feedstuffs
- Develop feeds
- Determine good feeding techniques or feeding management schemes.

Some basic concepts in nutrition

- Adequate nutrition is essential to good health.
- Nutrients in the body are in dynamic equilibrium, hence, a deficiency or over supply of one will affect the others.
- Dietary intake and nutrient needs should be known.
- Nutrient needs vary because of factors such as age, physical activity, body size, state of health, physiological processes like growth, reproduction, and pathological disorders.
- Nutrient content of food varies and diet preparations should aim to preserve the nutrient in the natural food.
- Nutrient requirements are known for some nutrients only and may differ from species to species, thus, requirements and allowances will have to be revised as new knowledge is obtained.
- A variety of feedstuffs is better than one source.
- The study of nutrition is interrelated with allied arts and sciences.
- Nutrition is also an art because there is no single approach to meeting the needs of the animal.

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