Future Considerations in Fish Nutrition Research

Chhorn Lim

Tropical Aquaculture Research Unit
USDA-ARS-PWA
Hawaii Institute of Marine Biology
P. O. Box 1346
Kaneohe, Hawaii 96744, U.S.A.

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Abstract

Considerable progress has been made In the field of fish nutrition during the past two decades. Nutritional data for some species such as trout, salmon, channel catfish, and common carp are well established and efficient feeds have been developed. However, nutrition of fish species commercially Important In the Southeast Asian region is still in its infancy and much of the existing Information needs further verification. Basic requirements for some of the 5 major nutrient classes and energy have been determined. However, knowledge of larval and broodstock nutrition is limited. The role of nutrition in immune function and disease resistance should be investigated. Nutritional value and nutrient bioavailability of local feedstuffs as well as methods for improving the nutritional quality of inferior feedstuffs should be given priority. The potential benefits of additives, and harmful effects of toxicants and anti-nutritional factors need to be assessed. The effects of the diet on product quality are becoming increasingly important, but work on feed processing technology in relation to the physical and nutritional quality of feeds is lacking. Emphasis must also be given to the improvement of feed performance and feeding strategies for various life stages under different production systems and management practices in order to reduce production costs and minimize the negative impact of feeds on the environment.

Introduction

As a result of recent technological advancement and improvement, aquaculture is now a well-established industry worldwide and is expected to continue to grow rapidly in the foreseeable future. As the industry expands, traditional extensive culture which has been practiced by farmers for generations is being replaced by semi-intensive and intensive production systems in which fish rely mostly or totally on prepared feeds as sources of nutrients for growth, reproduction and well-being. Thus, availability of least-cost, well-balanced feeds designed for practical production systems and good practices are fundamental in achieving the expected production goals.

The development of nutritionally adequate cost-effective feeds requires knowledge on nutrient requirements, nutrient bioavailability of various feedstuffs, their availability and cost, and feed technology. For some fish species such as salmon, trout, channel catfish, common carp, and eel, nutritional information has been fairly well defined (NRC 1981; 1983; 1993) and cost-effective feeds formulated. However, Robinson (1989) indicated that scientifically, channel catfish nutrition today is at a level where domestic animal nutrition was some 30 years ago.

Nutritional data for several commercially important fish species in Southeast Asia such as milkfish, sea bass, grouper, and marine shrimp are scanty. Nevertheless, considerable efforts have been made in the past few years to define their nutrient requirements and develop grow-out feeds with acceptable performance. However, more research needs to be done before cost-effective feeds that meet various production purposes can be developed.

This paper highlights the major problem areas in fish nutrition that should be taken into consideration in developing future research programs and priorities.

Nutrient Requirements

Energy

Energy is not a nutrient but is a property of nutrients which is released during metabolic oxidation of proteins, carbohydrates, and fats. Generally, protein is given the first priority in formulating fish feeds because it is the most expensive component of the diet. However, energy should be the first nutritional consideration in diet formulation since fish, like other animals, eat to satisfy their energy needs. A diet deficient or in excess of energy will result in poor performance. Even though metabolizable energy (ME) is a more precise estimate of energy available for metabolism (NRC 1993), digestible energy (DE) is an acceptable choice for expressing dietary energy for fish due to the ease of measurement, less stress on the fish, and the fact that fecal energy accounts for most energy losses in fish.

Energy requirements have generally been reported in relation to the dietary level of protein. Robinson (1989) indicated that, even for channel catfish and other species in which considerable nutritional information is available, energy requirements have not been well defined. Likewise, available data on the DE values of various feedstuffs is very limited. As a result, estimates of dietary energy requirements for many fish species have mostly been based on gross energy (GE), DE or ME values determined for other species, or mammalian physiological fuel values. The requirements reported are likely to vary due to differences in life stages, water temperature and salinity, source of dietary energy, and feeding management. Thus, effects of these parameters on energy requirements should also be evaluated. As more information on energy requirements for various metabolic functions in fish and energy availability in feedstuffs is known, aside from protein, other nutrients such as amino acids, lipids, vitamins and minerals can be expressed in relation to energy level in the diet (D'Abramo and Lovell 1991).

Protein and Amino Acids

The requirements for protein to supply the necessary amino acids for maximum growth have been determined for a number of fish species. These have been based on studies carried out with small fish in controlled environments using high quality protein sources. There were attempts to make diets isoenergetic but the intention was not always realized because data on energy requirement and energy values of various feed ingredients were unavailable. The assumption that carbohydrates such as starch and dextrin have the same metabolizable energy as protein may not be valid. Factors such as life stages, protein quality, amount of non-protein energy in the diet, feeding management, water quality parameters, and culture practices affect the protein requirements of fishes. This creates uncertainty as to the appropriate protein levels to be used in formulating cost-effective practical feeds. Thus, establishing the protein requirements in relation to the above-indicated parameters would be beneficial in optimizing fish growth at the least possible cost.

All fish species which have been studied thus far require the same ten indispensable amino acids. The quantitative amino acid requirements have been determined for only a few species (NRC 1993). The requirements for several amino acids show apparent differences among species. However, D'Abramo and Lovell (1991) indicated that this variation is probably less than the data indicated since several factors, both biotic and abiotic, as well as the methods used to interpret the data can influence the reported requirements. They suggested that, due to the importance of amino acid requirements in least-cost feed formulation, the requirement values should be reconfirmed. Nutritional values of the dispensable ammo acids and their sparing effects on some indispensable amino acids should be evaluated. Studies are also needed to assess the utilization of free amino acids as supplements to low quality protein. Methods to improve utilization efficiency such as by coating, chemical or physical binding to the protein sources, and more frequent feeding should be developed.

Lipids

Nutritional values of lipid sources, sparing effect of dietary lipid on protein utilization, and fatty acid metabolism and requirements have been determined in several species of juvenile fish. The requirements for phospholipids by some species of shrimp and larval fish, and for cholesterol by shrimp have also been demonstrated. However, much of the existing data, although very valuable and potentially useful as a guide for future research with other species, have not been well defined. Knowledge on the optimum level of dietary lipid and digestibility of fat from various sources and of feed ingredients is very limited. The importance of highly unsaturated fatty acids and phospholipids for broodstock maturation, egg quality, and larval viability, even for freshwater species which need only 18:2n-6 and/or 18:3n-3 should be evaluated. The effects of dietary lipid level, temperature, and salinity on essential fatty acid requirements need to be studied. The effects of dietary lipid concentration and source on the quality and shelf life of feeds should also be considered.

Carbohydrates

No specific carbohydrate requirement has been demonstrated for fish. However, carbohydrates are always included in fish feeds because they are the least expensive source of energy. They also serve as precursors for the formation of various metabolic intermediates (nucleic acids, dispensable amino acids, and fatty acids) essential for growth, function as pellet binder, and spare protein for growth.

The utilization of carbohydrate varies depending on its complexity, source, level in the diet, and degree of gelatinization. The ability of fish to utilize carbohydrate also differs greatly between species and life stages as a consequence of the marked variations in the anatomy of the digestive tract and in the food habit (Steffens 1989). Data on the available energy value of various types of carbohydrate from different sources at various proportion, although available for some species, are by no means sufficient. Research to determine the optimum levels of digestible carbohydrate in practical fish diets is required. This would allow maximum use of carbohydrates in the diets, thereby reducing feed costs. Enzymes for metabolic pathways involved in carbohydrate metabolism have been studied for some fishes, but the role and contribution of dietary carbohydrates to the total energy requirement of the fish remain unclear.

High proportions of plant ingredient in the formulae usually imply high levels of crude fiber in the diets. Crude fiber is generally considered indigestible in most fishes. One of the concerns in practical diet formulation is to avoid excessive levels of fiber because large amounts may reduce feed intake and increase fecal waste production and, consequently, pollute the environment (NRC 1983; 1993). However, small amounts of cellulose have a beneficial effect on growth due possibly to the presence of trace elements, partial digestion, and improvement of digestion and absorption of other nutrients by increasing retention time in the gut (Steffens 1989; D'Abramo and Lovell 1991). Since crude fiber is an inevitable component in practical feeds, its role should be properly defined and optimum level in the diets determined.

Vitamins

Qualitative and quantitative requirements of fingerlings of some fish species such as trout, salmon, channel catfish, common carp, and eel for 15 vitamins have been fairly well-defined but this information is very limited for other species including shrimp. The requirement data often differed due to differences in the method used to interpret the results and several other factors such as size, stage of sexual maturity, diet processing and storage, levels and quality of other dietary nutrients, diseases and environmental parameters as well as feeding management. Thus, the interrelationship between these factors and vitamin requirements need to be adequately defined.

Minerals

Compared with other nutrients, knowledge on mineral requirements of fishes is one of the least advanced areas of fish nutrition. One of the reasons for the paucity of research in this is the difficulty in formulating diets sufficiently low in mineral yet containing adequate levels of other nutrients to support good growth and survival. Some fish species and shrimp do not easily accept or efficiently utilize purified diets. Another problem is that the aquatic environment, especially seawater, is rich in minerals. It has been reported that fish can absorb Ca, Mg, Na, K, Fe, Cu, Zn, I, and Se from the water to satisfy part of the requirements for these elements (NRC 1993).

About 20 minerals are known to be required by terrestrial animals (Ensminger and Olentine 1978). Quantitative requirements for nine minerals (Ca, P, Mg, Fe, Cu, Zn, I, and Se) have so far been determined for selected fish species (NRC 1993) and only eight (Ca, P, K, Mg, Cu, Zn, Se, and Co) for marine shrimps (Lim and Akiyama, 1994). However, it has been suggested that most or all the minerals known to be essential for other animals are likely required by fish (NRC 1983). Thus, more work on this area of research is needed. Interrelationship between minerals, and mineral and other dietary nutrients must be evaluated. Mineral availability of various feed ingredients for different fish species should be determined. Currently, only phosphorus availability of some feed ingredients has been reported. This is because unutilized phosphorus and nitrogen waste are major sources of water pollution.

Non-nutrient Dietary Components

In addition to the essential nutrients, feeds also contain substances that have positive or negative effects on the growth and health of fish. These may be naturally occurring, intentionally or unintentionally added, or produced through chemical changes or microbial growth (Lovell 1989; NRC 1993). The most common non-nutrient dietary components that are intentionally added include antioxidants, antimold, hormones, antibiotics, pigments, pellet binders, and attractants. The naturally occurring substances or antinutritional factors commonly found in feedstuffs are trypsin inhibitors, gossypol, mimosine, phytates, glucosinolates and thiaminase. Feed ingredients may also be contaminated with other substances during harvesting, processing, and storage. These include mycotoxins, heavy metals, pesticides, and oxidative rancidity products. Interrelationship between these substances and the nutrient requirements, as well as their effects on the immune response and disease resistance of fish should be studied.

Nutritional Immunology

Early research on nutrient requirements of fish was primarily aimed to determine the optimum dietary level of nutrients necessary for maximum growth and prevention of deficiency signs. However, it is generally believed that nutritional status is one of the important factors which affects the ability of the animal to resist disease (Castell and Olivier 1988; Lall and Olivier 1993). Interactions between nutrition, immune function and disease resistance in fish are still very poorly understood. Information on this subject has been recently reviewed by Castell and Olivier (1988) and Lall and Olivier (1993). The reports also provide an overview of the immune system as well as the selected tests commonly used to evaluate the influence of nutrition on the immune system.

Most studies on the effects of nutrition on immune response and disease resistance have been confined to vitamins C and E. However, nutrition studies which involve unintentional and intentional infection of fish indicate that most, if not all, dietary nutrients affect the disease resistance of fish. A deficiency or an excess of any nutrient may have profound effects on disease infection and the survival of fish, largely through its effects on host defense mechanisms. Other factors such as diet composition, feed processing and storage, nutrient bioavailability and interactions, feeding management, species, genetic differences, size, environmental stress, and physiological needs also influence the health of fish (Castell and Olivier 1988; Lall and Olivier 1993). These complex factors and their interactions in relation to fish health constitute a new and very challenging area of research. In recent years, interest in this field has grown rapidly as a consequence of expansion and intensification of aquaculture production, and the prevalence of infectious diseases among fish. Information on nutrient requirements of fish will be incomplete if no information on the nutrient levels required by the immune system for normal disease resistance is included (Castell and Olivier 1988).

Alternative Feedstuffs

Compared to domestic animal feeds, least-cost formulation of aquaculture feeds has very limited flexibility due to limited choice of feed ingredients and heavy dependence on animal proteins, especially fish meal. In 1990, the aquaculture industry produced about 3 million tons of feeds and utilized about 800,000 tons of fish meal. If this trend continues, global feed production in the year 2000 is expected to reach 4.6 million tons. Aquaculture use of fish meal will increase to 1.2 million tons while fish meal supply will likely remain static or decline (Chamberlain 1993). Thus, there is a great need to look for alternative sources of feedstuffs, especially locally available materials, as replacements for fish meal. To achieve this goal, studies to determine the nutrient bioavailability of different feed ingredients must be carried out. Research to improve their nutritional value through proper processing techniques and supplementation of limiting nutrients, and their palatability through addition of attractants are fundamental to reducing feed costs. Maximum acceptable levels of each ingredient in diets for various life stages of each species must be established. These information will ultimately reduce our dependence on fish meal as has been done in domestic animal feeds.

Feed Manufacturing Processes and Feed Quality

Although feed manufacturing processes are generally beyond the scope of nutritionists, obtaining feeds with proper physical and textural characteristics, and correct particle size has always been the concern of practicing fish nutritionists. Feeds which cannot be readily eaten or disintegrate quickly are wasteful and may pollute the environment creating serious risk to fish growth and health.

Except for some starter diets, almost all commercial feeds currently available are processed into dry sinking or floating pellets. Although water stable pellets may be achieved by proper feed formulation, its quality can be considerably improved by the use of good feed processing techniques. The types of mill used and the different steps (conditioning, pelleting, and drying) affect not only the physical quality but also the nutritional value of pellets. For example, it is generally known that fine grinding improves the physical quality and digestibility of feed. Steam conditioning, the quality and quantity of steam added, and the retention time of the mash in the conditioners affect considerably the physical and nutritional quality of pellets. The application of heat and moisture improves the nutritional value of feed through destruction of antinutritional factors and microorganisms, and gelatinization of starch. In contrast, moisture- and heat-sensitive nutrients such as polyunsaturated fatty acids and some vitamins are destroyed. However, little attention has been paid to the understanding of these numerous and complex factors in fish feed manufacturing. Current technology used in fish feed manufacturing has mostly been borrowed from techniques developed for manufacturing livestock and poultry feeds (Foltz 1984). If more information on feed processing parameters is known, good quality feeds can be produced with minimum loss of essential nutrients. This would also reduce the levels of a wide range of nutrients which are normally added to provide large margins of safety.

Many fish species will swallow any type of suitable size feed once they have learned to feed on prepared diets. In such cases, the physical characteristics of the diet (type, size, shape, texture, hardness, density, color, and water stability) may have little significance. However, some species refuse diets of one type while readily accepting the same formulation if one or more physical characteristics are changed (Stickney 1979).

Relatively few studies have been conducted on the effects of physical characteristics on the acceptability and nutritional value of aquaculture feeds. Even with shrimp in which considerable attention has been paid to develop pellets with good water stability, the degree or duration of water stability required is unknown.

Feeding Practices

Little research has been devoted to the development of feeding practices. Yet, it is generally known that the performance of a feed is not only dependent on its quality but also on feeding management. Good quality, nutritionally adequate feed can give poor performance unless proper feeding practices (feed allowance, feeding frequency and method, and daily feeding schedule) are employed (Lim and Poernomo 1985). For maximum growth, farmers are interested in high rate of feed consumption. The risk of environmental pollution arising from aquaculture activities is an issue of growing concern in many countries. Thus, particular attention must be directed towards the development of feeding strategies necessary to obtain economical production and maintain a clean environment. It should be noted, however, that different life stages and species, management and environmental conditions, and nutritional and physical characteristics of feeds require different feeding strategies.

Conclusion

Economically productive, semi-intensive aquaculture systems rely heavily on the availability of good quality, low-cost feeds. This development requires a long-term commitment and concerted efforts of fish nutritionists to establish solid data on nutrient requirements and nutrient bioavailability of the ingredients. This information, although currently available for a few fish species, is by no means complete. Much more remains to be done for many other commercially-important species. Moreover, the information available are often confined to small fish cultured under well-controlled environmental conditions. The results obtained are usually well-defined but are of limited direct application to large-scale commercial production. Much of the published data are often difficult to compare due to variations in the experimental procedures and methods used for data interpretation. Data on nutrient requirements of larvae and broodstock are scanty. The effects of non-nutrient diet components on growth, health, and requirements for other dietary nutrients are poorly understood. Locally available feedstuffs need to be evaluated for their nutrient bioavailability. Maximum acceptable levels and methods for improving the nutritional value and palatability of different ingredients must be known. Parameters associated with feed manufacturing processes necessary to produce good quality feed with minimal nutrient losses should be developed. Optimum physical characteristics of pellet such as size, shape, texture, density, color, and water stability suitable for various sizes of different fish species are practically unknown. Interrelationship between dietary nutrients and immune response is a new and complex research area which needs considerable attention. Adequate attention should also be directed toward the development of feeding strategies in relation to life stages and species, culture management, and the negative effects of feeds on the environment.

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