Role of Nutrition in Aquaculture

In India although significant advances have been made in the culture of a variety of fish and shellfish species, studies on the nutrition and its relevance to culture have been very few till 1980. However, during the past five years research has been intensified at CMFRI through mission-oriented projects and Ph.D and M.Sc. research programmes.

During the past two decades there has been tremendous growth in the farming of aquatic organisms, both in the developed and developing nations of the world. This has been possible through the development of intensive production technologies using operational inputs such as seed, feed and fertilizers. Studies have shown that production can be increased manifold through the supply of nutritionally adequate formulated feeds. Although fish farming is an ancient practice in India the production system has been mainly of the traditional extensive type as followed in West Bengal, Orissa and Kerala. In this aquaculturists stock the ponds with seed from the wild in which all sorts of organisms are let in without any selection and are harvested periodically. In the currently practised improved aquaculture, selective stocking is followed and farms are fertilized to increase production of food organisms present in the system. This manner of enhancing production of food organisms by inorganic and organic manuring has its own limitations as they are capable of affecting the water quality. Thus if we are to progress to semi-intensive and intensive aquaculture there is a need for supplementary feeding along with enhancement of natural food organisms in the former system and for intensive feeding in the latter. In this context, the study of feed requirement and formulation of feed for individual species of cultivable organisms to suit their physiology of digestion and feeding habits althrough their life cyclce, storage and supply of appropriate supplementary and complete feeds are essential.

In India although significant advances have been made in the culture of a variety of fish and shellfish species, studies on the nutrition and its relevance to culture have been very few till 1980. However, during the past five years research has been intensified at CMFRI through mission-oriented projects and Ph.D. and M.Sc research programmes. Studies are being undertaken to acquire information on (i) nutritional requirements of larvae, juveniles and adults of cultivable fish and shellfish (ii) suitability of feed ingredients both conventional and non-conventional for formulation of practical feeds (iii) diseases associated with deficiency or excess of nutrients as well as toxic components in feeds (iv) effect of salinity on nutritional requirements and (v) digestive physiology of finfish and shellfish. The nutrition laboratory of CMFRI has been equipped with major instruments like aminoacid analyser, gas-liquid chromotograph, refrigerated centrifuge, kjeltec, soxtec and fibretec systems through the UNDP/FAO/ICAR Project, Centre of Advanced Studies in Mariculture to carry out research on the above lines.

Based on feeding habits the cultivable species have been categorised into herbivores, omnivores and carnivores. Despite the differences in feeding habits all aquatic organisms require five groups of nutrients. Among these, lipid and carbohydrate form primary energy sources for metabolism and protein in general is utilised for growth. Carnivores efficienly utilise lipids and herbivores carbohydrates while omnivores use both carbohydrates and lipids as energy sources. Protein on deamination can also serve as an energy source. Besides these, aquatic animals also require vitamins and minerals as components in their diets.

Protein

Among the nutrients, protein assumes a major role as it enhances growth. But its quantity and quality supplied is determined by the cost. The quality of protein is solely dependent on its essential amino acid profile. The essential aminoacids are arginine, histidine, leucine, isoleucine, lysine, threonine, tryptophan, valine, phenylalanine and methionine which the cultivable animals are incapable of biosynthesising. In the case of crustaceans, amino acid tyrosine too is considered to be essential. However, if adequate levels of phenylalanine is available, tyrosine can be synthesised by crustaceans. Thus although qualitative requirement seems to be similar in all studied aquatic organisms, there are substantial differences in quantitative requirements for these amino acids. It is vital that essential amino acids should be available in balanced proportion as well as in adequate levels. Studies conducted in various species have shown that fish and shellfish species differ markedly in their protein requirements, ranging from 22% and to as high as 55% in diet. Most of the carnivorous fish such as a salmon, trout, red sea bream, channel catfish and sea bass (Lates sp.) tend to require relatively higher protein levels in diet. The protein requirement is influenced by endogenous factors such as maturity, age and moulting and exogenous factors like water temperature, salinity, water chemistry, water quality and amino acid profile in the diet. In general, juveniles being fast growing require comparatively more protein in diets than adults. Similarly, maturing organisms too need higher levels of protein for gametogenesis.

Lipids

Until 1930, lipids were considered purerly as energy nutrient for animals. However, the work of Burr and Burr in 1930 radically changed the concept. They reported that one of the fatty acids, linoleic was essential for animals and its deficiency resulted in poor growth and caused severe pathological syndromes. Subsequent researches have shown that aquatic organisms too need essential fatty acids. Unlike higher vertebrates which require linoleic acid ($18:2\,w6$), aquatic organisms such as fish and crustaceans require linolenic ($18:3\,w3$), eicosapentaenoic ($20:5\,w3$) and docosahexaenoic ($22:6\,w3$) in addition to linoleic ($18:2\,w6$) acid as essential fatty acids. There has also been significant difference between species in their essential fatty acid requirements as some require only linoleic and linolenic acids. Among the aquatic species studied, all fish and crustaceans of marine origin require highly unsaturated fatty acids such as eicosapentanoic and docosahexaenoic acids, whereas most of the freshwater species require linoleic and linolenic acids as primary essential fatty acids. Recent studies have shown that requirement for essential fatty acids increases as the level of lipids in the diet is increased. Deficiency of essential fatty acids in diets would result in poor growth, severe pathological syndromes and mortality. The fecundity, fertilization rate and hatchability of the eggs have also been found to be very much reduced. Salinity and water temperature are the two important factors which affect the requirement of essential fatty acids in fish. Cold water species require more of linolenic acid than warm water fish. Though both freshwater and salt water species require relatively more linolenic acid than linoleic acid, fresh water fish need higher levels of linoleic acid in their diets compared to marine species. Further, crustaceans, unlike finfish require cholesterol as an essential nutrient and deficiency of the same results in their ability to synthesise hormones essential for moulting and gonadial maturation.

Minerals

Minerals are essential not only for the formation of hard tissues like bones, cuticles and appendages but also form cofactors in enzymes. Marine fish and shellfish are capable of meeting most of their requirements for minerals from the surrounding sea water. In the case of freshwater forms major minerals such as calcium, magnesium, phosphorus, potassium and sodium with trace minerals like iron, iodine, zinc, copper, cobalt, manganese and selenium have to be supplemented in the diets. Mineral deficiency though hard to be induced, when experimentally induced in finfish the symptoms were found to be nonspecific and resulted in lower growth, low haemocrit value, low bone ash and poor feed efficiency. Magnesium and zinc deficiency has been found to cause softening of muscle, renal calcinosis and visual problems in some species. Mineral deficiency syndromes in crustaceans and molluscs have not yet been thoroughly understood.

In aquaculture, feeding constitutes a major cost of production, often 40-70% of the operating cost. In the pond culture system, cost of production can be reduced by increasing the availability of natural food in the pond by adding fertilizers. In the flowing water and in cage culture systems the availability of natural food is very meagre and the fish have to rely on supplementary feeds.

Vitamins

Vitamins too are essential to aquatic animals. Deficiency of specific vitamins in higher animals manifests definite syndromes whereas in aquatic animals the symptoms are nonspecific. The water soluble vitamins, viz., thiamine, riboflavin, pyridoxine, niacin, pantothenic acid, ascorbic acid, choline, folic acid, cyanocobalamin, biotin and inositol and fat soluble vitamins like vitamin A, D, E and K are also essential to fish and shellfish. The water soluble vitamins are useful directly and as coenzymes, whereas fat soluble vitamins do not function as coenzymes. Ascorbic acid and tocopherol (vitamin E) being antioxidant aids in the prevention of oxidation of polyunsaturated fatty acids. The oxidised products have been found to cause liver malfunctions and fatty liver in fish. Ascorbic acid deficiency also causes spinal deformities like lordosis and scoliosis. It is seen that requirement for vitamin E increases with the increase in polyunsaturated fatty acid level in the diet. Some of the vitamin deficiency symptoms observable in fish are anaemia, poor appetite, atrophy of gills and muscles, opaqueness of eye lens, deformation of skeletal tissue,erosion of stomach, liver fin and skin, fatty liver, haemorrhage in vital organs such as eye gill, kidney, liver and skin, lethargy and erratic swimming. In crustaceans, ascorbic acid deficiency induces malfunctioning of collagen metabolism leading to a disease called black death.

Types of feeds

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The important factors affecting the cost of feeding are the cost of components in the diet and the feed conversion rate. Based on their nutrient composition, feed ingredients are classified into protein concentrates, energy concentrates, roughages, minerals, vitamins and additives. Ingredients containing more than 20% protein are generally considered as protein suplements those containing more than 18% crude fibre as roughage and those containing less than 18% crude fibre and less than 20% protein as energy concentrates.

The most commonly available conventional protein concentrates are fishmeal, crustacean meal, slaughter house waste and oil cake meal. Recently non-conventional ingredients such as feather meal, clam meal and single cell protein are also considered as important protein concentrates which can be used for the formulation of practical diets. Herbivorous and omnivorous species can be grown on diets comprising mainly plant protein. While the carnivores require a high percentage of animal protein the omnivores can be grown using a mixture of both plant and animal proteins. The commonly available energy concentrates are rice bran, wheat bran, cereals and tapioca starch which can be used for dietary formulations. Cooked starch has enhanced digestibility compared to raw starch. Proteins of plant origin do not satisfy the essential aminoacids requirement for most of the aquatic species. The most limiting amino acids are methionine, lysine and tryptophan. Soyabean oil cake is found to contain a high quality protein, though it is deficient in the sulphur amino acid methionine. The lipids of marine origin are superior to those of plant origin for most species of aquatic organisms. Marine fish and shellfish oils are rich sources of highly unsaturated fatty acids such as linolenic, eicosapentaenoic and docosahexaenoic acids. However, freshwater and brackishwater species can be grown successfully on a diet containing a mixture of oils of plant and marine origin.

Micro - particulate Feed- NPCL - 17

A micro-particulate compounded feed, NPCL-17, having 35% protein is successfully developed at the Narakkal Prawn Culture Laboratory using low-cost ingredients such as prawn waste, mantis-shrimp *(Oratosquilla nepa)*, fishmeal, groundnut cake and tapioca for mass culture of prawn larvae. The feed with a particle size of 50 microns is used for rearing protozoea to post larvae PL1 in open culture system along with diatoms. The particle size of the feed is increased to 200 microns for rearing the post larvae PL1 to post larvae PL5. The rate of survival with this feed is found to be more than 60%. The same feed with a particle size of 500 microns is used for rearing the post larvae PL5 in nursery until they become stockable size with an average recovery of more than 50% at PL20 stage. This feed at present is successfully used in the mass production of the seed of *Penaeus indicus* at the Narakkal Laboratory. Development of this compounded feed has helped in completely eliminating the use of more expensive live feeds such as rotifers and *Artemia*. The cost of the feed works out at Rs. 5 per kg. The quantity of particulate feed required to rear and obtain one million post larvae PL5 is about 20 kg.

High-energy Pelletized Feed NPCL-235

A high-energy pelletized feed, NPCL235, has been developed for the culture of penaeid prawns in grow-out ponds. Carbohydrate and lipid in appropriate proportion are used to obtain the value of 4500 K Cal. and 250 g protein per kilogram of feed. Using this feed an average food conversion ratio of 3 is obtained in *P. indicus*. The water stability of the feed pellets is 6 hours. The feed costs Rs. 4 per kg.

Compounded feeds have the following advantages:

- The feeds are nutritionally balanced.
- Easy to prepare
- Cheaper in cost
- Can be prepared in large quantities, stored and used off-the-shelf as and when required.
- Easy to dispense.

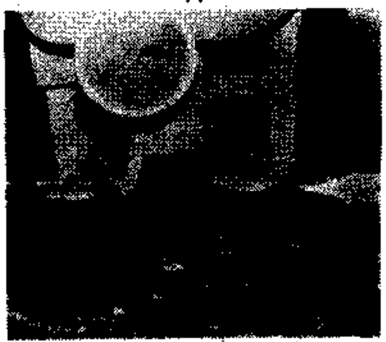
The water stability of the diet and its acceptability by the animals are dependent upon the form of diet. Various types of diet viz., hard pellets, soft pellets, floating pellets, flakes, crumbles, microcapsules, powdered diets, moist pellets and dough are used for feeding aquatic animals, depending upon the species and its size. Suitability of particle size of the feed offered is vital for filter feeders like larval crustaceans and molluscs. In most species the larvae are fed initially with live food organisms such as phytoplankters, rotifer, *Moina* and *Artemia* nauplii. Molluscan larvae are mostly reared with *Isochrysis galbana*. Of late microparticulate diets and microcapsules are used for feeding certain stages of larvae of prawn and fish fry on experimental scale. Advanced fry of certain species are also reared on flake and crumble diets. For the grow-out system the most successful diets are pellets. Finfish such as milkfish, mullets, carp and eel prefer soft dough for their diet. To prevent leaching of nutrients from diets various types of binders are used. Agar, alginates, chitosan, carrangeenan, guar gum, gelatinised starch, gelatin etc. are some of the most commonly used binders of feeds.

Feed ingredients containing adventitious toxins such as gossypol in cotton seed, trypsin-inhibitor and haemagglutins in oil cakes, cyclopropenoic fatty acids, tannins and hydrocyanic acid require proper treatment before their inclusion in compounded feeds.

Handling and storage of feed assumes great importance in nutrition. In humid regions growth of mould produces aflatoxins and bacteria, which produce T2 toxins. Feeds containing the above toxins may induce diseases in the organisms. Proper care and storage are essential to prevent loss of feeds through these toxins.

Feed Preparation - Different Stages

A



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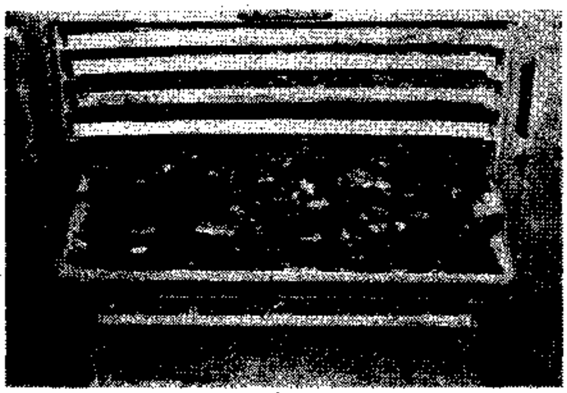

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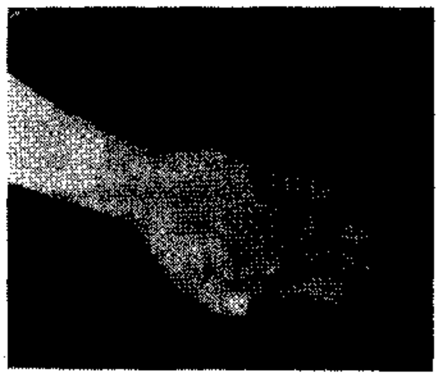

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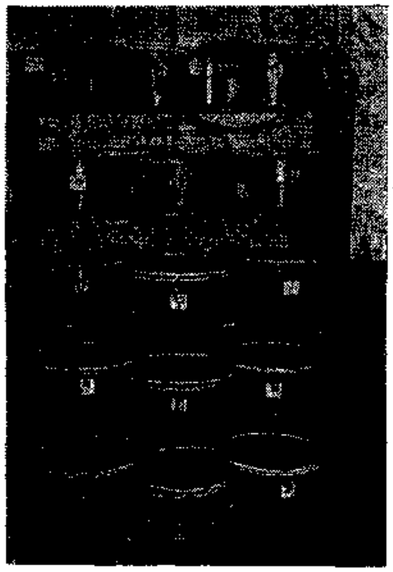

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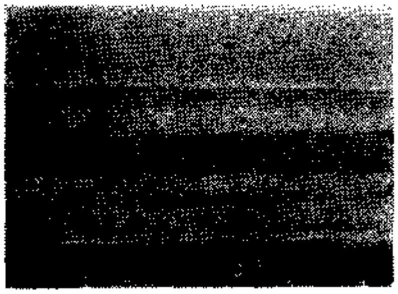

F

A. Grinding of raw materials
B. Pelletization
C. Drying of pellets
D. Different feeds developed at Narakkal
E. Evaluation of feeds in the laboratory through statistically designed experiments.
F. Prawns feeding on pellets
G. Feeding finfish with dough form of diet.