Nutrition and feeding aspects in nursery rearing of marine finfishes

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Introduction

Aquaculture gained its importance as fastest growing food production industry in the world. This sector has provided more fish for human consumption than capture fisheries and it is estimated that by 2030, the major source of fish production for human nutrition will be from aquaculture. The awareness about the fish as a part of healthy diet is well accepted by the majority of the population. Fish and fish products are excellent source of high quality protein. In addition to protein, fish contains all essential amino acids, long chain omega-3 fatty acids, all essential minerals such as calcium, phosphorus, Zinc, Iron, selenium, iodide; vitamins such as Vitamin A, B and D. More over fish proteins are easily digestible with highest digestibility coefficient of 100. Fish protein with only slight difference among groups, possess high nutrition value similar to that of meat proteins and slightly lower than that of egg.

Fish nutrition and nutrient efficiency in aquaculture

Fish nutrition is the study of nutrients and energy sources essential for fish health, growth and reproduction. The essential nutrients for fish are amino acids, fatty acids, vitamins, minerals and energy-yielding macronutrients such as protein, lipid and carbohydrate. Diets for fish must supply all essential nutrients and energy required to meet the physiological needs of growing animals. The bioavailability or digestibility of the diet is the proportion of nutrients in the feed that is digested and absorbed by the fish. Feeds that are poorly digested result in limited growth and faeces with high nutrient content, which pollutes the environment. Energy requirements for fish are dependent on a range of factors such as fish size, species, feeding preferences and environmental conditions. In general, fish have low energy requirements compared with other terrestrial animals because, being poikilothermic, fish do not need to maintain internal body temperature, fish live in water and have a swim bladder to adjust body buoyancy so that fish expend less energy to maintain body station in the water column and fish have a lower energetic expenditure for the detoxification and removal of ammonia (the end product of protein catabolism) prior to excretion.

In animal production systems, nutrition plays an inevitable role to ensure economic production of a healthy high quality product. In fish farming (aquaculture/mariculture), nutrition is a critical factor because feed represents approximately 50% of the variable production cost. Recent advances in fish nutrition could lead to the development of new, balanced commercial diets that promote optimal growth and health in fish. The development of new species specific formulated feeds satisfy the increasing demand for affordable, safe, high quality fish and seafood products, thereby supports the aquaculture industry. The prepared or artificial diets are of two types; complete or supplemental. Most fish farmers use complete diets, where fish are reared in high-density indoor systems or confined in cages and cannot forage freely on natural food (e.g., algae, aquatic plants, aquatic invertebrates, etc.). Complete diets supply all the ingredients (protein, carbohydrates, lipid, vitamins and minerals) necessary for the optimal growth and health of the fish. Supplemental (i.e., incomplete or partial) diets are intended only to support the natural food normally available to fish in ponds or outdoor raceways. Supplemental diets do not contain a full complement of vitamins or minerals but are typically used to help fortify the naturally available diet with extra protein, carbohydrate, and/or lipids.

Protein Requirement

Proteins are indispensable nutrients for growth and maintenance of living organisms. Protein consists of large molecules called amino acids, which are the required metabolic compounds used as either a major energy source for protein synthesis. Protein is required in the diet to obtain amino acids, which are utilized to synthesize new proteins or maintain existing proteins in tissues while excess protein is converted to energy. Protein constitutes 65–75% of the dry matter in fish tissues, therefore out of the three major nutrients it is the more essential nutrient in fish nutrition. Growing fish accrete new tissues and some of the energy supplied in the diet is stored as protein, lipid and some glycogen. Protein deposition depends on the balance of available amino acids in protein and the digestible protein-to-digestible energy ratio. Excess energy intake and low protein levels result in the deposition of lipid as recovered energy, which does not equate to faster growth and in an inefficient use of nutrients.

In general, marine carnivorous fish species have the ability to utilize the energy from dietary protein and lipid more effectively than dietary carbohydrate (CHO) in comparison with omnivorous species (Shimeno et al. 1996). If the energy content of a diet in the form of lipid or CHO is below the required level, then fish will utilize dietary protein for energy instead of utilizing the energy for protein synthesis, which reduces growth and also adds to the cost of production (Masumoto 2002). Warm water species such as Asian seabass, groupers and cobia are carnivorous marine species requiring a high level of protein in their diet. During grow-out, 40–50% CP is the optimal dietary protein level for Asian seabass (Boonyaratpalin & Williams 2002), groupers (Chen & Tsai 1994; Luo et al. 2005; Rachmansyah et al. 2005) and cobia (Chou et al. 2001), while juveniles generally have a higher protein requirement of >50% CP (Boonyaratpalin 1997).

A balanced diet with appropriate protein energy ratio (P: E ratio) is important in fish nutrition. This P : E requirement varies among cold water and warm water fishes. Cold water fish have the ability to utilize higher levels of dietary lipid for energy, thus requiring a lower dietary P:E level than temperate or warm water species. Most cultured fish species require 30–55% crude protein (CP) in the diet, which provides a suite of essential and unessential amino acids required for cell maintenance, growth, development and health of fish (NRC 2011).

Lipid requirement

Fish have the ability to utilize lipids for energy, saving protein for deposition and growth; therefore inclusion of lipids in diets for fish is important for both growth and energy purposes. Lipids (fats) are high-energy nutrients that can be utilized to partially spare (substitute for) protein in aquaculture feeds. Lipids have about twice the energy density of proteins and carbohydrates. Lipids typically make up about 7-15 percent of fish diets, supply essential fatty acids, and serve as transporters for fat soluble vitamins. Marine fish typically require omega-3 fatty acids for optimal growth and health, usually in quantities ranging from 0.5-2.0 percent of the dry diet. The two major essential fatty acids of this group are eicosapentaenoic acid (EPA: 20:5n-3) and docosahexaenoic acid (DHA: 22:6n-3). Many marine fishes lack or produce inadequate levels of elongase or desaturase enzymes for the fatty acid synthesis. The requirement of essential fatty acids can only be met by supplying Long Chain (LC) Polyunsaturated Fatty Acids (PUFA) in the diet, specifically á-Linolenic Acid (LNA, 18:3n3) and Linoleic Acid (LA, 18:2n6), with varying requirements for eicosapentaenoic acid (EPA, 20:5n3) and docosahexaenoic acid (DHA, 22:6n3) depending on species. Dietary lipids are also important structural components of membranes, and act as precursors of steroid hormones and prostaglandins in fish. Lipids are incorporated in the formulated diets to take advantage of their protein sparing effect to reduce feed cost (De Silva and Anderson, 1995). Farmed fishes have a tendency to show high lipid content in flesh when compared to their wild counterparts. The fatty acid composition of farmed fishes depends on the type of dietary fat used for raising the fish. Adequate quantity of lipid is necessary in the diet for better palatability and utilization of feed, but excess quantity causes problems related to feed manufacturing and besides produce fatty fishes (Cowey and Sargent, 1977). Lipid levels exceeding >15% lead to suppression of appetite, growth and lipid deposition within the carcass of tropical species (Wang et al., 2005). Warm water, carnivorous fish have a requirement for dietary n-3 FA, such as 1.0–1.7% n-3 LC-PUFA of the diet for Asian seabass fingerlings (Boonyaratpalin 1997) and 0.8–1.2% n-3 LC-PUFA of the diet for juvenile cobia (Chou et al. 2001).

Carbohydrate requirement

Carbohydrate is the cheapest food source for human beings, animals as well as aquatic living beings. It gives an energy value of 7.2 kilojoule/gram. It is also used as a binder in fish feed. The carbohydrate utilization by fish varies in different species. Carbohydrate also has protein sparing effect but high intake level gives deleterious effect to fish health. It is reported that high carbohydrate in the diet leads to liver damage of fish. It is also found that even after the digestion, glucose is not used for the energy by fish; sometimes it is lost through the urine. High glucose level in the diet will increase the oxygen consumption of fish when replaced with protein. High glucose intake also lowers the protein retention efficiency of fish. Therefore, the optimum level of carbohydrate in the fish feed is very essential. Marine carnivorous fishes are known to have limited ability to digest and utilize dietary carbohydrate due to paucity of amylolytic enzyme activity; hence excess intake resulted in poor feed utilization and reduced growth (Van Barneveld et al., 2001). Examples of good carbohydrate sources are: (1) cereal grains and by-products, rice bran and other rice by-products, corn, barley, millet, wheat, oats, sorghum; and (2) roots and tubers - potato starch, cassava starch, sago palm starch.

Vitamin requirement

Vitamins are organic compounds necessary in the diet to support normal fish growth and health. They are often not synthesized by fish and must be provided in the diet. It is a vital component for many proteins, enzyme and hormones. They come under micronutrients as they are needed in micrograms. But their absence in the diet make animals vulnerable to many diseases (Lavell, 1989). Many diseases encountered in farming animals are often connected with vitamin deficiency in their diet (Halver,2002). There are mainly two types of vitamins; water soluble (Thiamin, Riboflavin, Pyridoxine, Pantothenic acid, Inositol, Biotin, Folic acid, Choline, Nicotinic acid, Ascorbic acid and p-Aminobenzoic acid), which are soluble in the water and fat soluble (Vitamin A, D, E and K), which are soluble in fat. Fish mostly require all vitamins in the diet. Of these, vitamin C and E are the most important because they are powerful antioxidants and it they enhance the immune system of fish and shrimp. As a feed ingredient, vitamins E and C also inhibit dietary lipid oxidation, thus helping to improve shelf life. Deficiency of each vitamin has specific symptoms, but reduced growth is the most common symptom of any vitamin deficiency. Scoliosis (bent backbone symptom) and dark coloration may result from deficiencies of ascorbic acid and folic acid respectively. The vitamin deficiency (Avitaminosis) occurs mostly due to deficiency in water soluble vitamins; because water soluble vitamins are quickly utilised and absorbed by the animals. Avitaminosis in fish due to lack of fat-soluble vitamins are not common; because they metabolize slowly and often they are stored in the tissues. Hyper-vitaminosis is also recorded in the fish when they receive more fat soluble vitamins such as vitamin A and D in the diet (Burrows *et al*., 1952).

Vitamins in adequate quantities are required for normal function of the fishes. Like other freshwater fishes, marine fishes lack the physiological mechanisms to synthesise vitamins and must be supplied through the diet. Major natural sources of vitamins are: fish oils, vegetable oils, leaf meals, brans, yeasts, milk and milk products, soybean, cereals, citrus fruits, wheat germ, liver, fish meal and viscera, slaughterhouse wastes, fresh fish tissue, insects and animal offal. The quantitative requirement in fish varies with various aspects such as species, life stage, feeding habit, health condition, environmental parameters and nutrient interrelationships. Water soluble vitamins are absorbed from water through intestine and excess quantity is excreted out.

Mineral requirement

Minerals are inorganic elements necessary in the diet for normal body functions. They can be divided into two groups — macrominerals and micro minerals — based on the quantity required in the diet and the amount present in fish. Fish can absorb many minerals directly from the water through their gills and skin, allowing them to compensate to some extent for mineral deficiencies in their diet. Common dietary macrominerals are calcium, sodium, chloride, potassium, chlorine, sulphur, phosphorous, and magnesium. These minerals regulate osmotic balance and aid in bone formation and integrity. Common micro minerals are iron, copper, chromium, iodine, manganese, zinc, and selenium. The minerals are important element required for the animal physiology (Watanabe *et al*., 1997). They are part of many enzymes, hormones and proteins (Fotedar *et al*., 2016). They are also necessary for the formation of bones, regulation of pH and the maintenance of normal health physiology (Lall, 2002). As like vitamins, most minerals are required in micro grams; hence, they come under micronutrients. The requirement of minerals vary among for freshwater and marine water fishes as both systems have rich or less in some essential minerals in sufficient amounts. Certain minerals like Selenium have role in the strengthening of immunity by improving the antioxidant capacity of animals, zinc and manganese for reproduction in fish and copper have role in proper haematology, metabolism and stress (Wang *et al*., 2016; Damasceno *et al*.,2016) in fishes.

Impact of feeding in RAS system

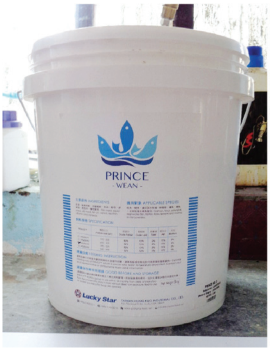
Aquafeeds are the main sources contributing to RAS nutrient accumulation and discharge. Low protein feed (< 35%) resulted in very good water quality, but fail to meet the nutrient requirements for fish growth resulting in the highest FCR with smaller sized fish. Whereas, high protein feed (> 45% protein) resulted in poor water quality as a result of diarrhea-like feces from the fish and provided no significant benefit to fish growth. Feed protein content as well as stressful environmental conditions are known to induce enteritis leading to diarrhea (Penn et al., 2011; Sarker et al., 2020). Medium protein content feed of 40 - 45 % can provide optimal amount of protein required for marine fishes yielding with good growth performance indicators without reducing water quality.

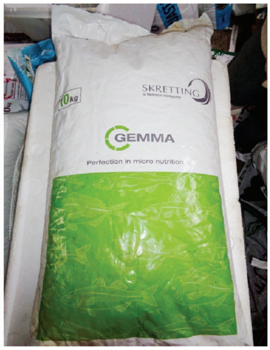
Although feed is the main source of nutrients excreted into water, the amount and form of waste output from commercial fish farming depend not only on feed composition, but also on feeding strategy (Pedersen et al, 2012). In RAS system, during the process of nitrification, nitrate becomes the end product of nitrogen metabolism regulated by feed composition, feeding and nutrient utilization. TAN and nitrite levels increased with feeding and nitrite-N concentrations were generally 1.35–2.04 times higher than the corresponding TAN concentration, indicating that the biofilm exhibited a lower nitrite-N removal rate. It seems that the TAN/nitrite-N ratio in RAS can vary considerably in practice, which is probably due to variable environmental conditions, biofilter design and management of the systems with different activity and strain variability in ammonia oxidizers and nitrite oxidizers.

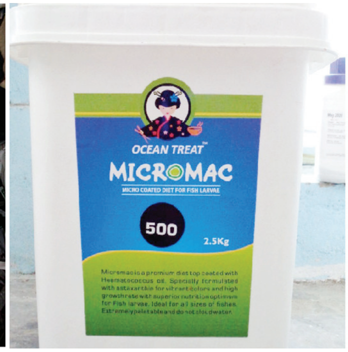
Nutrients retention and the potential release into the water are variable among different species and culture conditions. Thus, estimations of those are not readily available and are changing rapidly with feeds, feeding strategies and culture methods. Improved feed technology is required to increase nutrient retention and reduce losses such that most N is excreted in the dissolved form (primarily as ammonia) and most P as particulate (Bureau et al; 1999). The nitrogen and phosphorus balances form the variables during diet formulation and feeding regime. The retention efficiency for nutrients appeared to be good indicators for accounting for fish growth. Nutrients balance analysis for N and P provided information between feed intake and the resulting water quality. Feeding strategies like restricted feeding rate and reasonable frequency could be used as tools for increasing RAS operation efficiency, not only for better utilization of nutrients during periods with rapid growth, but also for decreasing N and P waste output to the environment.

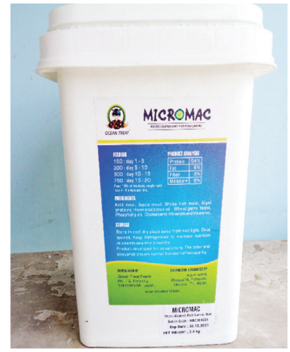
Manipulation of dietary carbohydrate composition can affect waste production, composition and biofilter load in recirculating aquaculture systems (Andre Meriac et al; 2014). NSPs components from source of carbohydrate during feed formulation resulted in decreased COD and dry matter digestibility and drastically increased COD output from RAS. The effective load of biochemical oxygen demand (BOD) is determined by the degradability of the supplied COD. Lignocellulosic material originating from unpurified plant ingredients can significantly decrease COD degradability. A decreased COD degradability will restrict the amount of readily degradable carbon for possible waste treatment processes like denitrification. Solid organic waste generated in RAS can be used as a carbon source for denitrification (Gelfand et al., 2003). Using denitrification on internal carbon sources does not only reduce COD and N output from RAS, but it even allows to lower the water exchange to 30 L/kg feed in RAS (Martins et al., 2009).

Commonly used commercial feeds during nursery rearing of marine finfishes in RAS










0.3-0.5 mm


0.8 mm


0.5 mm


0.3 mm

Conclusion

Nutritional aspects play an important role during the day to day maitenance of recirculatory aquaculture system (RAS). Proper formulation of feed with suitable feed ingredients, which can fullfill the nutritional requirement of the cultured animal will lead to good growth performance. Improvement in feed technology with manipulation in feeding strategy, feed ration and feeding frequency in RAS system, can ensure good water quality with minium water exchange during nursery rearing resulted in quality fingerling production.

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