

Review Article

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Feeding of Different Categories of Fish, their Nutritional Requirements and Implication of Various Techniques in Fish Culture – A Review

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ABSTRACT

Aqua cultural production is a major industry in many countries, and it will continue to grow as the demand for fisheries products increases and the supply from natural sources decreases. Good nutrition in animal production systems is essential to economical production of a healthy, high-quality product. In fish farming (aquaculture), nutrition is critical because feed typically represents approximately 50 percent of the variable production cost. 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 industry as it expands to satisfy increasing demand for affordable, safe, high-quality fish and seafood products. Article provides a general overview of the wide variety of nano-materials and technologies in fish culture that offer significant promising role for water recovery.

Keywords

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Introduction

Rearing of fishes in tanks is being practiced in India since as early as 350 B.C making it one of the oldest food based Industry however it apparently became more popular in later years. Fishing industry in India is more popular in coastal states including Bengal, Orissa and Andhra Pradesh as compared to other states and Punjab and is a source of livelihood for over 14 million people. Talking about the date around 11, 34,948 tonnes of seafood worth 5.78 bilion US\$ (37,870.90

crore) was exported in 2016-17, of which frozen shrimp was top item to be exported.

On a global scale, cultured fish production has doubled from 1990 to 1996, reaching 26 million ton, and output could reach 39 million ton by 2010 (Radhakrishna, 2002).

Though world fish capture has reached a plateau at approximately 94 million tons (FAO, 2007) yet most recent estimates suggest that 52 percent of marine stocks are fully exploited, 17 percent are overexploited and 7 percent are totally depleted (FAO,

2005a) while human population and demand has increased greatly in current years leading to great pressure on global aquaculture to bridge gap between supply and demand of fishes. According to (FAO, 2018) growing share of fish production is expected to be destined for human consumption (around 90 percent). The driving force behind this increase will be a combination of rising incomes and urbanization, linked with the expansion of fish production and improved distribution channels. In per capita terms, world fish consumption is projected to reach 21.5 kg in 2030, up from 20.3 kg in 2016. Fish nutrition has shown a boom in recent years due to increased demand and with development of new technologies like nano diets which have led to increased fish growth and health leading to manufacture affordable, safe and high quality fish and sea food products.

Feeding behavior according to different categories of fish

Aquaculture deals with farming of aquatic animals in inland or coastal areas, which involves a sole ownership to cultivate the stock (FAO, 2009). Fish being highly nutritive in nature, it provides a large amount of protein and oil in both basic and reduced (fish meal) form which is used for animal culture. Its unique amino acid profile and high digestibility makes it one of the essential component of modern day animal farming. Tacon *et al.*, 2006 divided aquaculture into four broad categories based upon the relative position of the animals cultured in the trophic hierarchy and thus the fishmeal and fish oil in their diets.

Carnivorous finfish: included fishes with high protein requirements which should be mostly from animal sources. This group includes the salmonids, as well as many marine and freshwater species such as seabass, seabream,

eels, amberjack, groupers and snakeheads. 20-40% of fishmeal is required these species require from 20 to 40 percent fishmeal in their diets.

Herbivorous/omnivorous finfish: depends upon lower protein requirement which can be derived from either plant or animal sources and includes fishes like common carp, grass carp, other cyprinids, catfish and milkfish, all of which require around 5 percent fishmeal content in their feeds.

Omnivorous/scavenging crustaceans: they require between 15 and 25 percent fishmeal in their diets and includes the marine shrimps, freshwater prawns, crabs and crayfishes.

Filter-feeding finfish: these species do not need supplementary feed and just thrives on phyto- and zooplankton for their dietary requirements. They include silver carp, bighead carp, catla and rohu.

Feeding behavior of fishes is mainly effected by factors like stocking density, sex ratio, biological and physiological status, however limited investigation can lead to conflict between and within species. Some of the rhythms are controlled by endogenous clock mechanisms, but environmental factors, such as day length or temperature, may either control others or act as time setters or synchronizers (Madrid *et al.*, 2001).

Understanding of the physiologic rhythms in farmed fish can help to provide useful information about the selection of proper times for feeding fish to maximize growth, improve feed efficiency, and reduce feed wastage and fecal output to minimize the environmental impacts of aquaculture. The three marked feeding rhythms that affect food consumption in fish are diel(daily), annual (seasonal), and tidal (lunar) rhythms. Most fish in culture systems have diel feeding

rhythms whereby they are either diurnal feeders (eat during the day) or nocturnal feeders (eat at night). Biotic factors (such as threat of predation) and abiotic factors (such as lighting conditions) affects changes in many fishes on the feeding pattern (Daan S 1981 and Bougard *et al.*, 1992). On the basis of culture system used, feeds and feeding of fish depend upon: extensive, semi intensive or intensive system. In extensive and semi intensive, fish derive all or a substantial part of their nutrients from natural food organisms in culture ponds. However fishes are maintained in tanks and cages in case of intensive system and are totally dependent on provisional nutritionally complete diets produced in dry, semi-moist, or moist forms. Diets fed to fish are subject to leaching of nutrients while they remain in the water column or at the bottom of the culture system. Dried feeds are formulated using steam or cold compression technique for pelleting.

Different shapes and sized pellets are formed which shows different buoyancies for fishes with different floating levels. For example, catfish, salmon, and shrimp require floating, slow-sinking, or fast-sinking feeds, respectively because of their different preferred feeding habits in the water column. For salmonids and marine fishes extrusion technology is widely used to produce cold water feeds. Extruded feed contains high energy contents based on high levels of lipid (20%–40% of the diet). Feed efficiency for fishes is based upon their distribution and amount of feed to be fed depends upon factors like percentage of body weight and water temperature. Young fish require feed at a greater percentage of their body weight per day (>5%) than older fish. Demand or ad libitum feeding is commonly used in hatcheries where demand feeders dispense small quantities of feed when activated by the fish.

Nutrient requirements of fish

Nutrient requirement for fishes and animals are not very different as fishes too thrive on nutrients including amino acids, fatty acids, vitamins, minerals, and energy-yielding macronutrients (protein, lipid, and carbohydrate). Nutrients are required for physiological needs of growing and reproductive brood stock. With increasing population and depleted aquatic reservoirs the popularity for intensive and extensive fish rearing has greatly increased. Despite considerable advances reported over the past 5 decades, the quantitative requirements for all essential nutrients for most farmed fish species are not well established.

Nutrient requirement containing 40 specific nutrients with their quantitative nutrient requirements have been very well formulated for rainbow trout, Pacific salmon, channel catfish, tilapia, and common carp, while partial nutrient requirements have been established more recently for numerous other fish species (NRC 1993, Halver *et al.*). Minimum requirements established can promote growth without any deficiency symptoms however additional amount of nutrients will increase reserves present in muscles. Although the minimum nutrient requirements established promote growth and prevent deficiency signs, higher intakes of vitamins, minerals, amino acids, and essential fatty acids increase buildup of their reserves in the tissues. However continued intake of certain nutrients in excess amounts leads to saturation of various coenzymes. It has also been found that certain fat-soluble vitamins (eg, vitamin A) and trace elements (eg, copper, selenium) can be toxic when given in excess. Deficiencies or excesses of each of the major dietary components effects largely through their effects on host defense mechanisms. Nutritional deficiencies can predispose fishes to various infections by

affecting their skin and mucus integrity, changes in composition of tissue and body fluids and by reducing mucus secretions. However, with anorexia being a common symptom of nearly all nutrient deficiencies (NRC 1993).

Particle size is closely related to feed intake and the correct feed particle size induces a positive behavioral response. Feed particles must be sufficiently small to be ingested, while being large enough to be consumed without expending too much energy in the process.

Macronutrients

Protein forms one of the most important component of fish diet as they require a well-balanced amino acid profile which can be provided from plant or animal sources. Deficiency in protein can lead to decreased growth and tissue development however excessive protein can lead to increased nitrogenous waste excretion which can lead to increased economic losses as protein is the most expensive part of the fish nutrition. Most herbivorous and omnivorous fish require 25% to 35% protein in their diet but carnivorous species require higher levels of protein ranging from 40% to 55% of diet (NRC 1993). This difference can be easily explained as carnivorous fishes uses proteins as an energy source as compared to carbohydrates used by herbivorous/ omnivorous fishes. The efficient use of dietary protein in these fish is also attributable to the mechanism by which ammonia, produced by deaminated protein, is excreted by way of the gills with limited expenditure of energy. Dietary protein requirements are influenced by both energy density of the diet and the ratio of energy to protein in the diet. Ten amino acids, namely arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine, are considered

indispensable(essential) for most fish species studied to date. Among the dispensable (nonessential) amino acids that commonly make up protein, two are particularly important for their ability to partially replace or spare indispensable amino acids. It has been observed that in fishes, requirement of phenylalanine can be spared by tyrosine upto 50% and cysteine can replace upto 50% of methionine requirement (sulfur containing amino acid). Carbohydrate requirement has not been demonstrated in fish, though lack of carbohydrates leads to excessive catabolism of proteins and lipids. Lipids supply essential fatty acids (EFAs) and energy in the diet of fish and the EFA requirement of most fish can only be met by supplying the long-chain unsaturated fattyacids of linolenic (18:3 n-3) and linoleic (18:2 n-6) series. Salmonid and marine fish seem to have limited ability to chain elongate and desaturate 18:3 n-3 and 18:2 n-6 to meet their requirement, unlike many freshwater fish that have been shown to meet their requirements for these essential fatty acids (Bell *et al.*, 1998).

Micronutrients

Fish have unique physiologic mechanisms to absorb and retain minerals from their diets and from the surrounding water (Lall SP 2002). Though the requirements of trace elements by fish is not clear yet, though trace elements are required for skeletal growth, cellular respiration, oxygen transport, immune function, and regulation of acid–base equilibrium, they are also important components of hormones, enzymes, and enzyme activators. Toxicity can occur due to excessive intake of minerals from gills therefore maintaining a fine balance between mineral deficiency and surplus is vital for aquatic organisms to maintain their homeostasis either through increased absorption or excretion. Quantitative dietary requirements have been reported for

phosphorus, magnesium, zinc, iron, copper, manganese, iodine, and selenium for selected fish species. In particular, fresh water of moderate hardness (w50 mg/L as CaCO₃) has been shown to provide fish with adequate calcium to sustain metabolic functions in the presence of low levels of dietary calcium. Limited presence of phosphorus in water makes phosphorus requirement critical as common plant ingredients as also lacks phosphorus availability.

Use of Micro algal nutrients

With over exploitation of fishes and increasing demand a great decrease in availability of fish meal for aquaculture has been observed. Thus making alternative protein sources for aquaculture a necessity. A lot of work has been done over the period of time and micro alga has proved to be a very good protein source which could partially or wholly replace the fish meal from fish diet.

Partial or complete replacement of fish meal has remained a topic of concern and a huge amount of work has been done for same in different fish species, like, salmon, rainbow trout, chinook salmon—*Onorhynchus* spp. (Steffens 1994; Stickney *et al.*, 1996; Bureau *et al.*, 2000), Indian major carp—*Labeo rohita* (Hasan *et al.*, 1993, 1994, 1997), Java and Nile tilapia—*Oryochromis* spp. (El-Sayed 1998), India major carp—*Cirrhinus mrigala* (Hasan *et al.*, 1988) and common carp—*Cyprinus carpio* (Yilmaz *et al.*, 2003) etc. In feeding trials with fish, many types of microalgae have been found to increase growth (protein accretion), feed utilization, physiological activity, stress response, starvation tolerance, disease resistance, and carcass quality (Mustafa and Nakagawa 1995). For example, when tested in fish diets, enhanced growth and improved protein digestibility was found on feeding of *Spirulina* (Mustafa *et al.*, 1994), stress and

disease resistance (Henson 1990; Olvera-Novoa *et al.*, 1998), improved carcass quality (Belay *et al.*, 1996; Floreto *et al.*, 1996), and induced early maturation thereby leading to a shorter breeding cycle and period of cultivation (Braun 1988). Regunathan and Wesley 2006 stated that microalgae can be used as caretonoid sources for shrimp brood stock and as a protein or lipid source to partially replace fish meals or fish oil in fish feeds (Patnaik *et al.*, 2006). Recent studies have shown incorporation of *Ulva* meal may enhance carcass composition (Gu'roy *et al.*, 2007; Azaza *et al.*, 2008). The present group also tested a number of microalgal biomass mix as value added feed employing different algal genera like *S. platensis*, *S. subsalsa*, *Phormidium valderianum*, *Phormidium tenue*, *N. ellipsosporum*, *N. minima*, *Rhizoclonium fontinale*, *Rhizoclonium riparium*, *Spirogyra* sp., *Enteromorpha intestinalis*, *U. lactuca* for Prawn, Rohu, Tilapia and Gold fish (Khatoon *et al.*, 2009, 2010a, b; Sen Roy *et al.*, 2011; Mukherjee *et al.*, 2011).T

Feed conversion efficiency

Nutrition forms 70% of the total cost of animal or fish production thus making feed efficiency an important parameter for a successful business (Craig *et al.*, 2017). Feed conversion ratio is considered as one of the most important parameter in intensive rearing. Feed conversion ratio is calculated as the weight of the feed fed to the fish divided by the weight of fish growth. For example, if fish are fed 20 pounds of feed and then exhibit a 10-pound weight gain, the FCR is $20/10 = 2$. FCR above 1.5 is considered to be good growth parameter for most of the species, however fishes like tilapia, Trout and salmon tend to have lower FCR values ranging from 0.9 to 1.3. Reciprocal of the feed conversion ratio ($1/FCR$) is also known as feed efficiency. In the example above, the FE is $10/20 = 50$ percent. Therefore, if fish are fed

24 pounds of feed and exhibit an 8-pound weight gain, the FE = 8/24 = 30 percent. An FE greater than 50 percent is generally considered acceptable. In addition to growth, some of the energy in feed is used by the fish for metabolic and digestive processing, respiration, nerve impulses, salt balance, swimming, and other living activities. Feed conversion ratios will vary among species, sizes, and activity levels of fish, environmental parameters, and the culture system used (Craig *et al.*, 2017).

Managing fish waste

Excessive fish wastes can lead to water contamination, reduced dissolved oxygen, increased B.O.D and increased bacterial load in water. Fish wastes increases with overfeeding which can lead to huge amount of economic loss, making fish waste an important economic indicator. Usually, fish

should be fed only the amount of feed that they can consume quickly (in less than five to 10 minutes). As a good general rule of thumb is to feed the fish about 80 percent of the amount of feed they want for satiation. However the needed amount of feed is fed only twice a month after regular cycle of providing 80% of feed (Craig *et al.*, 2017). Even following the above technique there is some amount of feed which remains uneaten and gets totally wasted. On an average around 5% of feed remains uneaten, and out of 100 units of feed fed about 10-15% of feed is released as solid waste and 30-35% of feed is released as liquid waste. Of the remaining feed, about 25 units are used for growth and another 25 units are used for metabolism (heat energy for life processes). However these numbers may vary greatly with species, sizes, activity, water temperature, and other environmental conditions.

Table.1 FAO, 2018

Year	2011	2012	2013	2014	2015	2016
Total Capture	92.2	89.2	90.6	91.2	92.7	90.9
Marine capture	23.2	24.4	25.4	26.8	27.5	28.7
Inland capture	38.6	42	44.8	46.9	48.6	51.4
Total aquaculture	61.8	66.4	70.2	73.7	76.1	80.0
Total world fisheries and aquaculture	154	156	160.7	164.9	168.7	170.9
Human consumption	130	136.4	140.1	144.8	148.4	151.2
Non-food use	24	19.6	20.6	20	20.3	19.7
Per capita apparent consumption (kg)	18.5	19.2	19.5	19.9	20.2	20.3

Supplementation of carbonic anhydrase

Though the use of carbohydrase enzymes has not been as nearly as common in aquatic species, despite their promising effects in improving nutrient digestibility by hydrolyzing non-starch polysaccharides present in plant feedstuffs. Supplementation of exogenous carbohydrases to plant-based fish diets should improve nutrient digestibility and reduce nutrient excretion. On the other hand, the effects of exogenous carbohydrases on fish performance are still unclear due to the difficulty in cross-study comparisons. Overall, based on the information gathered in this review, it is clear that research on exogenous carbohydrase supplementation in aquaculture nutrition is not extensive. According to promising results and opportunities found in other non-ruminant animals, and favorable effects found in aquaculture species studied to date, it may be significant to increase research on this subject because it could be a useful tool to improve and sustain commercial aquaculture. (Castilo *et al.*, 2015)

Nanotechnology

Nanosciences and nanotechnologies are highly promising and rapidly progressing disciplines in research and industrial innovation. Nano sciences has helped food related streams in many ways like smart packaging, nanosensors for pathogen detection or registration of storage conditions, nano-formulations of agrochemicals, nano-encapsulation / nanodelivery of food ingredients. In the same way aquaculture can be revolutionized using the same technique as it can help in detection of diseases and enhancing the ability of fish to rapidly absorb drugs such as hormones, vaccines and nutrite feeding, disease control, and bio-fouling control processes are being re-engineered to get the maximum benefit from

nanotechnology. It has been proposed that nanoparticles can increase absorption of trace elements instead of being excreted without usage. Adding other mineral nutrients to the regular fish diet at the nanoscale level might also have a tremendous impact not only on growth but also on the overall health of the fish physiology. It has been propose that the use of nanomaterials in recycling process, the waste by-products from seafood processing plant scan enhance the feed for farm-raised fish. Nano-bio-bag recycling unified filter water purification equipment shall be inoculated in the water can help very effectively degrade fish, shrimp, shellfish, crabs, sea cucumbers and ammonia metabolites. Nano-water stone: can block, the internal water bacteria and keep the water clean to control pollution. Nano technology can help in reducing B.O.D of the water and reduce the nitrite and nitrate waste of the water. Nano silver ion antimicrobial coating nano-composite coatings, is the ideal fish pond green wall paint and these are now introducing in Japan and South Korea. Nanoparticles can be used in aquaculture as a vaccine delivery agent and promises better immunity to the fishes as compared to traditional vaccinations. However, there are concerns that the benefits associated with distribution of nanoparticles may also be accompanied with risks to the environment and health. Chitosan is used to wrap the vaccine and deliver it to fish using nano encapsulation technology. Nanoencapsulated vaccines against the bacterium *Listonella anguillarum* can be introduced in Asian Carp. However it has been observed that engineered nano particles can cause oxidative damage to DNA, but adverse health effects have not been observed. It is obvious that the potential health risks associated with exposure to engineered ENPs are now a major international concern, yet almost nothing is known on fate and

biological uptake of engineered nanoparticles in the aquatic environment. Furthermore, almost all studies in recent decade have been focused on the raw engineered nanoparticles, rather than the forms entering in the environment.

In conclusion, reliable estimates of nutrient requirements have been established for major cultured fish species. These estimates are rather similar among species whose natural feeding habits and environmental requirements are comparable. Aquatic environment for aquaculture is an important part and that can be maintained by our recent technique – the nanotechnology. Within this nano vision, a revolution is inevitably occurring in science and technology, based on the recently developed ability to measure, manipulate and organize matter on the nanoscale 1 to 100 billionth of a meter. Article provides a general overview of the wide variety of nano-materials and technologies in fish culture that offer significant promising role for water recovery. It is quite evident from the foregoing discussion that nanomaterials have enormous potential to provide innovative solutions for proper or sustainable aquaculture. However, for their successful implementation in aquaculture, as commercially viable technologies, one needs to carry out a thorough study on the engineering aspects, environmental issues, scalability and cost analysis.

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