Fresh Water Aquaculture Nutrition Research in India

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REVIEW

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ABSTRACT

This paper summarizes the available information on nutritional requirements and feeding practices of freshwater fishes in India. Fishes plays an important role in supply of protein diet to the consumers and responsible for nutritional security of the population. The Indian major carps *viz. Catla catla* (catla), *Labeo rohita* (rohu) and *Cirrhinus mrigala* (mrigal) contribute about 87% of total aquaculture production. Fish convert feed into body flesh more efficiently than farm animals. All the nutrients (protein and amino acid, fat and fatty acids, carbohydrate, minerals and vitamins) contribute to normal growth and development of fish. The protein requirement of carp, catfish and prawn feed varies from 25-35, 30-45 and 30-40%, respectively in their feed. The fat requirement of carp and catfish feed varies from 6-8% and in prawn feed the fat requirement is 6%. Amino acid and fatty acid requirement also influence the feed formulation for finfish and shellfish. Feed additives incorporation in fish feed improves feed intake. Feeding of fish with balanced diet helps in optimization of normal growth and fish production.

Key words: Fresh water aquaculture, Nutrients, Requirement, Additives

INTRODUCTION

The fisheries sector occupies an important place in the socio-economic development of the country envisaging livelihood, nutritional security, employment generation and export earnings. Indian fisheries occupies second position in global fish production and aquaculture in the world with an annual growth rate of 4.7% recording 3.2% growth in marine sector and 6.2% in inland sector. As per the estimates of CSO, the gross value added from fisheries sector at current prices during 2013-14 was ₹ 96, 824 crores which is about 5.15% of the gross value added from agriculture, forestry and fishing sectors. The fisheries sector has grown from traditional activity in the early fifties to commercial enterprise with impressive growth in production from 0.75 million tonnes in the 1950s to 9.58 million tonnes during 2013-14. This sector has emerged as the largest single sector in the country employing more than 14 million people (DAHDF, 2014-15). About 35% of the Indians eat fish and the per capita consumption is 9.8 kg while recommended intake is 13 kg (FAO, 2012).The growth in fish production has shown a cyclical pattern with an increasing long term trend. Inland fisheries has emerged as a major contributor to the overall fish production in the country with a present share of 63.3% in total fish production in the country. Within inland fisheries, there is great shift from captured fisheries to aquaculture and at present freshwater aquaculture share is 80% of total inland fish production.

There is huge demand for fish food for human consumption and reduction in capture fishery resources has created a gap between the supply and demand of fish. Under such circumstances, increased aquaculture production can reduce the gap. Indian aquaculture sector comprises of large scale culture of Indian major carp such as rohu, catla and mrigal with a combination of exotic carps, *viz.* grass carp, silver carp and common carp in fresh water sector. Carp which contribute about 87% in total aquaculture production in the country forms the mainstay of freshwater aquaculture activities. Beside this, catfish and prawn culture are also important components. Typical fish farming involves the enclosure of fish in a secured system. Fish culture has gradually been shifted from manure based low input extensive culture to manure/fertilizer and supplementary feed based medium input semi-intensive culture and finally to complete feed based high input

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intensive culture. Intensification implies increasing the density of individuals requiring greater use and management of inputs particularly balanced feed.

The use of traditional feed mixture consisting of cake: bran in 1: 1 ratio is still in vogue and this is provided in fertilized pond ecosystem to supplement the nutritional deficiencies. Since the traditional feed mixture is not nutritionally balanced and intensive or super-intensive production is a primary objective of the industry, there is a need to use balanced diet which provides the required essential nutrients. This approach necessitates an understanding of the basic nutrient requirements in order to formulate cheap and nutritionally balanced feeds for the aquaculture species. Recently, the aquaculture has shifted towards feed based aquaculture. In 2014, a total of 14.776 MT feed was used to sustain fish production. In feed based aquaculture, over 60% of operational cost goes to feed source alone (Paul and Mohanty, 2002). Feeding of fish with balanced diet is very essential as excess feeding not only makes financial losses but also deteriorates the pond water quality. The feed and nutrition standards of Indian fishes are available (BIS, 2013; ICAR, 2013). The nutrient requirements of fish have been derived largely from the experiments under controlled conditions.

FEEDING FISH VS. LAND ANIMALS

Feeding fish in water environment is quite different than that of land animals. While feeding fish, the nutrient contribution of natural aquatic organisms in ponds, the effects of feeding on water quality and the loss of nutrients if the feed is not consumed immediately are taken into consideration.

- Energy requirements are lower for fish than for warm-blooded animals and hence fish requires a higher dietary protein to energy ratio.
- Fish require some lipids which terrestrial animals do not, such as ω-3 fatty acids for some species.
- Crustaceans require dietary supplementation of sterols (cholesterol) due to lack of *de novo* synthesis.
- Fish have got ability to absorb soluble minerals from the water.
- Most fish do not synthesize ascorbic acid and depend upon dietary sources.
- Fish are not fed *ad lib*. like livestock and poultry and their feed allowances are based on mode of feeding. Hence, feed allowance influences the dietary nutrient requirements for maximum growth.
- As fish are fed in water, the feed that is not consumed within a reasonable time leads not only to economic losses but also greatly reduces water quality. Therefore, feed allowance, feeding method and water stability of feeds are very important considerations for aquaculture.
- Fish convert feeds into body tissue more efficiently than do farm animals.

The reason for the superior food conversion efficiency of fish is that they are able to assimilate diets with higher percentage of protein apparently because of their lower dietary energy requirement. Fish requires low energy in comparison to land animals because of a lower maintenance requirement and heat increment. The primary advantage of fish over land animal is lower energy cost of protein gain rather than the superior food

Table 1. Efficiency of utilization of feed, dietary ME and protein in fish, poultry and cattle

Animal	Feed composition		Efficiency		
	CP (%)	ME (kcal/g)	Weight gain (g/g of feed consumed)	Protein gain (g/g protein consumed)	ME required (kcal/g of protein gain)
Channel catfish	32	2.7	0.75	0.36	21
Broiler chicken	18	2.8	0.48	0.33	43
Beef cattle	11	2.6	0.13	0.15	167

conversion efficiency (Giri *et al*., 2004). The comparision is presented in Table 1 (Lovel,1998).

ROLES AND REQUIREMENTS OF NUTRIENTS IN FISHES

Carbohydrates/energy

Carbohydrates are important, less expensive and immediate source of energy. Besides, dietary carbohydrates provide carbon chains necessary for the synthesis of physiologically important biochemicals such as steroids, fatty acids and chitin. Distribution of amylolytic activity has been reported in major carps (Dhage, 1968). Sen *et al.* (1978) reported that 26% carbohydrates (dextrin) in the diet were sufficient for attainment of optimum growth of carp spawn, fry and fingerlings. Rohu can tolerate higher levels of carbohydrates in the diet (Mohapatra *et al*., 2003). Das and Tripathi (1991) showed that in fingerlings and adult grass carp, the pattern, distribution and activity of digestive enzymes are related to the type of diet ingested by fish. Erfanullah and Jafri (1995 a) studied the protein sparing effect of dietary carbohydrate in diets for rohu fingerlings and Erfanullah and Jafri (1995 b) the response of rohu fingerlings to various sources of dietary carbohydrate and found that sucrose was better source of carbohydrate than glucose, dextrin and potato starch. Satpathy and Ray (1998) indicated that *Labeo rohita* fry can utilize carbohydrate (dextrin) upto 35% in formulated diets. The inclusion of carbohydrates in fish diets improves the pelleting ability of feeds. The source and complexity of carbohydrate and the presence of carbohydrate metabolizing enzymes are known to influence carbohydrate utilization in fish. Erfanullah and Jafri (1998) reported that a diet containing 40% carbohydrate and 40% protein produced maximum growth, the best conversion efficiency and higher nutrient retention in catla fry. Rangarcharyulu *et al.* (2000) reported that diet having 30% protein and 370 kcal/100 g energy produced maximum growth. A level of 45% carbohydrate and 30% crude protein in the diet was efficiently utilized by catla fry (Mohapatra *et al.,* 2003). Cooking of grain increased digestibility of starch in catfish by 10 to 15%. Ray *et al*. (2012) suggested that fish gut microbiota might have positive effects on the digestive processes of fish and they also isolated and identified enzyme producing microbiota. The requirement of crude fibre for carp feeds has been shown to be 6% for spawn and 8% for fry, grow out and brood stock feed (BIS, 2013).

Prawn can efficiently utilize polysaccharides and disaccharides than monosaccharides (Ali, 1993). Dietary carbohydrates in the form of complex polysaccharides appeared to be more effective energy source (Mukhopadhyay *et al.*, 2003). The higher specific activity of amylase found in *M. Rosenbergii* supports the fact that the species efficiently utilize carbohydrates as energy source. It has omnivorous feeding habit. During fasting, energy metabolism in prawn is dominated by carbohydrates followed by lipids and proteins. *M. rosenbergii* can utilize dietary carbohydrates level of 30% (Fair *et al*., 1980). Diaz-Herrera *et al*. (1992) found that carbohydrates are the principal substrates used for energy production in larval and post larval *M. rosenbergii*. Crustaceans in general and prawn in particular are equipped with digestive enzymes to handle appreciable quantities of dietary carbohydrates (Karunkaran and Dhage, 1977). Law *et al*. (1990) reported the digestibility of carbohydrates in soybean meal and wheat flour to the extent of 80-100% and 93-100%, respectively. The high assimilation of carbohydrates may be related to high activities of specific carbohydrases particularly chitinases and cellulases. The requirement of crude fibre in the feed of *M. rosenbergii* is 8% for starter and grower and 10% for finisher prawn diet (BIS, 2013).

Energy

Protein and lipids are the primary sources of metabolic energy followed by carbohydrate in fish. The energy level in carp diets are normally maintained at 3.5-4 kcal/g. Under the conditions where energy intake is inadequate, fish derive energy first from protein at the cost of flesh growth. Excess protein is not only wasteful but also causes stress to fish while excess energy is known to induce lipogenesis thus necessitating a balance between protein and energy in diet formulation. Hassan and Jafri (1996) reported that an energy level of 355 kcal/100 g corresponding to an energy: protein ratio of 8.87 kcal/g protein showed maximum growth in mrigal. Rangacharyulu *et al.* (2000) demonstrated that diet having 30% protein and 370 kcal/100 g energy was optimum for growth in rohu fingerlings. The gross energy requirement of carp feeds is 4000 for spawn, 3500 for fry and 3000 kcal/kg for grow out and brood stock feed (BIS, 2013).

In catfish, very low level of energy in the diet affects the utilization of protein while excess energy in the diet creates nutrient imbalance and gets deposited in the adipose tissues in the form of body fat which is not at all desirable for marketing of fish. It has been suggested that the optimum protein to energy ratio in catfish is 90-100 mg protein/kcal digestible energy (DE) or 10-11 kcal DE/g protein. Magur (*Clarias batrachus*) larvae require 4000 kcal/kg energy while fry, grow out and brooder require 3500 kcal/kg of energy (BIS, 2013). Energy from cereal grains is less digestible in fishes than the livestock. The optimum protein to energy ratio for maximum growth in *M. rosenbergii* varies between 130 to 158 mg protein/kcal (Summerlin, 1988) and the energy requirement is 2800 kcal/kg for starter and finisher and 3000 kcal/kg for grower feed (BIS, 2013).

Protein and amino acids

In fish nutrition, protein is the most important nutrient promoting growth and is the major component of body tissues. Since protein acts both as structural component and as most preferred energy source, its requirement for fish is more than the mammals. As protein rich ingredients are costlier, therefore, it is necessary to ascertain the qualitative and quantitative requirements of dietary protein in order to reduce the cost of feed. Fishes are ammonotelic which excrete ammonia as the end product of protein metabolism. Ammonia is diffused to water through gills. The excretion of ammonia demands lesser amount of energy (4.1 kcal/g) in comparison to ureotelic mammals and uricotelic birds. Hence, fishes utilize protein more efficiently in comparison to other terrestrial animals.

The optimum protein requirement for larvae and fry of carp worked out by using purified diet varied from 35–45% (Sen *et al.,* 1978). Mohanty *et al.* (1990) reported that 40% protein in diet was optimum for larvae and fry of this species. The contribution of natural feeds in the feeding system made the protein requirement less than 40%. Murthy and Varghese (1996 a, b) reported that isoleucine and threonine requirement of *Labeo rohita* fry was 1.2 and 1.71% of diet, respectively corresponding to 3 and 4.28% of dietary protein. The optimum protein requirement for rohu fingerlings has also been reported to be 40% (Satpathy *et al.*, 2003) while Gangadhar *et al* (1997) found that a diet consisting of 30% protein and 6.5% lipid maximised growth in rohu fingerlings. Chakraborty *et al.* (1999) found optimum growth in rohu fingerlings fed on diet having 33% crude protein.

Though protein requirement of rohu has been reported to be 40% of diet under laboratory conditions, the economically optimal dietary protein content was reported to be 31% (De Silva and Gunasekera, 1991). Mohanty *et al.* (1992) showed that diet containing 35% casein and 10% gelatin resulted in the best amino acid balance for rohu which requires all the 10 essential amino acids like other finfish (Mohanty and Kaushik, 1991). In rohu, Khan and Jafri (1993) reported the requirement of arginine, lysine, methionine and tryptophan to be 2.94, 5.88, 2.64 (1% cystine fixed dry diet) and 0.59% of protein, respectively while Murthy and Varghese (1997, 1998) observed that the optimum dietary requirement of lysine, methionine and total sulphur containing amino acid (Met+Cys) for *Labeo rohita* was 2.24, 2.88 and 2.32% of dietary protein. Rohu brood stock required a dietary protein level of 25% for maximum reproductive performance and egg quality (Khan *et al.*, 2005).

Growth and nutrient utilization was highest at 45% protein with oilcake–fish meal based diet for catla (Mohanty *et al.*, 1990). Khan and Jafri (1991) studied the protein requirement of small and large classes of catla (0.134 g and 5.12 g) and the protein levels were 40 and 35%, respectively. Ravi and Devaraj (1991) reported that catla fry requires arginine, histidine, isoleucine, leucine, lysine, methionine (in absence of cystine), phenylalanine (with 1.0% tyrosine), threonine, tryptophan and valine 4.80, 2.45, 2.35, 3.70, 6.23, 3.55, 3.70, 4.95, 0.95 and 3.55 as percent of dietary protein.

Catla fingerlings performed better on diets of 30 and 35% protein when fat and carbohydrate levels were 4 and 35%, respectively (Seenappa and Devraj, 1995). Fingerlings utilized higher levels of carbohydrate when dietary protein levels were low. Higher fat levels resulted in poor growth and a level of 4% was optimum. Lysine is essential amino acid for catla and dietary requirement of lysine is 2.4% diet (Satheesha and Murthy, 1999).

A dietary protein level of 40% was required for mrigal fingerlings fed fish meal and groundnut cake based diets (Swamy *et al.*, 1988). Das and Ray (1991) worked out the protein requirement of mrigal by using semi-purified diet as 35%. Mohanty and Kaushik (1991) did not find any significant difference among the amino acid composition of the three Indian major carp species and they suggested that the amino acid requirements of carps were similar. Mrigal fry and fingerlings fed with 40% crude protein diet resulted in higher growth under field conditions (Kalla *et al*, 2004). The dietary protein requirements for carp are 35% for spawn and fry and 25% for grow out and brood stock feed (BIS, 2013).

Total protein requirement for optimum growth in catfish has been reported to vary from 25 to 50% of the diet (Giri *et al*., 2003, 2011; Paul *et al*., 2012). Protein requirement for younger catfish is higher than that of adult ones. The dietary protein requirement is 40% for magur larvae (*Clarias batrachus*), 35% for fry and grow out and 30% for brooder (BIS, 2013). Catfish require all the 10 essential amino acids as required for other species of fish.

Balazs and Ross (1976) reported that fresh water prawn (*M. rosenbergii)* requires more than 35% protein in the feed whereas a dietary protein requirement of 30-45% has been found in the same species by Rangacharyulu (1999). Digestible protein level above 30% is required in freshwater prawn feeds for maximum growth and protein efficiency (Mukhopadhyay *et al.,* 2003). The protein requirement of *Penaeus monodon* varied from 43-46% (Colvin, 1976). The requirement values differ with species, size, protein quality and level of non-protein energy, water quality and ratio of natural feed and formulated feed. The dietary essential amino acids for prawn are methionine, arginine, threonine, tryptophan, histidine, isoleucine, leucine, lysine, valine and phenylalanine (Kanazawa and Teshima, 1981). The protein requirement of freshwater prawn (*M. rosenbergii*) feed is 30% for starter, 24% for grower and 18% for finisher prawn (BIS, 2013). To achieve optimum growth production, all essential amino acids and protein in general needs to be taken into consideration for feeding of finfish and shellfish.

Lipids and fatty acids

Lipids are the richest energy component of feed and act as insulator and regulate body temperature. Lipids are almost completely digestible by fish and seem to be favoured over carbohydrate as an energy source (Cho and Kaushik, 1985). Dietary lipids, besides providing energy, serve as sources of essential fatty acids. Dietary lipids influence flavour and texture of fish feeds and also flesh quality of fish. Excess dietary lipid suppresses *de novo* fatty acid synthesis and reduces ability of fish to digest and assimilate other nutrients resulting in reduced growth. Also, feeding excess lipids is known to produce fatty fish and has deleterious effects on flavour, consistency and storage life of finished products.

A dietary lipid level of 9% was optimum for growth of rohu (Gangadhar *et al.,* 1997) while lipid requirement for rohu fingerlings has been reported to be 8% (Mishra and Samantaray, 2004.) Supplementing the feed of juvenile rohu with 1% ω-3 PUFA enhanced immunity against bacterial pathogens (Mishra *et al.,* 2006). A combination of ω-3 and ω-6 fatty acids is important for growth and survivability of catla fry (Mukhopadhyay and Rout, 1996). In the practical diet, while satisfying essential fatty acid the lipid level should be maintained at 9-10%. Incorporation of soybean oil (2.7%) and fish oil (0.3%) in the diet of brood female catla (3.0-5.5 kg) for a period of 93 days resulted in improved reproductive performance such as advanced maturation, increased fecundity and significantly higher fertilization rates of eggs (Nandi *et al.*, 2001).

The optimum level of protein, lipid and P/E ratio for catla fry were 35%, 12% and 18.51 mg protein/kj, respectively (Murthy and Naik, 2000). Marimuthu and Sukumaran (2001) reported that the lipid requirement of mrigal fry was 7.5%. The PUFA (n3+n6) requirement of carp is 0.5% for spawn, fry and grow out and 1% for carp brood stock feed (BIS, 2013). For rearing of Indian major carp larvae with maximum growth and higher survival rate, a provision of 4% phospholipids at the early feeding stage seems to be optimum (Paul *et al.,* 1998). Dietary phospholipids incorporation study in Indian major carp has shown that tissue phospholipids level can be enhanced in all the three species of IMC to maximize the survival and growth rate. The crude fat requirement of carp feeds are 8% for spawn and fry; and 6% for grow out and brood stock carp feed (BIS, 2013).

In the feed of magur (*Clarias batrachus*), the combination of ω-3 and ω-6 fatty acids elicited the best growth responses among the species (Mukhopadhyay and Mishra, 1998). In common with other vertebrates, catfish cannot synthesize ω-3 and ω-6 fatty acids *de novo.* Hence, one or both fatty acids must be supplied in the diet depending upon the EFA requirements. Giri *et al.* (2007) reported the nutrient digestibility and intestinal enzyme activity of magur on incorporation of dried fish and chicken viscera in their diet. *Ompak pabda* requires 6.5% lipid in their diet (Paul *et al*., 2011). The fat requirement in magur is 10% for larval feed, 8% for fry feed and 6% in case of grow out and brood feed (BIS, 2013).

About 2-6% lipids are required in the diet of prawn (*M. rosenbergii*) with proper proportion of essential fatty acids and phospholipids (Sheen and D' Abramo, 1991). The ω-3 PUFAs have a growth enhancing effect on *M. rosenbergii*. Freshwater prawns require relatively low levels of dietary PUFA and the PUFA content in body is also less as compared to that of marine shrimps. Four fatty acids are considered essential for shrimp: linoleic, linolenic, eicosapentaenoic and decosahexaenoic (Kanazawa *et al*., 1979). Sterols are important in prawn and shrimp diets as precursors of steroid hormones which have diverse physiological functions in growth promotion, moulting, sex control and maturation. *M. rosenbergii*, like other crustaceans, is unable to synthesize cholesterol due to absence of the enzyme 3-hydroxy 3-methylglutaryl-CoA reductase. D'Abramo and Daniels (1994) reported that dietary requirement for cholesterol in freshwater prawn is 0.5-0.6%. It is essential for normal growth, moulting and metamorphosis. A dietary source of phospholipids especially phosphatidyl choline in the form of soya-lecithin is essential for larval growth and survival. Dietary phosphatidyl choline may also enhance the assimilation of ingested fats by acting as temporary emulsifier. The fat requirement in feed for *M. rosenbergii* is 4% for starter, grower and finisher prawn (BIS, 2013).

Minerals

Minerals play important role in fish nutrition (Watanabe *et al*., 1997, Paul and Mukihopadhyay, 2001; Paul and Giri, 2009; Chanda *et al*., 2015). Calcium and phosphorus requirements of mrigal and rohu fingerlings worked out by feeding purified diets containing calcium lactate and sodium phosphate were 0.19 and 0.75%, respectively (Paul *et al*., 2004; 2006). Availability of P from fish meals has been found to be lower in carp than in the rainbow trout. A dietary phosphorus deficiency causes organ specific induction of HSP70 (heat shock protein) in catla fingerlings (Sukumaran *et al.,* 2008). Calcium requirement is also very high for catfish, however, catfish absorbs a significant amount from the water. Minimum requirement for available phosphorus in diets for catfish is approximately 0.45% while Meena *et al*. (2010) found that rohu fingerlings require 30 mg Zn/kg of feed.

Shrimp can absorb calcium from water. Phosphorus availability from water is negligible. The requirement of this element for penaeid shrimp ranges from 1.0 to 1.5%. The ratio of calcium to phosphorus in diet seems to be important. Juvenile *Penaeus indicus* fed with diet containing 0.53% of calcium and 1.05% of phosphorus gave significantly higher growth with better FCR. Higher levels of dietary calcium suppressed growth with a poorer FCR (Ali, 1999). The juveniles of *P. indicus* fed with diets containing a total copper content of 22.7 mg% gave the best FCR and higher survival (Ali, 2000). Rath and Dube (1994) recorded that 90 mg zinc/kg feed is optimum for improved growth and feed conversion in *M. rosenbergii*. Phosphorus requirement for starter, grower and finisher *M. rosenbergii* feed is 0.65% (BIS, 2013).

Davis and Galtin (1992) evaluated the requirement of thirteen elements, Ca, P, Na, Cl, K, Mg, Mn, Fe, Zn, I, Se, Cu and Cr for the shrimp (*Liptopenaeus vannamei*) and reported that minerals are essential for prawn nutrition. Trace minerals are sometimes deficient in plant ingredients produced in mineral deficient areas and thus fish feeds containing low levels of animal byproducts may be deficient in one or more trace minerals. A premix to fulfil the requirements of Zn, Fe, Mn, I, Cu and Se is recommended in commercial feeds.

Vitamins

Vitamins are also essential for optimum growth and physiological functions of fish, but required in small quantity as compared to energy and protein (Sahu *et al.*, 2004). Mahajan and Agarwal (1980) found that the ascorbic acid requirement in mrigal is 700 mg/kg feed. Even marginal deficiencies in some of the macro or trace elements or vitamins lead to severe morphological deformities and other pathological signs in addition to poor growth of carp. Some information is available on the mineral and vitamin requirement for common carp and catfish (NRC, 1993). Mishra and Mukhopadhyay (1996) reported ascorbic acid requirement of *Clarias batrachus* to be 69.0 mg/kg diet. The dietary thiamine requirement of *Cirrhinus mrigala* fingerlings for growth and body composition has been reported to be 20 mg/kg diet. (Gupta and Dodia, 1997). Rangacharyulu *et al.* (1999) reported vitamin A requirement of rohu fry to be 2000 IU/kg diet. Biotin deficiency in *Clarias batrachu*s resulted in anorexia, dark skin colour and convulsion (Mohammad *et al.,* 2000) and the optimum biotin requirement for maximal growth of *C. batrachus* is 2.49 mg/kg diet. In *Heteropneustes fossilis* fingerlings, the optimum dietary biotin requirement was 0.25 mg/kg diet (Mohammad, 2001).) The dietary niacin requirement of *Heteropneustes fossilis* has been found to be 25 mg/kg diet (Mohamed and Ibrahim, 2001). Sahu *et al.* (2004) worked out vitamin E requirement of rohu fry to be 131 mg/kg. The vitamin E requirement of mrigal fry and catla fry was 99 and 98 mg/kg diet, respectively (Paul *et al*., 2004 b; Paul *et al*., 2005).

Reddy *et al*. (1999) demonstrated that fat-soluble vitamins (A, D, E, K) and 11 water soluble vitamins (thiamine, riboflavin, pyridoxine, cyanocobalamin, pantothenic acid, folic acid, niacin, biotin, choline, inositol and ascorbic acid) are dietary essential for prawns (*P. Monodon*). D'Abramo and Sheen (1994) estimated the dietary vitamin C requirement to be 100 mg/kg in *M. rosenbergii*. Cavalli *et al.* (2003) suggested that diets containing 60 µg ascorbic acid/g dry weight and 300 µg β-tocopherol/g dry weights are sufficient to ensure proper reproduction and offspring viability in *M. rosenbergii.* Shiau and Wu (2003) indicated that the dietary pyridoxine requirement of *P. monodon* is 72-89 mg/kg feed. He and Lawrence (1993) reported that 99 mg vitamin E/kg diet is required for optimum growth of shrimp (*L. vannmei*). Choline and inositol are needed in the diet of shrimp @ 60-600 mg and 200 mg/kg feed, respectively (Kanazawa *et al*., 1976). Shiau and Lung (1993) determined vitamin B_{12} requirement in the diet of *P. monodon* and recommended 0.2 mg/kg diet for optimum growth of shrimp.

FEED ADDITIVES

In aquaculture nutrition, some feed additives have also been used for better growth performance. Mohanty *et al*. (1996) observed fast growth rate and 100% survival in spawn of rohu and catla in indoor rearing when they were fed a larval diet containing 30% bioboost forte (a probiotic supplement source of live yeast culture of *Saccharomyces cerevisiae* and *Lactobacillus coagulans*). Nutrient utilization and growth of mrigal fry improved due to probiotic supplementation @ 0.15% of diet (Swain *et al*., 1996). Paul *et al*. (1996) indicated that blue colour incorporation at 1% level in carp feed enhanced growth. Addition of L-carnitine @ 0.5 g/kg diet was the optimum dosage for maximizing growth in rohu (Keshavanath and Renuka, 1998). Supplementary Livol (herbal feed additive) at a level of 0.5% in the diet showed higher growth in catla fingerlings (Gireesha *et al*., 2002). Paul *et al*. (2004a) advocated the utilization of mixture of different plant attractants at 1% level in the feed of *L. rohita* fingerlings. Venkateshwarlu *et al.* (2009) reported that attractant actively of different herbs are species specific in case of Indian major carp. In catfish, *Ompak pabda*, the preferred plant attractant was Ekangi when incorporated upto 1% level in feed (Paul *et al*., 2012 a). In catla, tambul and awbel at 1% level in mrigal feed could be incorporated as plant attractant (Paul and Giri., 2013, Paul *et al*., 2014). Incorporation in small amounts of feed additive in aqua feed helps in increaseing DM intake of fish.

FEEDING PRACTICES

Feeding practices for carp

The size of the feed particle should commensurate with mouth aperture of fish. Dust or fine particles of feed may often clog gills causing their damage. Feeding of formulated diets as crumbles to fry and early fingerlings is advocated.

Feeding schedule followed in different phases of carp culture practices

a) Spawn to fry (culture period 15 days): 4 times of initial body weight during first week and 8 times of initial body weight during second week. Feeding is provided 4-6 times a day.

b) Fry to fingerlings (culture period 90 days): 6-8% of biomass during first month, 5-6% of biomass during second month and 3-4% of biomass during third month and feeds are provided twice a day.

c) Grow out culture (culture period 10-12 months): 3% of biomass in the first month and 2% of the biomass in the subsequent months and feeds are provided twice a day.

Finely powdered feed is broadcasted in nursery ponds for spawn and fry rearing. The feed is provided in the morning after sunrise and before sunset in the afternoon. In some hatcheries, automated feeders are being used for feeding the larvae which provide feed at desired intervals. Frequent feeding of larvae at hourly intervals in hatcheries results in good growth and survival. For feeding fingerlings or growers, feed dough or dry pellets are provided in check-trays or feeding baskets. Another popular feeding practice in carp culture is that the powdered feed ingredients are mixed and put in perforated bags. Each bag contains 8-10 kg feeds. The bags are tied in bamboo-poles and kept suspended in pond-water at several locations. When fish nibbles the holes, feeds come out of the holes. Therefore, this acts as a demand feeder. Such feeding practices are common in feeding of carps in Andhra Pradesh. In Punjab, farmers use a number of feed baskets tied up in a row in a floating material which is kept floating across water bodies. There are two types of pelleted feed *viz*., sinking and floating pellet. The sinking pellets are offered in the basket or tray at different corners of the pond. The floating pellet is gaining importance in the recent aquaculture practices. The wastage is minimum due to feeding floating pellets. The floating pelletets are provided inside the plastic or bamboo traps or inside the net traps to prevent escape of pellets.

Feeding practices for catfish

The spawn (5-5.5 mm) of magur (*Clarias batrachus*) are reared for 12-14 days in indoor rearing system. No supplemental feeds are fed to the larvae till 3 days of hatching. Though period of yolk absorption varies, feeding may be started with provision of little quantity of natural food and formulated larval feeds from fourth day onwards. The feed quantity may be adjusted depending on the density of spawn. Identification of acceptable feed and appropriate particle size are important considerations for larval feeding. Mixed zooplankton, *Artemianauplii*, molluscan meat, Tubifex and egg custard with 40-45% proteins are used for larval feeding. A weaning diet ‘Starter-M’ has been developed for magur larvae at the ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar, India that contained a minimum level of 33% crude protein, 8% crude fat and 32% nitrogen free extract and maximum levels of 5% crude fibre and 14% total ash. On feeding this, the survival of magur larvae increased over 90%. Feed particle size or the size of natural fish food organism of 20-30 µ are considered ideal for initial phase of feeding which is gradually increased to 50-60 µ for feeding 1 week old magur fry. For *Pagasius pangasius* larval feed “Starter Pangas, for fry ‘Pangas Grow-I’ and for fingerlings ‘Pangas

Grow-II' feeds are developed at CIFA, Bhubaneswar.

The fry are usually reared indoor in tanks for a few weeks before releasing them into ponds. During indoor rearing, they are fed with high energy and protein diets with main contribution from animal source and having a particle size of 0.3-0.5 mm. The feed should be adequately fortified with water-soluble vitamins to compensate the leaching losses during feeding. Like spawn, fry in tanks must be fed several times a day and feeding at hourly intervals is always preferable. In ponds, feed is normally dispensed from all sides to provide feeding opportunity to all fish. Feeding should be done twice daily. Either extruded or steam compressed pelleted feed is ideal for feeding fish to minimize nutrient leaching and wastage unlike dust or dough feed which should be discouraged. Supplemental feeding of fry in ponds is done soon after stocking. As size of the fish increases, diameter of pellet feeds should be increased. Crumbles of pellets should be used to feed fry and fingerlings whose size should be such that fish can easily ingest so as to minimize dissolving of nutrients in water.

Type and particle size of feed

The type of feed to be used during rearing should be selected as per the feeding behaviour of the catfish. Feeds with more water holding capacity are usually preferred by the farmers for catfish culture. Floating, sinking and slow sinking pellets are mostly used for catfishes during their rearing. The size of pellets usually varies with the age of fishes. Usually dust feed, small crumbles and pellet of 1-4 mm diameter are fed to catfish larvae, fry and grow-out fish, respectively.

Ration size

The feed is offered on body weight basis during catfish culture. Small fish eat more compared to their body size and they need feed more frequently. The feed should be broadcasted in ponds to increase the possibility of getting feed in all areas of the pond while rearing larvae/fry. The ration size is strictly followed during fingerling production till marketable size. Therefore, monthly sampling is followed to manipulate the ration size during catfish culture. Provision of feed @ 1.5-2% of body weight is sufficient for bigger fish for their growth. The ration size of the catfish is greatly influenced by water temperature and body physiological stages.

Feeding practices for prawn

Prawns normally prefer natural feeds than the artificial ones during their initial days of life. Prawns have nocturnal feeding habit. For grow out culture of prawn, feed is initially given at 5-8% of the body weight. The feeding rate declines with the growth of prawn e.g. when they are about 20 g in weight, the feed intake declines to about 1.5-2% of body weight. Prawns are fed twice daily. Prawns are very slow eaters and browse at the bottom of the pond. Sinking pellets with very high water stability are used in prawn culture. Broodstocks are fed with balanced artificially formulated pelleted feed at 3-5% of the body weight twice daily. The particle size of the feed also affects the feed intake and utilization. During the early stages, the particle size should be small and as the animal grows, the particle size can also be increased. The recommended particle size for starter is 0.6 to 2.0 mm diameter of crumbles or pellets and in case of grower and finisher the particle size varies from 2.2 to 2.5 mm diameter (BIS, 2013). The best method of feeding freshwater prawns is proper distribution of the feeds in the pond during culture.

CONCLUSIONS

The natural feed available in the pond meets the partial nutrient requirement of the animal in aquaculture. Therefore, supplementary feeding is important in semi-intensive aquaculture practices. Well balanced formulated feeds are required for the intensive type of aquaculture where availability of natural feed is negligible and fish solely depend on the artificial feeds. Nutrient requirement of fish at different life stages give guidelines for feed formulations. The protein and lipid requirement of carp feed ranges from 25-35% and 6-8% irrespective of body weight. The protein requirement of catfish and freshwater prawn is about 30-40% which is higher than that of carps. The aquaculture producers should select appropriate feed for a given species in right form to ensure efficient conversion of feed to fish flesh for optimum production.

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