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E Prabu
Ph.D. Research Scholar, Fisheries College and Research Institute, Ponneri, Chennai, India

S Felix
Vice Chancellor, Tamil Nadu Fisheries University, Nagapattinam, Tamil Nadu, India

N Felix
Director, Directorate of Aquaculture Technology Training and Incubation, Tamil Nadu Fisheries University, Muttukadu, Chennai, India

B Ahilan
Dean, Fisheries College and Research Institute, Ponneri, Chennai, India

P Ruby
Ph.D. Research Scholar, Fisheries College and Research Institute, Ponneri, Chennai, India

Correspondence
E Prabu
Ph.D. Research Scholar, Fisheries College and Research Institute, Ponneri, Chennai, India

An overview on significance of fish nutrition in aquaculture industry

E Prabu, S Felix, N Felix, B Ahilan and P Ruby

Abstract
Global aquaculture production is increasing year by year and it is the fastest and reliable sector to fulfil the protein deficiency among the human beings around the world. Various innovative integration and intensification approaches has been adopted for finfish and shellfish culture by many countries. Nutrition and feeding is the significant criteria should be focused for economical and sustainable aquaculture. Sustainable production of aquatic organisms can be obtained by formulating and producing low cost, low polluted and nutrient rich high quality artificial feeds. Like terrestrial animals around 40 essential nutrients are required by the aquatic organisms which includes protein, carbohydrate, fatty acids, vitamins, minerals, growth factors and other energy sources essentially for maintaining growth, reproduction and other normal physiological functions. The variation in the nutritional requirements can be identified with warm water or cold water, finfish or shell fish and marine water or freshwater species. Successful production of good quality fishes can be achieved by feeding the fishes with nutritionally balanced feeds. The nutritional requirements of various fish species are fulfilled by a different animal and plant based artificial feeds. Standardization of feeding method is another innovative way for preserving sustainable production of aquatic organisms in cages, ponds and short seasonal tanks. Ideal fish protein concept is also the superlative advance towards maximizing the effective utilization of protein by the fishes through the production of cost efficient, nutritionally high and low polluted feeds.

Keywords: Aquaculture, Nutrition, Protein, Feeding, Antioxidant, Pigment.

1. Introduction
Aquaculture has sustained a global growth at present and is expected to increasingly fill the shortfall in aquatic food products. Aquaculture activity is considered as the only alternative for the development and improvement of fisheries resources and revitalization of ecosystems (Okechi, 2004) [1]. Fish feeds constitutes 40-60% of the total cost of aquaculture production which is expensive and led to extensive studies on replacing a costly fish meal in the diets. Growth performances and survival of aquatic organisms can be influenced by the development of nutritionally balanced commercial diets (Tom and Van-Nostrand, 1989) [2]. The improvement of nutritional interventions supports the aquaculture industry sustainable, economical and nutritious finfish and shellfish production (Robinson *et al*., 1998) [3].
The science of nutrition draws heavily on findings of chemistry, biochemistry, physics, microbiology, physiology, medicines, genetics, mathematics, endocrinology, cellular biology and animal behavior. To the individual involved in aquaculture, nutrition represents more than just feeding. Nutrition becomes the science of the interaction of a nutrient with some part of a living organism, including feed composition, ingestion, energy liberation, wastes elimination and synthesis for maintenance, growth and reproduction. Feeds and feed stuffs contain the energy and nutrients essential for the growth, reproduction and health of aquatic animals. Deficiencies or excesses can reduce growth or lead to disease. Dietary requirements set the necessary levels for energy, protein, amino acids, lipids (fat), minerals and vitamins. The subcommittee on Fish Nutrition of the Committee on Animal Nutrition of the National Research Council (NRC) examines the literature and current practices in aquaculture. The NRC publishes the nutritional recommendations for fishes. Dietary nutrients are essential for the construction of living tissues. They also are a source of stored energy for fish digestion, growth, reproduction and the other life processes. The nutritional value of a dietary ingredients is in part dependent on its ability to supply energy. Physiological fuel values are used to calculate and balance available energy values in prepared diets. They typically average 4,

4 and 9 kcal/g for protein, carbohydrate and lipid respectively (Helfrich and Smith, 2001) [4].

Prepared or artificial diets may be either complete or supplemental. Complete diets supply all the ingredients (protein, carbohydrates, fats, vitamins and minerals) necessary for the optimal growth and health of the fish. Most of the commercial diets containing the essential nutrients including protein, lipid, carbohydrate, ash, phosphorous, water, minerals and vitamins in the range of 18-50%, 10-25%, 15-20, <8.5%, <1.5%, <10%, 0.5 and 0.5 respectively. Natural foods may not available for the aquatic organisms which are culturing in the indoor systems or confined cages, hence the nutritional need of this cultured organisms can be fulfilled only by the addition of nutritionally enriched supplementary feeds (Craig and Helfrich, 2009) [5].

2. Digestion and Absorption

The digestive or gastrointestinal tract is described as a continuous, hollow tube extending from the mouth to the anus with the body build around it. The digestive system of fish includes the mouth, pharynx, esophagus, stomach, pylorus, intestine, liver and gall bladder. It acts like an assembly line in reverse, taking the feedstuffs apart to their basic chemical components so that the fish can absorb them and rearrange them into its own characteristic body composition. Table 1 summarizes all structures of the digestive system in digestion and absorption. Other considerations of digestion and absorption in fish include the type of eaters, the anatomy of the mouth and feeding behavior (Fagbenro, 1998) [6].

Table 1: Digestive system structures and functions

Structure	Functions
Teeth	Grasping, holding, crushing, depending on species
Pharynx	Opening to the gills
Esophagus	Short, Simple passage to stomach, lined with mucus secreting cells
Stomach	Walls lined with cells secreting hydrochloric acid and pepsinogen for initial stages of protein digestion; holding compartment for feed
Pyloric cecum	Secretes enzymes for digestion; Increased surface area for absorption of nutrients
Intestine	Secretes enzymes for digestion; Increased surface area for absorption of nutrients
Gall bladder	Stores and releases bile for digestion and absorption of fats
Liver	Synthesis or storage from absorbed nutrients, production of bile, removal of some waste products from blood

3. Feeding type and anatomy

Fish can be divided into three types of eaters

1. **Carnivores** consume primarily animal material. Foods consumed by this type of fish may be as small as a microscopic crustacean or insect or as an amphibian or a small mammal.
2. **Herbivores** subsist primarily on vegetation and decayed organic material in the environment.
3. **Omnivores** consume almost any food source, either plant or animal origin.

Certain anatomic changes in the mouth of fish occurred through evolutionary development. Fish can be classified according to their feeding habits into the following categories:

- **Predators:** Trout are an example of fish that feed on animals generally large enough to be seen with the naked eye. Teeth are well developed and act as a means of grasping and holding the prey. Some predator rely primarily on sight to hunt, whereas others rely on the senses of taste and touch or on lateral line sense organs.
- **Grazers:** The mullet is an example of a fish that grazes in the same sense as mammalian grazers. Generally, mullets graze continuously on the bottom of the water habitat for either plants or small animal organisms. Food is taken in well-defined bites.
- **Strainers:** The menhaden is an example of a fish that selects food primarily by size rather than type. An adult menhaden can strain in excess of 6 gal of water per minute through its gill rakers. Through this process of rapid straining, the menhaden able to concentrate a relatively large mass of plankton and other organisms.
- **Suckers:** The buffalo fish is an example of a fish that feed primarily on the bottom of its habitat, sucking in mud and filtering and extracting digestible material.
- **Parasites:** Some fish, like the lamprey, attach themselves to other animals and exist on the host’s body fluids.

4. Protein requirements

Proteins are long chains of amino acids linked by bonds called peptide bonds. All amino acids contain nitrogen, so all proteins contain nitrogen. In fact, measuring nitrogen content is a method of calculating protein content. Metabolism of protein for energy produces nitrogen end products. Fish eliminate these through gills, feces and urine. These nitrogen end products can cause problems in fish ponds. Protein is the major concern during formulation of fish feed. It is the most expensive for fish feed and the most important factors that contributing to the growth performance of cultured species (Deng *et al*., 2011) [7].

Protein serves three purposes in the nutrition of fish:

1. Provide energy
2. Supply amino acids
3. Meet requirements for functional proteins- enzymes and hormones and structural proteins

The requirement for protein in fish diets is essentially a requirement for the amino acids in the dietary proteins. Some amino acids the fish cannot synthesis are called indispensable or essential amino acids

1. Arginine
2. Valine
3. Histidine
4. Isoleusine
5. Leucine
6. Lysine
7. Methionine
8. Threonine
9. Tryptophan
10. Phenylalanine

Some of the dietary requirements for methionine and phenylalanine can met by the amino acids cysteine and tyrosine respectively. The amino acid requirement given by the NRC is shown in table 2 for catfish, trout, salmon, carp and tilapia. Research evidence suggests that large differences exist among fish species in their requirements for amino acids. Some of these differences are probably caused by differences in growth rate, feed intake and the source of amino acids in the diet. When proteins in most feedstuffs are properly processed, they are highly digestible. For a variety of protein rich-feed stuffs, the digestibility ranges from 75 to 95 percent. As dietary carbohydrate increases, the digestibility of protein tends to decline. Also, overheating during drying or processing reduces proteins nutritive value. But, insufficient heating of soybean meal decreases the availability of protein. Protein requirements for fish are considerably higher than those for warm blooded land animals. Protein requirements of fish decline with age. Animal protein sources are generally considered to be of higher quality than plant sources, but animal protein costs more. In diets, a combination of protein sources yields better conversion rates than any single source (Pandey, 2013) [8].

Table 2: Protein and Amino acid requirement for finfish (NRC, 1993) [9].

	Channel Catfish	**Rainbow trout**	**Pacific salmon**	**Common carp**	**Tilapia**
Energy Base^b (Kcal DE/Kg diet)	3000	3600	3600	3200	3000
Crude protein (%)	32 (28)	38 (34)	38 (34)	35 (30.5)	32 (28)
Amino acids %					
Arginine	1.20	1.5	2.04	1.31	1.18
Histidine	0.42	0.7	0.61	0.64	0.48
Isoleucine	0.73	0.9	0.75	0.76	0.87
Leucine	0.98	1.4	1.33	1.00	0.95
Lysine	1.43	1.8	1.7	1.14	1.43
Metheonine + Cysteine	0.64	1.0	1.36	0.94	0.90
Phenylalanine+ Tyrosine	1.40	1.8	1.73	1.98	1.55
Threonine	0.56	0.8	0.75	1.19	1.05
Tryptophan	0.14	0.2	0.17	0.24	0.28
Valine	0.84	1.2	1.09	1.10	0.78

Fish do not have the ability to use non-protein nitrogen sources. Such nonprotein nitrogen sources as urea and diammonium citrate, which even non-ruminant animals can use to a limited extent, have no value as a feed source for fish. In fact, nonprotein nitrogen can be toxic at high levels. A protein deficiency or indispensable amino acid deficiency is observed as a reduction in weight gain. But some specific amino acid deficiencies manifest as disease conditions. Cataracts from salmonids, including rainbow trout, when given diets are deficient in methionine or tryptophan. A tryptophan deficiency also causes a lateral curvature of the spinal column or scoliosis in some salmonids. In trout, a tryptophan deficiency disrupts the metabolism of the minerals calcium, magnesium, sodium and potassium. In fish diets, protein and energy should be kept in balance. A deficiency or excess of energy reduces the growth rates. When dietary energy is deficient, protein is used for energy. When dietary energy in excess, feed consumption drops and this lowers the intake of the necessary amounts of protein for growth (Abowei and Ekubo, 2011) [10].

5. Carbohydrates

Carbohydrates are the most economical and inexpensive sources of energy for fish diets. Although not essential, carbohydrates are included in aquaculture diets to reduce feed costs and for their binding activity during feed manufacturing. Dietary starches like cassava starch are used in the extrusion production of floating feeds. Floating feeds for the various finfishes are prepared with varying ranges of carbohydrates (Robert, 1979) [11].

Fishes are having the capability of digesting simple sugars efficiently. Digestibility will get decrease rapidly when the sugar becomes larger and more complex. Warm water fish can digest dietary carbohydrates efficiently when compared with cold water or marine fish. Utilization of carbohydrates as an energy source varies with different species. There is no recommended levels or ranges by national research council for formulating and preparing finfish and shellfish feeds. Some form of digestible carbohydrate should be included in the diet. Carbohydrates improve growth and provide precursors for some amino acids and nucleic acids. Also, carbohydrate is the least expensive source of dietary energy. In warm water fish, cereals grains provide an inexpensive source of carbohydrates, but their use is limited in cold water fish. Digestible carbohydrates in trout feed are generally lower than the levels in catfish feed. In nutrition, carbohydrates spare protein because less protein will be will be used for energy. An excess of dietary carbohydrates can cause livers to enlarge and glycogen to accumulate in the liver. A general recommendation is a diet of no more than 12 percent digestible carbohydrates. Fats and proteins supply most of the energy in fish diets (Parker, 2011) [12].

6. Fat

Each gram of fat contains 2.5 times the energy in a gram of carbohydrates or proteins. The digestibility of fat varies, depending on

- Amount in the diet
- Type of fat
- Water temperature
- Degree of unsaturation
- Length of carbon chain

Animal fats and fats that are highly saturated have a lower digestibility. On the other hand, in highly unsaturated fats – fats that fish can rapidly digest- there is danger of oxidation of the fats, resulting in feed spoilage. Antioxidants are routinely added to most fish diets to prevent fats from becoming rancid in storage. Besides being an important source of energy for fish, dietary fats provide essential fatty acids (EFA) needed for normal growth and development. Fish cannot synthesize these fatty acids. Also, dietary fats assist in the absorption of fat-soluble vitamins. Freshwater fish require a dietary source of linoleic acid and linolenic acid. These are both 18 carbon fatty acids. Marine fish, like the yellow tail or red sea bream, require a dietary source of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These are 20 ad 22 carbon fatty acids respectively. Channel catfish, coho salmon and rainbow trout require linolenic acid or EPA or DHA. Table 3 indicates the essential fatty acid requirement for several species of fish (Parker, 2011) [12].

Table 3: Essential fatty acid requirements of fishes (NRC, 1993) [9]

Species	Requirement
Channel catfish	1.0 to 2.0% linoleic acid or 0.5 to 0.75% EPA and DHA
Chum salmon	1.0% linoleic acid and 1.0% linolenic acid
Coho salmon	1.0 to 2.5% linolenic acid
Common carp	1.0% linoleic acid and 1.0% linolenic acid
Rainbow trout	0.8% to 1.0% linolenic acid 20% of fat as linoleic acid 10% of fat as EPA and DHA
Tilapia	0.5% to 1.0% linoleic acid
Red sea bream	0.5% EPA and DHA
Yellow tail	2.0% EPA and DHA

Essential fatty acid deficiency sings include skin lessions, shock syndrome, heart problems, reduced growth rate, reduced feed efficiency, reduced reproductive performance and increased mortality. In the body essential fatty acids function as a part of cell membranes and precursors of biochemical that perform a variety of metabolic functions. Fish diets are formulated to meet the optimum ratio of energy to protein for each species. Fats serve as an important source of energy, but no definite percentage of dietary fat can be given without considering the type of fat, as well as the protein and energy content of the diet. Too much dietary fat can result in an imbalance of the digestible energy to crude protein ratio and excessive deposition of fat in the body cavity and tissues (Endinkeau and Kiew, 1993) [13].

7. Vitamin requirements

Vitamins are organic compounds required in the diet for normal growth, reproduction and health. They function in a variety of chemical reactions in the body. The simple digestive system of the fish establishes a definite need for the supplementation of vitamins in fish diets. Vitamin requirements for fish resembles those of nonruminant animals such as pigs and chickens. Fish and humans are among the few higher animals that require a dietary source of vitamin C (Halver, 1985) [14].

Vitamins are divided into two categories, water soluble and fat soluble.

Water-soluble vitamins include

- Thiamin
- Riboflavin
- Pyridoxine
- Pantothenic
- Niacin
- Biotin
- Folate
- Vitamin B12
- Choline
- Myoinositol
- Vitamin C

Choline, myoinositol and Vitamin C serve a variety of functions. Choline function as a:

- Component of membranes
- Precursor of acetylcholine, a chemical for nerve transmission
- Provider of methy groups for chemical reactions

Myoinositol is also a component of membranes and is involved in sending signals during several body processes. Vitamin C is involved in the formation of connective tissue, bone matrix and wound repair. It also facilitates the absorption of iron from the intestine and helps prevent the peroxidation of fats in tissues. Most water soluble vitamins serve as coenzymes in the body's biochemical reactions. Enzymes are biological catalysts. Most enzymes are proteins and they are unique for each biochemical reaction. Coenzymes then work with or become part of an enzyme (Parker, 2011) [12].

The fat soluble vitamins are

- Vitamin A
- Vitamin D
- Vitamin E
- Vitamin K

Fat soluble vitamins are absorbed in the intestine along with fats in the diet. Unlike water soluble vitamins, fat soluble vitamins can be stored in body tissues. Excessive amounts in the diet can cause a toxic condition called hypervitaminosis. Functions of the fat soluble vitamins are quite specific. Vitamin A is necessary for sight, proper growth, reproduction, resistance to infection and maintenance of body coverings. As many land animals, fish can use betacarotene as a Vitamin A precursor. Vitamin D helps the body mobilize, transport, absorb and use calcium and phosphorous. It works with two hormones from an endocrine gland, the parathyroid. Vitamin E is the name given to all substances that act like alpha-tocopherol. Vitamin E working with selenium, protects cells against adverse effects of oxidation. Vitamin K is required for the normal blood clotting process. Many animals can syntheses vitamin K in their intestines (Woodward, 1994) [15].

8. Mineral requirements

Fish can absorb a number of minerals directly from the water: calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), iron (Fe), zinc (Zn), copper (Cu) and selenium (Se). This reduces the mineral requirement in the diet. But this also makes research on dietary mineral requirements difficulty and inconclusive. Most researchers agree that fish require all of the minerals required by other animals. Based on their requirement or use of an animal, minerals are divided into two groups: macrominerals and microminerals. Macrominerals are present in the body in relatively large quantities. The macrominerals include:

- Calcium (Ca)
- Chlorine (Cl)
- Magnesium (Mg)
- Phosphorous (P)
- Potassium (K)
- Sodium (Na)

Calcium and phosphorous are most directly involved in the development and growth of the skeleton and they act in several other biochemical reactions. Fish absorb calcium directly from the water by the gills and skin. The requirement for calcium is determined by the water chemistry (Athithan *et al*., 2013) [16].

Dietary phosphorus is more critical. Phosphorous is derived from dietary phosphate. Phosphorous deficiency sings include poor growth, reduced feed efficiency and bone deformities. The availability of phosphorous in feedstuffs varies widely. Feedstuffs from seeds contain phosphorous in a form known as phytin. The availability of phosphorus in phytin is low. Simple stomach animals lack the enzyme to release the phosphorus (Davis and Gatlin, 1996) [17].

Magnesium functions with many enzymes as a cofactor. The dietary requirement can be met from either the water or the feed. Deficiencies of magnesium cause anorexia, reduced growth, lethargy, vertebrae deformity, cell degeneration and convulsions. Sodium potassium and chlorine are electrolytes. Sodium and chlorine reside in the fluid outside the cells. Potassium resides inside the cells- an intracellular cation. Because of the abundance of these elements in the environment, deficiency signs are difficult to produce.

Microminerals are present in very small amounts in the bodies of fish, but they are still important to fish health.

The microminerals include:

- Copper (Cu)
- Iodine (I)
- Iron (Fe)
- Manganese (Mn)
- Selenium (Se)
- Zinc (Zn)

Copper is a part of many enzymes and it is required for their activity. Although it is necessary for fish health, copper can be toxic at concentrations of 0.8 to 1.0 m per liter of water. Fish are more tolerant of copper in feed than in water. Iodine is necessary for the formation of hormones from the thyroid gland. Fish can obtain iodine from either water or feed. Similar to land animals, a deficiency causes the thyroid gland to grow, a condition similar to goiter (Halver and hardy, 2002) [18].

Iron is necessary for the formation of heme compounds. These compounds carry oxygen. Because natural waters are low in iron, feed is considered the major source of iron. Iron deficiency causes a form of anemia. At high levels, iron can be toxic and cause reduced growth, diarrhea, liver damage and death. Manganese functions as a part of enzymes or as a cofactor. Although it can be absorbed from the water, it is more efficiently absorbed from the feed. A deficiency causes reduced growth and skeletal abnormalities.

Selenium protects cells and membranes against peroxide danger. Selenium deficiencies cause reduced growth. Both selenium and vitamin E are required to prevent muscular dystrophy in some species. When dietary selenium exceeds 13 – 15 mg per kg of dry feed, it becomes toxic resulting in reduced growth, poor feed efficiency and death. Zinc is also a part of numerous enzymes. Dietary zinc is more efficiently absorbed than that dissolved in water. Dietary calcium and phosphorous, phytic acid protein type, all affect zinc absorption and use. A zinc deficiency causes suppressed growth, cataracts, fin and skin erosion, dwarfism or death. Other trace minerals such as fluoride and chromium may be important but evidence is limited (NRC, 1993) [9].

Other dietary components

Many fish diets contain other ingredients that can affect them. Some of these ingredients are natural, others are added. These ingredients include substances such as water, fiber, hormones, antibiotics, antioxidants, pigments, binders and feeding stimulants.

9. Water

All diets contain water. The water may be a part of the feedstuff, come from the air or be added. The less water in a diet, the easier the storage and handling. When moisture in a diet exceeds 12 percent, the feed is more susceptible to spoilage. Some commercial diets contain high moisture levels because fish seems to prefer moist feed (Lovell, 1989) [19].

10. Fiber

Fiber refers to plant material such as cellulose, hemicellulose, lignin, pentosums and other complex carbohydrates. These are indigestible and they do not play an important role in nutrition. Fiber adds bulk to a feed but increases the amount of fecal material produced. The goal in commercial aquaculture is to limit the diets fiber content and use highly digestible feeds (Krontveit *et al*., 2014) [20].

11. Hormones

Researchers have evaluated the use of various natural and synthetic hormones of fish. These hormones include growth hormone, thyroid hormones, gonadotropin, prolactin, insulin and various steroids like androgens and estrogens. Hormones are used for two purposes: (1) Induced or synchronized spawning and (2) Sex reversal. Induced or synchronized spawning increases the availability and dependability of seed. Sex steroids reverse the sex of salmonids, carps and tilapia, producing a monosex culture of sterile fish. This improves growth rate, prevents sexual maturation and reduces flesh quality (Prins *et al*., 2016). [21]

12. Antibiotics

With the arsenal of antibiotic available for humans and other livestock, only two have received FDA approval for use in fish that are sulfadimethoxine / ormetoprim and oxytetracyclin. When these antibiotics are used in the, the quantity fed, the feeding rate and the withdrawal time must be strictly controlled. Only licensed manufacturers can add antibiotics to feed in the United States. Unlike livestock, fish do not demonstrate any benefit from sub therapeutic levels of antibiotics in their feed (Pruden *et al*., 2013) [22].

13. Antioxidants

Fish feeds containing high levels of fats often use antioxidants. Oxidation of the fats affects the nutritional values of the fat and some vitamins. Synthetic vitamin E in diets usually less little antioxidant activity, so synthetic antioxidants like ethoxyquin, BHT, BHA and propyl gallate are used (Wang *et al*., 2016) [23].

14. Pigments

Pigmentation of the skin and flesh in fish comes from carotenoids. Fish cannot make these carotenoids, so they must be present in the diet. In salmonids, the carotenoids astaxanthin and canthaxanthin are responsible for the red to orange color of their flesh. In the wild, these carotenoids come mainly from zooplankton. Some of the natural materials used to pigment the flesh of salmonids include crab, brill, shrimp and yeast. Yellow pigmentation of the flesh of catfish is undesirable. It is caused by the carotenoids lutein and zeaxanthin from plant material in the diet (Ramya *et al*., 2016) [24].

15. Pellet Binders

Binders improve stability in the water, firmness and reduce fines during processing and handling. Widely used binders are sodium and calcium bentonites, lignosulfates, carboxymethylcellulose, hemicellulose, guargum alginate and some new inert polymers.

16. Feeding stimulants

The acceptance of the fish feed is determined by the smell and attractants of the feed. Many researchers are focusing on increasing the palatability and acceptance of feed for increasing the feed utilization. This is especially important in starter and larval feeds. In general, carnivorous fish respond to alkaline and neutral substances. Herbivorous fishes respond to acid substances. Besides increasing feed consumption, some compounds act as deterrents (Barry *et al*., 2017) [25].

17. Conclusion

Nutrition and feeding influences the growth, reproduction and health performances of fishes and their response to physiological and environmental stressors and pathogens. In seems that nutrition is the heart of aquaculture. Feeding the fishes with nutritionally enriched feeds may dramatically increase the overall production. So nutrition is one of the essential area to be focused by aquaculture industry. Cage culture in inland open waters is a fast growing activity and using low quality feeds could have some environmental impacts. So the production of high quality cum low polluted feeds for cage culture systems may reduce the negative impacts on environment by aquaculture activities and brings the inland fish farmers towards cage culture. The fish farmers are struggling hard to reduce the cost of fish feed since fish feed accounts for over 50% of the total cost of fish production. Many researches are currently undergoing towards the development of cost efficient feed for enhancing the fish and shrimp production. Replacement of fish meal with various plant based ingredients will be a superior way to reduce the cost of the fish feed without changing the nutritional profile. There are several plant based ingredients like soybean meal, rapeseed meal, cottonseed meal, cassava starch, canola meal, corn gluten meal, ipil ipil meal sesame meal, corn starch could be used to replace fishmeal in the fish diet.

Though fish convert feed to human food very efficiently, the feeding cost of production needs to be controlled. Feeding fish require an understanding of the process of digestion, the digestive system and fish nutrition. Fish consume feed for energy. They use this energy for growth, activity and reproduction. In the fish diet, feeds containing protein, fats and carbohydrates supply energy. These feeds enter the digestive system, where enzymes break down the protein, fats and carbohydrates to simpler compounds that the fish uses for energy and to form tissue, enzymes and bone. Protein in the di*et al*so supplies 10 essential amino acids and fat in the diet supplies essential fatty acids. Fat soluble and water soluble vitamins are also supplied by the diet. Minerals are supplied by the diet and by the water. Feed additives and attractants are added into the fish diets to increase the growth performances, immunity, survival, effective feed utilization and feed acceptance. With the great understanding of the nutritional aspects, it is very much possible to make the feed nutritionally balanced. So that higher growth, best food conversion ratio and less polluting to the environment could be achieved.

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