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MARINE FISH NUTRITION, FEED FORMULATION, FEED PRODUCTION AND FEEDING

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With the initiation of cage culture of food fish in India by Central Marine Fisheries Research Institute (CMFRI) the major recurring inputs into these food production systems to be addressed are seed and feed. As the availability both of these inputs have to be maximized, we shall discuss here the pros and cons of nutrition mainly under the heads, principles of nutrition, feed ingredients, feed formulation, feed production and feed management.

Nutrients and their roles

Any material used for feeding contains the following five principles.1.Protein,2. Carbohydrate,2.Fat,4.Minerals and 5.Vitamins.

Proteins are building blocks in the feed and they are made up of amino acids. There are 20 amino acids among which 10 are

called essential amino acids and the remaining 10 are called non-essential amino acids. Essential amino acids are those which cannot be synthesized by the animal at a rate required for the normal growth of any organism and so they have to come through food. Non-essential amino acids are the amino acids which can be synthesized by the animal in case they are not available through the food. Therefore, proteins are essential for growth of the animal and a deficiency can lead to what can be called as sub-normal growth. Other than the growth promoting role of protein they are required for the normal immune function of the animals preventing them from disease attack. Most of the enzymes present in animals are proteins, there are protein hormones, and there are structural proteins like keratins. In short protein have multiple functions in the animal body among which growth can be considered to be the most important.

Carbohydrates (starch and sugars) are energy yielding components in food. Even though fishes do not have an absolute requirement of carbohydrates, they are used in fish feeds for imparting several functional properties to pelletized feed like buoyancy, that is, sinking, slow sinking and floating properties to the pellet.

Fat are also energy yielding components if food. The quantum of energy available from fat is 2.5 times more than the energy available from carbohydrates. Fats are made up of fatty acids, among which, a few are considered essential (essential fatty acids). These fatty acids have to be supplied through feed.

The aforementioned three components of feed are called macronutrients because they make up the major chunk of the feed. Minerals and vitamins are called micro nutrients because they are required only in small quantities in the feed.

Minerals generally looked at in feeds are Calcium (Ca), Phophorus (P) which are called macro minerals because of their relatively high levels of inclusion. Other minerals, Copper (Cu), Cobalt (Co), Iron (Fe), Sulphur (S), Iodine (I), Magnesium (Mg),

Manganese (Mn), Zinc (Zn) etc., are called microminerals. Most of these minerals have diverse functions in the body and deficiencies in the diet and water can lead to deficiency diseases. Similarly, an excess can lead to toxicity also which can be lethal.

Vitamins are micronutrients which can be classified as fat soluble and water soluble. Fat soluble vitamins are the ones which are soluble in fat. As fat is stored in the body these vitamins dissolved in fat is also stored. The fat soluble vitamins are A, D, E and K. Waters soluble vitamins being soluble in water cannot be stored in body and hence any excess is voided through urine. As mentioned in the case of minerals, vitamin deficiencies in the feed can lead to deficiency diseases and excesses can also cause certain metabolic disorders.

Having described the macronutrients and micro nutrients in feed, we shall have a look at their requirements in marine carnivorous fish which is summarized in the Table below

Table 1.Nutrient requirements of marine carnivorous fishes (in percent)

Size of fish	Moisture	Crude protein (CP)	Crude fat or Ether Extract (EE)	Crude Fiber (CF)
Fingerling (1 inch – 20 g)	<12	>42	>5	<4
Juvenile (20-50 g)	<12	>40	>5	<4
Grower (50-300 g)	<12	>38	>5	<4
Marketable size (> 300 g)	<12	>35	>5	<4

Carnivorous fish feed on live prey in nature and in practice also feeding the cultured fish with low value trash fish is practiced. This practice is not only unsustainable but also uneconomical. Trash fish feeding pollutes. It is fairly estimated to be 38% as compared to 10% for pelleted feeds. This may be an underestimate because there are some reports which say 45000 t trash fish is required to produce 300 t of high value fish in marine cages. In this situation, the amount of food needed to produce

1 kg fish equals 15 kg (i.e., apparent food conversion ratio or AFCR). However, under well managed experimental conditions it is reported to be as good as 3.5: 1 in the case of cage cultured groupers. In practice, it varies from 6:1 to 17:1. When converting this into dry matter basis (excluding the eater content in trash fish) true food conversion ratio (TFCR) – 1 kg trash fish is capable of producing 1 kg fish. The fact which cannot be ignored is that trash fish cannot be procured on a dry matter basis. Moreover, under typical farming conditions it is observed that TFCR's vary from 2:1 to 4:1 for marine carnivorous fish.

Feed ingredients

Feed ingredients used for making feeds can be classified as protein rich ingredients which are mainly fish and meat products of animal origin and oilcakes of plant origin. Energy rich ingredients are mainly cereals and cereal by products. Other than these there are non-conventional feed resources (NCFR) which are used in feed manufacture.

Table 1.Proximate composition of selected feed ingredients of plant origin in India (%)

	Moisture %	Crude protein %	Crude fat %	Crude fibre %	Ash %	NFE % Nitrogen (free extract)
rice bran	10.0	8.0-12.0	8.0-10.0	12.0-20.0	15.0-19.0	35.0-40.0
rice polish	10.0	10.0-14.0	10.0-16.0	8.0-10.0	5.0-6.0	40.0-45.0
wheat bran	8.0	12.0-14.0	2.0-3.0	10.0-12.0	4.0-6.0	50.0-55.0
groundnut cake	10.0	40.0-42.0	6.0-8.0	10.0-12.0	3.0-4.0	25.0-28.0
sunflower cake	9.0	30.0-32.0	4.0-6.0	15.0-20.0	5.0-7.0	35.0-40.0
mustard cake	9.0	30.0-35.0	7.0-9.0	10.0-15.0	7.0-9.0	30.0-35.0
sesame cake	9.0	32.0-36.0	7.0-10.0	10.0-14.0	8.0-10.0	20.0-25.0
rapeseed cake	10.0	30.0-35.0	2.0-3.0	12.0-14.0	5.0-7.0	30.0-34.0
salseed cake	9.0	8.0-10.0	2.0-3.0	3.0-5.0	8.0-10.0	65.0-70.0
cotton seed cake	8.0	35.0-40.0	3.0-5.0	11.0-13.0	6.0-8.0	25.0-28.0
rubber seed cake	9.0	30.0-35.0	10.0-15.0	7.0-8.0	8.0-10.0	32.0-36.0
copra cake	12.0	20.0-24.0	6.0-8.0	12.0-14.0	5.0-6.0	40.0-43.0
soybean cake	9.0	45.0-50.0	1.0-2.0	8.0-10.0	7.0-8.0	30.0-35.0
palm kernel cake	9.0	12.0-14.0	5.0-7.0	25.0-28.0	3.0-4.0	42.0-46.0
tamarind seed cake	9.0	13.0-15.0	6.0-8.0	13.0-15.0	3.0-4.0	60.0-65.0
black gram husk	9.0	24.0-26.0	10.0-15.0	8.0-10.0	40-6.0	30.0-34.0
green gram husk	9.0	24.0-26.0	3.0-5.0	5.0-7.0	5.0-6.0.	30.0-35.0
mulberry leaf	10.0	24.0-27.0	2.0-4.0	10.0-12.0	6.0-8.0	45.0-48.0
ipomoea leaf	12.0	16.0-20.0	2.0-4.0	9.0-10.0	8.0-10.0	45.0-48.0
ipil-ipil (leucaena)	8.0	18.0-21.0	4.0-6.0	5.0-7.0	8.0-9.0	48.0-52.0
Tapioca leaf meal	12.65	34.37	5.93	15.73 5.05	26.27	

Modified from P. K. Mukhopadhyay and Gopa Mitra 2007 Plant derived feedstuff for freshwater aquaculture in India .AQUA Culture AsiaPacific Magazine 19-21 pp.

Table2.Proximate composition of selected feed ingredients of plantorigin in India (%)

Ingredient	Moisture	Crude protein	Crude fat	Crude fibre	Ash	Nitrogen free extract
Rice polish	12.6	14.5	17.3	7.5	n.a.	n.a.
Rice polish	10.0	12.2	16.0	9.0	6.0	46.8
Rice polish	8.4	11.4	15.3	11.0	12.9	41.0
Rice, broken	10.0	12.0	4.2	5.3	3.1	65.4
Rice bran	10.1	12.6	11.3	19.3	10.2	36.5
Rice bran	7.8	7.8	6.1	14.4	20.5	43.4
Rice bran	8.4	2.9	5.0	18.0	27.3	38.4
Rice bran	8.7	9.4	4.7	13.5	31.4	32.3
Defatted rice bran	7.2	12.1	1.3	15.2	23.8	40.4
Wheat bran	12.3	15.8	4.3	8.7	n.a.	n.a.
Wheat bran	10.0	13.5	2.6	12.2	3.0	58.7
Wheat bran	13.0	8.2	6.6	33.5	4.2	34.5
Wheat bran	9.3	12.6	7.5	11.9	4.2	54.5
Wheat, broken	9.0	11.5	1.9	4.0	0.2	73.4
Wheat flour	12.6	14.5	3.7	2.7	2.3	64.2
Groundnut cake	7.8	28.6	13.8	7.5	13.4	28.9
Groundnut cake	6.0	37.7	11.5	13.2	7.3	24.3
Groundnut cake	10.0	42.0	7.3	13.0	2.5	25.2
Groundnut cake	8.3	46.6	7.7	6.5	7.7	23.2
Groundnut cake	7.1	35.8	8.5	8.2	10.5	29.9
Groundnut extr.	7.0	48.0	2.0	11.2	2.7	29.1
Sunflower extr.	8.0	31.0	2.1	18.4	1.5	39.0
Sunflower extr.	10.2	30.1	2.9	24.7	6.5	25.6
Palm kernel cake	8.9	12.2	4.9	25.6	2.6	45.8
Soybean meal	11.8	46.3	1.3	5.0	n.a.	n.a.

Soybean meal	3.0	58.6	1.4	0.4	5.3	31.3
Soybean meal	10.0	46.0	0.9	7.3	0.6	35.2
Soy sauce waste	12.0	13.5	8.2	5.8	5.3	55.2
Rapeseed cake	11.0	35.9	0.9	13.2	6.9	32.1
Salseed cake	8.6	8.2	2.9	1.7	10.2	68.4
Sesame cake	8.3	41.9	9.2	6.2	14.8	19.6
Sesame cake	10.0	29.0	12.9	18.3	10.0	19.8
Sesame cake	10.0	42.7	6.9	5.7	12.9	21.8
Mustard cake	8.5	30.8	9.3	6.2	10.3	34.9
Mustard cake	9.2	23.6	9.6	6.3	10.4	40.9
Cotton seed cake	7.0	37.0	6.7	13.0	1.0	35.3
Cotton seed cake	8.2	42.7	1.0	12.6	8.2	27.3
Gingely cake	9.0	34.0	7.8	7.9	3.1	38.2
Gingely extr.	7.0	40.0	2.0	9.7	2.9	38.4
Niger extr.	7.0	35.0	2.0	19.0	3.5	33.5
Copra cake	12.0	22.0	6.5	12.2	5.2	42.1
Copra cake	8.4	20.3	11.4	16.2	6.2	37.5
Copra cake	n.a.	22.0	6.0	12.0	2.1	n.a.
Tobacco seed extr.	7.7	30.6	0.3	-	13.7	47.7
Maize meal	13.5	9.5	4.0	4.0	1.5	67.5
Maize	10.4	4.6	7.8	3.5	1.0	72.7
Sorghum	10.0	9.0	2.8	3.0	0.1	75.1
Spirulina	8.7	50.5	1.0	2.1	11.0	26.7
Tapioca flour	11.5	3.1	2.3	2.0	2.3	78.8
Tapioca flour	8.0	1.8	1.3	1.8	0.2	86.9
Coffee pulp	12.3	14.0	1.2	20.8	8.2	43.5
Colocasia meal	5.8	24.6	4.5	8.2	9.9	47.0
Eichornia meal	3.3	19.5	2.3	18.3	9.3	47.3
Pistia meal	4.9	19.5	1.3	11.7	25.6	37.0
Leucaena meal	11.8	33.1	4.7	9.0	7.2	34.2
Mulberry leaf, dry	8.9	27.7	2.4	11.5	8.1	41.4
Salvinia meal	2.6	16.2	1.1	18.5	22.0	39.6

Table3. Proximate composition of selected feed ingredients of animal origin in India (%)

ngredient	Moisture	Crude protein	Crude fat	Crude fibre	Ash	Nitrogen free extract
Fish meal	8.6	64.4	7.5	0.3	19.2	-
Fish meal	9.5	53.6	5.4	3.1	20.9	7.5
Fish meal	9.2	56.1	2.5	17.8	2.5	11.9
Fish meal	14.0	47.8	10.3	2.6	18.3	7.0
Fish meal	10.0	72.0	10.0	0.5	n.a.	n.a.
Fish meal	9.0	50.0	7.0	1.0	4.0	29.0
Fish meal	10.0	45.0	8.0	1.2	6.0	29.8
Shrimp waste	10.0	28.0	2.7	12.5	n.a.	n.a.
Shrimp waste	9.0	22.5	3.6	35.3	18.6	11.0
Shrimp waste	3.6	34.2	6.7	12.2	27.9	15.4
Shrimp waste	15.6	28.3	1.1	7.1	31.6	16.3
Squilla meal	14.1	46.0	2.6	13.5	18.0	5.8
Squid meal	8.0	75.0	6.5	4.0	n.a.	n.a.
Clam meal	7.0	52.0	11.6	5.5	n.a.	n.a.
Clam meal	8.1	50.7	8.9	3.9	6.4	22.0
Silkworm pupae	7.1	43.9	25.7	4.2	15.8	3.3
Defatted sw. Pupae	8.1	68.0	2.6	1.3	7.2	12.8
Blood meal	10.0	65.3	0.5	n.a.	n.a.	n.a.
Blood meal	12.9	76.6	1.1	1.0	3.8	4.6
Meat meal	8.0	50.0	4.4	6.8	5.0	25.8
Meat meal	10.0	71.2	13.3	0.7	n.a.	n.a.
Liver meal	7.0	65.0	3.4	1.2	2.4	21.0
Earthworm meal	5.0	51.7	3.4	12.8	12.5	14.6

Table 4.Proximate composition of feed ingredients (analyzed values% on Dry matter basis)

	DM	Moisture	CP	EE	CF	NFE	Ash	AIA	Cost INR kg-1
Malabar Sole – Kozhikode	97.02	2.98	47.35	3.21	45.57	0.729	3.14	2.37	80
White bait - Kozhikode	94.66	5.34	61.74	3.39	23.97	0.13	10.77	1.63	100
Shrimp waste – Kozhikode	94.85	5.15	45.00	3.45	40.26	7.02	4.27	16.92	
Black clam - Kochi	94.92	5.08	67.60	7.52	9.12	0.30	15.46	2.95	100
Wheat flour - Kochi	89.93	10.07	11.15	1.29	0.59	1.84	85.13	0.08	20
Soy flour - Kochi	91.64	8.36	52.09	0.51	7.85	6.95	32.6	0.02	60
Shrimp meal - Kochi	96.39	3.61	68.98	3.42	17.59	3.08	6.93	1.67	120
Squid - Kochi	94.56	5.44	84.75	5.62	4.53	0.31	4.79	00.05	160

Apart from these ingredients, mineral mixtures, vitamin mixtures and other additives such as oil, phospholipids, carotenoids are also added according to the needs. Non-nutrient additives such as synthetic binders, anti-oxidants and anti-fungals are also added.

Feed formulation

With a fair knowledge of nutrients and the feed ingredients, the next aspect to be understood is the need for blending of feed ingredients to have a nutritionally complete and balanced feed mix. As is the case in human nutrition, when feed material is blended the food that is consumed will be balanced in terms of nutrients and complete in terms of nutrition. For eg. Plant proteins are deficient in sulphur containing amino acids like cysteine and methionine. Animal proteins are rich in both these amino acids. Similarly, plantz proteins are rich in calcium and poor in phosphorus and cereals are poor in calcium and rich in phosphorus. Likewise many examples can be seen in nature. In essence, mixing of feed ingredients takes care of these imbalances and when done with a scientific basis a nutritionally complete feed can be made which will be effective in producing the desired results in terms of fish production.

In feed formulation, when we mix two ingredients in equal proportion, the resulting mixture will have only 50% of the nutrients contained in each. Suppose, a mixture of groundnut oilcake (GNOC) containing 45% protein is mixed with rice bran (RB) containing only 10% protein in equal quantities the mixture will contain only 22.5 + 5 = 27.5% protein. If we vary the percent composition to 60% GNOC and 40% RB then the mixture will contain 27 + 4 = 31% protein. Let us not forget that this is applicable to all other nutrients present in these two ingredients. From this simple scenario, we will be able to visualize complex scenarios which will contain more ingredients and more no of constraints. Such scenarios can have only mathematical solutions which can be solved in a simple Excel spreadsheet which

will be demonstrated. More complex problems are solved using linear programming with dedicated software. Solver is one such linear programming software available in MS Office in Excel.

Feed production technologies

In aquatic nutrition the feeds should have the physical properties suitable for the fish to consume the feed with minimum loss of nutrients in water. The evolution of the technologies starts from a dry mash to a wet ball to a pellet. Now, the pellets are produced which sink, slow-sink or float depending upon the feeding habit of the fish farmed. For marine carnivores a floating pellet of a slow sinking pellet is found to be appropriate. Sinking pellets, mainly used in shrimp culture are produced using steam pelletizers where steam is used to cook and gelatinize the starch to obtain binding. For production of floating and slow-sinking pellets the technology used is extrusion which is the state-of-the-art in aqua feed production. In this process the starch and protein are gelled using different time temperature combinations forcing the feed mixture to pass through two screws which are co-rotating (twin-screw extrusion). Moreover, puffing of the starch which traps air imparts the floating property to the product.

Feeding

Feeding rates, feeding frequency and time of feeding are all important factors to be considered in feeding of the fish. As a general rule of the thumb most of the vertebrates including fish consume 2.5 to 3.0% of the body weight in dry matter. Feeding rates and frequencies are related to fish growth. Small larval fish and fry need to be fed a high protein diet frequently and usually in excess. When fishes grow bigger, feeding rates and frequencies should be lowered. Feeding fish is a labour intensive activity and feeding frequency has to be programmed in such a way that it is economically viable. Generally growth and feed conversion increases with increase in feeding frequency. Apart from this many

other factors affect feeding rates in fish. Feeding of the fish is also influenced by the time of the day, season, water temperature, dissolved oxygen levels and other water quality variables. Even though, several feeding charts are available it is better to construct one of your own with information on Days after stocking, Fish weight, Protein in feed, Meal/day, Feed consumed as % of body weight, Average daily gain(ADG) and Feed conversion ratio (FCR).