ECO-FRIENDLY FEED MANAGEMENT FOR SUSTAINABLE SHRIMP CULTURE

R. PAULRAJ *

Central Marine Fisheries Research Institute, Cochin-682 014

INTRODUCTION

Shrimp farming is emerging as a successful bio industry in the maritime states of India. Supplementary feeding is one of the important items for increasing production in shrimp culture. The annual feed requirement is directly related to the area under culture, potential FCR of the feed and intensity of the culture system. Currently about 10% of the potential culturable area of about 1.2 million hectares is utlilised for shrimp culture. Feed requirement for the 1,20,000 ha of shrimp ponds currently under culture with annual production of about 80,000 tonnes of shrimp would be in the range of 1.2 to 1.4 lakh tonnes, with potential FCR of 1.5 to 1.75. Annual average production from the existing farms is about 0.75 t/ha/yr. With any technological improvements to raise the average production to 1t/ha/yr in about 2 lakh hectares of the potential area, India's annual shrimp feed requirement would exceed 3 lakh tonnes with a potential value of Rs. 900 to 1000 crores at current rates for the different types of feeds. A total of 35 feed mills with a production capacity of 85,000t have now been set up in India, adopting indigenous and imported technologies. In order to meet the current and future demands, organised quality controlled indigenous shrimp feed industry should develop in India.

Feed holds the key not only for success of shrimp culture, but also for its sustainability. Until the late 1980's choice of a shrimp feed was primarily based on its cost, potential FCR, and growth and production potential. Concerns of environmental degradation, disease outbreaks, mortalities, and poor growth and production in the 1990s have posed new challenges to shrimp feed industry and shrimpt culture.

NEED FOR ECOFRIENDLY FEED AND FEED MANAGEMENT SYSTEM

Wastes derived from unconsumed food, faeces and metabolism of nutrients are the major contributors to pollution in poorly managed shrimp farms. These wastes are excellent nutrient media for the propagation of microbes, some of which are pathogenic while some others like luminiscent bacteria produce toxins which induce stress, and predispose the shrimp to diseases, cause reduced growth and production from farms. Excessive waste nutrients in turn cause plankton blooms, drastically alter the dissolved oxygen profile in shrimp farms due to high BOD and COD, and produce toxic gases like H_2S.

Waste production is related to the performance of a feed in shrimp culture and feed conversion ratio (FCR) could be used as an index of the feed based wastes (Table 1). A rough estimate of the waste production from shrimp culture is given in Table 2. In a four month

---

Present address: Madras Research Centre of CMFRI, Chennai - 600 006.

crop about 47% of the organic matter, nitrogen and phosphorus wastes come during the 4th month of feeding. Thus it is imperative to produce less pollutive, quality assured feeds and evolve ecofriendly feed management strategies for shrimp culture.

CHARACTERISTICS OF ECO-FRIENDLY FEEDS.

Feed quality is defined by the physico-chemical characteristics matching the specific requirements of the growing stages to support maximum growth at optimum intake, with minimum output of feed, faecal and metabolic wastes. The factors which determine the quality of a feed are its nutrients profile, anti-nutrients status, particle size, texture, stability of nutrients, attractability, digestibility, anabolic efficiency and shelf-life.

NUTRIENTS BALANCE

An eco-friendly feed should have a balanced nutrients profile. It should contain optimal level of digestible energy plus a blend of essential aminoacids, and fatty acids, phospholipids, sterol, vitamins and mineral elements. One of the major constraints in developing high performance eco-friendly feeds is the non-availability of complete data on quantitative nutrient requirements for the different stages. The recommended levels are presented in Table 3.

The nutritive value of a dietary protein is dependent on its amino acids profile and their bioavailability. All the essential aminoacids, viz., arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine should be found in adequate levels and balanced proportions. Amino acids imbalance besides affecting growth and feed efficiency, leads to increased production of nitrogenous wastes mainly in the form of ammonia. Similarly excess of protein in the diet, more than necessary to sustain protein synthesis, also results in nitrogenous waste production.

Nitrogen is the major source of waste derived from protein in the food (Table 1) Reduction in nitrogen output could be achieved by optimum use of amino acids-balanced protein, by maintaining optimum protein-energy ratio and by ensuring balance of non-protein nutrients. Amino acids imbalance in the diets can also occur during processing of feed proteins and manufacture of feeds. Excessive heat treatment markedly reduces protein digestibility and biological value due to the destruction of amino acids by oxidation through the formation of linkages between individual amino acids which are more resistant to digestion. Bioavailability of lysine and methionine are markedly affected by improper procesing. Heat treated fish meals containing free histidine and histamine have decreased EAA availability and also contain toxic substances such as gizzerosine. There are also reports of antagonism between amino acids when they are found in disproportionate levels. Leucine/isoleucine antogonism as well as arginine/lysine antagonism are well established. Even when a protein has well balanced amino acids profile, its utilization can be affected if protease inhibitors are present in the ingredients used.

It is therefore necessary to prepare a protein-mix which satisfies the amino acid needs of the shrimp. The levels of digestible energy, essential fatty acids, vitamins, and anti-metabolites also significantly influence the protein utilization and nitrogen waste output.

Crude fibre levels should not exceed 4%. High fibre levels offer low food retention time in the digestive tract for the enzymes to effectively digest the ingested food. Thus a good proportion of the food is excreted as faeces, in high fibre diets.

Quantitative requirements of most of the vitamins have not been clearly defined for shrimps. Vitamin premixes currently in use are mostly empirical formulations. Water soluble vitamins as a group need monitoring as some of the vitamins leached from the diet, and unconsumed feed promote the growth of phytoplankton and microbes, occasionally causing blooms. Thiamine, biotin, and cyanocobalamin have been known to trigger blooms.

Mineral and trace element requiremetns of shrimps are also not well established. Phosphorus is considered to be the dominant element in the feed derived wastes being about 86% in shrimp culture. Dietary source and level of phosphorus affects its utilization by shrimps. Phosphorus from plant ingredients and tricalcium phosphate are poorly utilised. Eco-friendly feed should contain optimum level (0.9%) of bioavailable phosphorus. Excess of trace elements such as Zn, Co, Fe, Mn in the diets, when excreted also trigger phytoplankton blooms as they are essential for the growth and multiplication of phytoplankton.

ANTI-NUTRIENTS

Several anti-nutrients (toxic principles) occur in some of the raw materials used in feed formulation (Table 4). Gossypolo, Cyclopropenoic acid, thioglucosides, cyanogens, hemagglutinin, phytic acid, mycotoxins, antivitamin, anti-mineral and enzyme inhibitors fall under this category. Inclusion of ingredients containing any of the toxic principles could affect the food intake, bioavailability of nutients, and also nutrients metabolism and cause physiological and metabolic disorders. Such ingredients should either be excluded from the diet or added after adequate preprocessing to remove the toxic principles, thereby minimising wastage of feed.

ADDITIVES

Binders, antioxidants, antimicrobial agents, attractants, feeding stimulants, growth promoters, pigments and therapeutants are essential in feed to meet specific needs. Judicious use of these additives either direcly or indirecly helps to reduce feed derived wastes in shrimp culture. However, therapeutants, especially antibiotics should be used with utmost care adhering to prescribed dosage and schedules. Immunomodulations such as B-glucans, lectins, lipopolysaccharides and other bioadditives which have been shown to enhance disease resistance should be used in disease management progammes.

QUALITY OF RAW MATERIALS

The quality of a feed is gretly determined by the ingredients. Ingredients with high levels of non-protein nitrogen, crude fibre, ash, salt content, oxidised lipids and antinutritional factors should be excluded from shrimp feeds.

PROCESSING

Microgrinding and homogeneous mixing of ingredients, premixes and additives, optimum conditions of pelleting, cooling and drying are very important for proper utilization of the feed by shrimps and to minimise feed waste. Microgrinding makes available more surface area for enzymatic action and hence improves digestibility of the feed. Fine grinding also helps in better gelatinisation of starch and binding. Mixing process should ensure uniform disperson of the mocronutrients and additives so that each unit weight of the finished feed has a balanced nutrients profile.

FEED PARTICLE SIZE

Feed particle size is very important for proper utilization. Particles should be adequately sized to suit the mouth parts (Table 5a) and digestive capabilities of the growing shrimp. Under-sized and over-sized feed particles should be screened before feeding to prevent feed wastage, degradation of the culture environment, and propagation of pathogenic organisms.

DIGESTIBILITY

Shrimps have a very small digestive tract, which is capable of utilising soft food material, similar to that of the live food which they consume in nature. Artificial dry diets should have rehydration characteristics and render flexibility for feeding by the shrimps. Addition of exogenous enzymes or inclusion of enzyme or bio-preprocessed ingredients would further improve the digestibility of nutrients.

SHELF-LIFE

Prolonged storage lowers the biological value of feeds. Shelf-life is also dependent on the shelf-life of ingredients used in the feed. Ingredients and finished feeds should be used as fresh as possible. Prolonged storage alters the quality due to enzymatic action and chemical changes. Chemical changes include breakdown of lipids, formation of free fatty acids and rancidity. Rancidity reduces the palatability of the feed and the availability of amino acids, and certain vitamins. Raw material and compounded feeds being highly nutritive, attract insects such as beetles, weevils and moths which expose the feed to fungi and introduce contaminating bacteria. Fungi produce highly potent mycotoxins like aflatoxins which are toxic to shrimps. Vitamin potence decreases during storage. Feed stored for period exceeding six months needs thorough chemical and biological evaluation for acceptability and digestibility.

ECO-FRIENDLY FEED MANAGEMENT SYSTEM

Judicious feed management is also an important factor in achieving good feed efficiency and reducing feed wastage. Waste production could be reduced by selecting feeds which are freshly made, quality assured, proven with best potential FCR, rejecting feeds which have lost their nutritional potency and have poor acceptability to shrimp and poor stability when introduced into water, by using feed of appropriate particle size designed for a particular stage, and by regulating the ration and feeding schedules with reference to feeding guides, response of the shrimp to the feed and environmental conditions. Shrimps are bottom feeders and they consume feed at a very slow rate, making it difficult to make direct observations on feeding behaviour. The check net method is useful to monitor the feeding behaviour of the shrimp once they reach about 2g. This is carried out by offering a certain percentage of the meal in a check net. About 6 to 8 check nets are usually required for a pond of 1 ha size. The amount of feed put in the check net and checking time schedule respectively vary from 2.0% meal and 2.5 hrs for shrimp weighing 2-3g to about 4.0% meal and 1 hr for 30-40 g shrimp. Feed adjustment for subsequent meal is made based on the amount of left over feed.

Response of the shrimp to the feed (food intake) depends on quality of the feed, health and physiological state (moulting) of the shrimp, and environmental conditions prevailing in the ponds. Maximum intake of the feed occurs when the shrimps are healthy, the feed is good and environmental conditions are optimal. Feed intake is affected when any one or more of these factors are beyond the optimum level. A low quality feed is poorly accepted though the shrimp may be healthy and environment congenial. Conversely poor health, physiological and environmental stress may induce a poor feeding response in shrimps towards a quality feed. Thus day to day observations would help optimise feeding thereby reduce feed wastage and culture environment degradation. Shrimps are slow feeders. Chemoreception is the mode of the food detection. The feed should contain adequate levels of attractants, which are mostly amino acids, glycine-betaine and nucleotides.

Regular observations on health of the shrimp are also very important. If any diseases are noticed immediate treatment should be given and a reduction in the ration may become necessary.

Environmental conditions by and large, have the greatest influence on the shrimps. Best growth and feed efficiency occur under optimal environmental conditions. Tropical shrimps have a temperature optimum of 27-31 °C, pH 8.0- 8.5 and dissolved oxygen 4-7 ppm for normal growth and feed efficiency. A 50% reduction in feed has been widely advocated when temperature drops to between 22 and 24 °C and feed supply may have to be stopped below 22 °C. Similarly temperatures above 32 °C affect feed consumption.

Dissolved oxygen levels below 3 ppm lead to poor feed intake. A reduction of 25% feed is recommended when DO levels vary from 2.8 to 3.0, 50% reduction when DO levels are between 2.5-2.7 and no feed supply when DO levels go below 2.5 ppm. Similarly when water pH is above 9 feed intake is affected. Feed supply should be reduced by 25% when pH is in the range 9-9.5, 50% at pH 9.5-10 and no feed is recommended when pH is above 10. Other parameters which need regular monitoring and remedial action include total ammonia (preferred level < 0.1 ppm), nitrite (<0.25 ppm), hydrogen sulphide (< 0.002 ppm). Other factors which can cause stress include cadmium (safe level 10 μ/1). chromium (100 μg) copper (25 μg), lead (100μg), mercury (0.10 μg), zinc (100 μg), aldrin dieldrin (0.003 μg), BHC (4 μg), DDT (0.001 μg) and Endrin (0.004 μg). The number of meals offered in a day and time of feeding are also important. Frequent feeding reduces starvation and stunting, enables uniform growth and results in minimum feed wastage. The number of meals offered per day ranges from 4 to 6 (Table 5b). In the case of extensive and improved extensive systems in the absence of artificial aeration systems, it is preferable to avoid feeding between midnight and early morning (5 a.m.) as the dissolved oxygen levels reach sub-optimal levels then, from the third month of the crop. (Table 5c.)

Feeding method should ensure that the shrimp obtains feed particles without much searching. Broadcasting is the most appropriate method for granules and pellets. Small shrimps mostly concentrate in the shallower area along the dike. So during the first two month feed can be broadcast manually from pond dikes to about 1-10 metres. When the shrimp grows bigger the feed should be broadcast in the middle portion of the pond also. Thus feed derived wastes can be minimised through scientific diet planning, processing, and judicious feeding based on the health and physiological status of the shrimp, and by adoption of environment dependent feed management strategies.

Table 1: Relationship of FCR to waste production per tonne of shrimp

FCR	Organic Matter (Kg)	Nitrogen (Kg)	Phosphorus (Kg)
1.0	500	26	13
1.5	875	56	21
2.0	1250	87	28
2.5	1625	117	38

Table 2: Rough estimate of the feed derived waste production/crop/ha

(Production 2 tonnes/ha: FCR 1.5)

	1st M Kg.	2nd M Kg.	3rd M Kg.	4th M Kg.
Feed offered	120	510	960	1410
Waste production				
Organic matter	70	298	560	822
Nitrogen	5	20	36	52
Phosphorus	2	7	14	20

Table 3: Nutrient requirements of shrimps

	Nutrients	**Recommended level (per kg of feed)**
Digestible energy		3200 - 3600 kcal
Protein	Larvae + post larvae	450 - 500 g
	Grow-out diets (Semi-intensive)	350 -450 g
	Grow-out diets (Extensive)	300 - 350 g
Lipids	Larvae + post larvae	100 - 120 g
	Grow-out diets	40 - 80 g
Essential fatty acids		
	Linoleic + Linolenic (1:1)	5 - 10 g
	Eicosapentaenoic + Docosahexaenoic (1:1)	5 - 10 g
	Phospholipids	10 - 20 g
	Cholesterol	2 - 5 g
	Glucosamine	5 - 8 g

Essential amino acids (as % of protein)

Arginine 5.8;
Histidine 2.1;
Isoleucine 3.5;
Leucine 3.5;
Leucine 3.5;
Lysine 5.3;
Methionine 2.4;
Phenylalanine 4.0;
Phenylalanine-tyrosine 7.1;
Threonine 3.6;
Tryptopha 0.8;
Valine 4.0

Vitamins (per kg of feed)		Minerals (per kg of feed)	
Fat soluble			
Vitamin A (I.U.)	500 - 10000	Calcium (g)	12.4
Vitamin D3 (I.U.)	1000 - 2000		
Vitamin E (I.U.)	100 - 200	Phosphorus (g)	10.4
Vitamin K (mg)	5 - 20	Magnesium (g)	0.6-0.7
Water soluble			
Ascorbic acid (mg) (as ascorbyl polyphosphate)	200-400	Sodium (g)	6
		Potassium (g)	9
Cyanocobalamin (mg)	0.1-0.2	Sulphur (mg)	200
Biotin (mg)	1.0	Copper (mg)	25
Choline (mg)	400-2000	Manganese (mg)	20
Folic acid (mg)	5-10	Zinc (mg)	50-00
Inositol (mg)	200-300	Iron (mg)	5-20
Niacin (mg)		Cobalt (mg)	10
Pantothenic acid (mg)	50-100	Selenium (mg)	1
Pyridoxine (mg)	30-50	Iodine (mg)	5
Riboflavin (mg)	30-58		
Thiamine (mg)	50-100		

Table 4: Antinutrients present in commonly used feed ingredients

Anti-nutrient		Ingredient
Protease inhibitor	:	Soyabean, wheat, sunflower, maize
Arginase inhibitor	:	Sunflower
Amylase inhibitor	:	Wheat
Tannins	:	Sunflower
Cyanogens	:	Cassava
Gossypol	:	Cotton seed
Cyclopropenoic acid	:	Cotton seed
Phytic acid	:	Soyabean, rice bran, cotton seed, ground nut.

Anti-biotin (Avidin) factor	:	Raw egg white
Phytoharmagglutonins	:	Soyabean, rice bran, cotton seed, ground nut
Anti-thiamine factor (thiaminase enzyme)	:	Raw fish, shell fish, rice polishings
Anti-pyridoxine factor	:	Linseed
Anti-vitamin A,E,D & B12	:	Soyabean
Oxalic acid	:	Sesame
Micotoxins (Fungal toxins)	:	Groundnut, maize

Heavy Metals

Arsenic	:	Poultry waste
Cadmium	:	Shellfish
Copper	:	Brewery by products
Zinc	:	Shellfish, hydrolysed feather, poultry by products.

Table 5: Examples of feed particle size, feeding schedules and daily ration

a. Feed particle size for growing shrimp (General)

Size/Weight	Feed type	Particle Size
PL 20 - PL 40	Granules	200 - 800 Micron
0.5 to 1.0 g	Granules	0.8 - 1 mm
1 to 5 g	Granules	1.0 - 1.5 mm
5 to 10 g	Pellets	2.0 x 2.5 mm
10 to 20 g	Pellets	2.5 x 4.6 mm
20 to 30 g	Pellets	3.0 x 6.8 mm
Above 30 g	Pellets	3.0 x 8 mm

b. **Feed particles and feeding programme of selected commercial feeds.**

Example 1

Feed type	Size of feed (mm)	Size of shrimp (g)	Daily ration (% biomass)	Feeding per day
Fine crumble	0.42	PL 15-PL20	-	3
Crumble	0.89	PL20-PL45	-	3
Crumble	1.41	1-3g	-	4
Pellet	2.3 x 3.5	3-8	10-9	4
Pellet	2.3 x 3.5	8-15	8-7	5
Pellet	2.3 x 4.5	15-20	6-4	5
Pellet	2.3 x 4.5	20-25	4-3.5	5
Pellet	2.3 x 6.7	25-30	3.5-3	6
Pellet	2.3 x 6.7	30-33	3.0-2.5	6
Pellet	2.3 x 6.7	33-37	2.3	6
Pellet	2.3 x 6.7	37-41	2.2	6

Example 2

Feed Type	Size of feed (mm)	Size of Shrimp (g)	Daily ration (% biomass)	Feeding per day
Fine crumble	25-40 mesh	1.2-2.5 cm	20-25	4-6
Fine crumble	15-25 mesh	2.5-4 cm	20-25	4-6
Pellet	2.2 x 2.3 mm	1.5 g	15-8	4-6
Pellet	2.2 x 4.5	5-12	8-5	4-6
Pellet	2.2 x 4.5	12-20	5-3	4-6
Pellet	2.2 x 6.8	20	4-2	4-6

C. Examples of feeding schedules and percentage feed distribution

Time of feeding	Percentage of daily ration
Extensive system	
6 - 6.30 A.M.	30
10 - 10.30 A.M.	10
5 - 5.30 P.M.	30
10 - 10.30 P.M.	30
Semi-intensive system	
6 - 6.30 A.M.	25
10 - 10.30 A.M.	15
2 - 2.30 P.M.	5
5.30 - 6.00 P.M.	25
10.00 - 10.30 P.M.	25
2.00 - 2.30 A.M.	5