On-farm feed management practices for black tiger shrimp *(Penaeus monodon)* in India

Umesh N. Ramaswamy, A. Balachandra Mohan and Marc Metian[1]
National Centre for Sustainable Aquaculture
Rajendra Nagar, Kakinada
Andhra Pradesh, India

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ABSTRACT

This paper is based on a case study of on-farm feed management practices for the black tiger shrimp (*Penaeus monodon*) culture in India. Ninety percent of shrimp farming in India is a small-scale farming activity. Feed is the largest cost input in shrimp farming, accounting for 50 to 60 percent of production costs. Reducing feed costs through improvements to feed management practices is essential to improving the economic performance of the culture operations. The study was carried out in 2010, and focused on four different types of farming systems that were based on different stocking densities, and used either manufactured or farm-made feeds.

The review assesses feed use in small-scale shrimp aquaculture, with particular emphasis on the use and selection of feed types. The paper also provides an overall assessment of feed management practices and feed utilization. The review identifies feed practices and feed specifications, and provides practical measures that can be taken to improve on-farm feed management. The study revealed that 98 percent of the shrimp farmers in India used manufactured sinking dry pellets, and only two percent (the extensive farmers) use farm-made feeds. Currently, feeds produced by the big aquafeed manufacturers dominate the market, and, through local feed dealership networks, these feeds are available in all the farming areas. In the study, 36 percent of the farmers reported Food Conversion Ratios (FCR) of 1.2:1 to 1.4:1; 37 percent recorded FCR greater than 1.4:1; and the remaining 27 percent recorded FCR below 1.2:1. The farmers in the survey indicated that an FCR of <1.5:1 was adequate.

Issues related to feed management are discussed, and recommendations to promote capacity building and improved management through the clustering of small-scale shrimp farmers are made. These recommendations are designed to reduce risk, promote good on-farm feed management practices and reduce feed and feed ingredients costs. Research recommendations that are driven by commercial realities are provided, the policy and regulatory frameworks are analyzed and appropriate interventions to support sectoral growth provided.

[1] Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden.

1. INTRODUCTION

1.1 Global trends in black tiger shrimp production

Shrimp farming is one of the most profitable and fastest-growing sectors of the aquaculture industry. Over the past decade, global farmed shrimp production has grown almost threefold from 1.13 million tonnes in 1999 to over 3.43 million tonnes in 2009 (Jory, 2010). A number of factors have contributed to this phenomenon. In the 1980s the growing demand for shrimp, mainly from North America, Europe and Japan, coupled with a levelling-off of production from capture fisheries, resulted in high market prices (Neil *et al.*, 2001). Within the last 20 years, major technical improvements have been made to farming systems. These include the emergence of new production technologies and the production of pellet feeds with high protein levels. These advancements have enabled farmers to stock at higher densities, increase yields and correspondingly increase profitability. These successes have provided the impetus for increased investment in shrimp aquaculture (Naylor *et al.,* 2000).

Global production of black tiger shrimp increased from about 21 000 tonnes in 1981 to almost 200 000 tonnes in 1988; by 1993, production had increased to nearly 495 000 tonnes with a value of US$3.2 billion (FAO, 2012). Since 1993, production has been variable, ranging from a low of ~480 000 tonnes in 1997 to a high of 781 582 tonnes in 2010.

Since 2003, *P. monodon* production has declined in Thailand. This decline is due to various factors including disease and the poor quality of *P. monodon* seed (Wyban, 2007). Diseases affecting *P. monodon* include white spot syndrome virus (WSSV), yellow head virus (YHV), monodon baculovirus (MBV) and to a lesser extent, luminescent bacterial infections. In addition, poor quality *P. monodon* seed has restricted the expansion of the industry. Poor quality seed, coupled with the slow growth of *P. monodon*, is encouraging farmers to switch to the production of whiteleg shrimp, *Litopenaeus vannamei* in several countries. Domestication technologies and the development of disease-free broodstock is a major requirement for sustaining *P. monodon* farming and increasing production parameters (Flavio Corsin, International Centre for Aquaculture and Fisheries Sustainability, personal communication, 2010; Wiwath, Department of Fisheries, Hanoi, Viet Nam, personal communication, 2010; Arun Padiyar, FAO Consultant, personal communication, 2010).

Asia, particularly South East Asia, is the most important shrimp producing region of the world. Asia has favourable natural resources for shrimp production, with the coasts of the Pacific and Indian oceans providing suitable culture areas. The climate in Southeast Asian countries is tropical or subtropical, and provides favourable conditions that are suitable for shrimp production (Xinhua, 2008). In 2010, all farmed *P. monodon* was produced in Asia (FAO, 2012); the major producers were Viet Nam (333 000 tonnes), Indonesia (125 519 tonnes), India (96 500 tonnes), China (56 634 tonnes), the Philippines (48 162 tonnes), Myanmar (46 105 tonnes) and Bangladesh (43 154 tonnes). The majority of farmed shrimp from India is exported to the European Union, the United States and Japan (MPEDA, 2008).

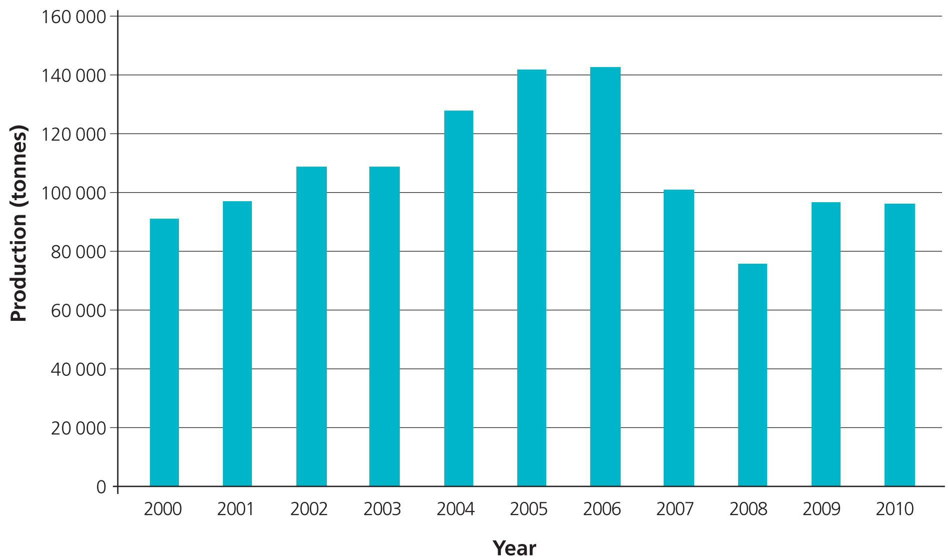
India, the third largest producer of *P. monodon*, possesses an extensive coastline, measuring approximately 8 000 km. The country utilizes only about 40 percent of the available 2.36 million hectares of freshwater resources that are suitable for pond and tank aquaculture, and 13 percent of the 1.2 million hectares of brackishwater resources. Between 1990 and 1994 there was a phenomenal increase in the area under shrimp culture. The increase in production was primarily a result of strong international demand for shrimp, combined with the development of commercial hatcheries, credit facilities from commercial banks, and technical and financial assistance programmes from the Marine Products Export Development Authority (MPEDA), the Indian Council of Agricultural Research (ICAR) Institutes and the State Fisheries Departments (De Silva and Davy, 2010). Indian shrimp farming is mainly based on black tiger shrimp, which contributed 86 percent to the national shrimp and prawn production (112 100 tonnes) in 2010 (FAO, 2012). In the mid-1990s in Andhra Pradesh and Tamil Nadu, a large number of integrated commercial shrimp farms were developed. These facilities adopted modern culture practices and included production facilities for shrimp seed, feed and processing. Unfortunately, the advent of viral diseases in the region made these large-scale integrated facilities unprofitable, and shrimp culture there has now largely reverted to a small-scale farmer activity.

Currently, coastal aquaculture in India is synonymous with shrimp aquaculture and is mainly carried out by small-scale farmers (MPEDA, 2009). It comprises three categories of farmers/entrepreneurs, *viz.* small- to medium-scale farmers, middle-level entrepreneurs and large-scale entrepreneurs. At present, 91 percent of the shrimp farmers in India own less than two hectares, six percent own between two to five hectares and the remaining three percent own more than five hectares (MPEDA, 2009). Out of the total area devoted to aquaculture, 0.152 million hectares is currently being utilised for shrimp farming. The state of Andhra Pradesh alone provides 47 percent of the area and contributes 50 percent of the total production (FAO, 2005a). Small-scale farmers contribute around 80 percent to the total *P. monodon* production (MPEDA, 2009). There are 283 *P. monodon* hatcheries operating in the country, which provide a total production capacity of 12.0 billion postlarvae/year. Prior to the establishment of shrimp feed factories, shrimp feed was imported from Thailand, Taiwan Province of China and other countries but, by 2009, national shrimp feed production was 150 000 tonnes (MPEDA, 2009).

In India there are two distinct seasonal shrimp crops. The first crop starts in February or March and ends in May or June. The second crop starts in August or September and ends in November or December. Typically the first crop produces a much higher yield than the second crop (Suresh, 2007). Warm weather in summer is cited to be the main reason for this difference. The average duration of each production cycle is 120 to 140 days, and the average size of *P. monodon* harvested ranges from 20 to 40 g.

Shrimp farms use land that is either leased from the government or the private sector, or land that is owned and operated by the shrimp farmers. A credit system is available to the farmers, primarily operated and controlled by intermediaries who also act as input suppliers at each stage in the supply chain, and also purchase the harvested shrimp. On average, farmers pay 25 to 30 percent interest on the loans from these intermediaries, significantly affecting the profitability of their operations (De Silva and Davy, 2010).

FIGURE 1
Production trends of *Penaeus monodon* in India (2002–2010)



Source: FAO (2012).

Farmed shrimp production increased from 40 000 tonnes in 1991–1992 to 143 170 tonnes during 2006–2007, generating export sales valued at US$0.8 billion (MPEDA, 2008). In recent times, black tiger shrimp production in India declined from a peak of 142 967tonnes in 2006 to 96 500 tonnes in 2010 (FAO, 2012) (Figure 1). The recent decline in production was probably due to the low market price for this species in 2007. In recent years, many farmers have felt that the returns from *P. monodon* farming have declined, and as a result the area under farming became reduced from a peak of 149 600 hectares during 2006 to 76 000 hectares (MPEDA, 2009). With the improved market price for *P. monodon* during 2008, the farming area in 2009 was increased to 102 200 hectares. During 2010, the farming area grew to 113 852 ha and production rose to 118 575 tonnes (MPEDA, 2010).

1.2 Market trends

Globally, shrimp is the most valuable traded aquaculture commodity, and in 2006, it accounted for 17 percent of the total value of internationally-traded fishery products (FAO, 2008); however, despite growing global export volumes, its share has been declining, with average prices showing a downward trend. In value terms, the major exporting countries are Thailand, China and Viet Nam (Jory, 2010). The EU is the main market for shrimp exports from India and, with the exception of the United Kingdom, all the major European countries are currently experiencing a stable or increasing trend in consumption. In the first half of 2010, the prices remained high for black tiger shrimp; compared to 2008, prices increased by almost US$2/kg (30 to 40 g shrimp). In addition, there was a general increase in domestic shrimp consumption in countries such as China and Thailand and, more recently in India. An increase in demand for organically certified shrimp from developed countries is anticipated over the coming years. This is attributed to growing health consciousness among consumers in these countries.

1.3 Legislation, policy and regulatory frameworks

No national standards have been set for the nutrient composition of shrimp feeds. However, recently the Coastal Aquaculture Authority of India started a feed manufacturer registration programme, and feed standards are being developed in collaboration with research institutes. The mandatory legislative requirements for *P. monodon* production in India (FAO, 2005b) comprise:

- Legislative acts: the government of India enacted the Coastal Aquaculture Authority Act (2005), establishing the Coastal Aquaculture Authority (CAA) that is mandated to enforce aquaculture regulatory measures in the coastal zone and promote environmental sustainability in the sector. The Act excludes freshwater aquaculture, but encompasses all forms of aquaculture in saline or brackishwaters in the coastal zone.
- Legislative Requirements for feed and feed manufacturers: all shrimp feed manufacturers are required to be registered by the CAA. The CAA has the power to review the registration of feed mills and, where necessary, to take appropriate management actions.
- Regulatory frameworks: There is no legally binding regulatory framework in place. However, voluntary guidelines are being developed.

2. METHODOLOGY

The study focused on four types of farming systems that use different stocking densities and feed types. A number of data sources were interrogated; data on feeding practices and the average Feed Conversion Ratios (FCR) were obtained. The survey was undertaken during the summer crop of 2010, and included 183 ponds located across three states on the east coast of India, namely Andhra Pradesh, Tamil Nadu and West Bengal, and one state on the west coast, Karnataka (Figure 2 and Table 1).

Twenty-eight ponds from traditional farms which use supplementary feeds in West Bengal were included in the survey. The survey was carried out by field staff of the National Centre for Sustainable Aquaculture. During the survey it was apparent that shrimp farmers predominantly use commercially manufactured pelleted feeds, and a small percentage of traditional farms make their own farm-made feeds using locally available ingredients. The feeding practices applied and the type of commercial feeds used at different stages of the growth cycle were established. All the farmers practiced *P. monodon* monoculture and all were members of aquaculture societies. Aquaculture societies constitute a group of aquaculture farmers in a specific locality who use participatory approaches for reducing disease risks, production costs, and meet market demands through sustainable farming (De Silva and Davy, 2010). Each society comprises 20–50 farmers who have registered their farms with the Coastal Aquaculture Authority (CAA). Membership is voluntary and subject to certain conditions. Broodstock feed and feed management data was collected from the hatcheries that supplied seed to the study farms, and information pertaining to the raw material sources used in the manufactured feeds was collected and collated.

The four states (Table 1) that were selected for the study (Figure 2) produce 81 percent of total farmed shrimp in India (MPEDA, 2008).

FIGURE 2
Map showing the study area

Source: Field survey (2010).

TABLE 1
Distribution (% of ponds surveyed) of the farming systems included in the survey

Farming system	Stocking density	Andhra Pradesh	Karnataka	Tamil Nadu	West Bengal
Traditional	<2 postlarvae/m^2				13.27
Extensive	<4 postlarvae/m^2	24.28	0.00	0.00	
Modified extensive	4–8 postlarvae/m^2	26.63	6.60	5.20	
Semi-intensive	>8 postlarvae/m^2	22.55	0.69	0.78	
			n = 183		

Source: Field survey (2010).

2.1 Farming systems

The farming systems currently employed in India can be broadly divided into four basic categories: traditional farming systems (TFS), extensive farming systems (EFS), modified extensive farming systems (MEFS) and semi-intensive farming systems (SIFS). At present, there is no intensive *P. monodon* farming in India.

2.1.1 Traditional farming systems (TFS)

TFS are polyculture systems that are based on earthen ponds ranging in size from <1 hectare to 25 hectares. The systems are characterized by low stocking densities of less than 2/m^2, hatchery or wild postlarvae/juveniles, and in the smaller ponds, the limited use of supplementary feeds. This type of traditional coastal farming – locally known as *Bheri*-culture in West Bengal – is primarily practiced in the states of West Bengal and Kerala. The farms rely on tidal water exchange to replenish natural food sources. The stocking is undertaken on a monthly basis, and the larger shrimp are harvested every fortnight during full moon. Due to the open tidal water exchange nature of the system, other fish and shrimp species are also found in the ponds. Typically, shrimp production is less than 300 kg/ha/year and in 2008 the estimated national production attributable to this farming system was 26 000 tonnes (27 percent of total *P. monodon* production) (MPEDA, 2009).

As a polyculture system, other species that are cultured include *Metapeneaus monoceros* (speckled shrimp) *Lates calcarifer* (Asian seabass), *Liza tade* (rock mullet), *Mugil cephalus* (striped mullet) and *Anguilla* sp. (eel). When the salinity falls below 10 ppt during the monsoon season, additional species are also produced, including *Macrobrachium rosenbergii* (giant river prawns, known in India as 'scampi'); the carps *Labeo rohita* (rohu), *Catla catla* (catla) and *Cirhinnus cirrhosus* (mrigal); and *Oreochromis niloticus* (Nile tilapia).

2.1.2 Extensive farming systems (EFS)

The EFS system is based on earthen ponds ranging in size from 0.5 to 2 hectares, which are characterized by low stocking densities of less than 4/m^2, using hatchery-reared postlarvae (PL)/juveniles, and the use of manufactured feeds. Shrimp production is <500 kg/ha/year. In 2008, the estimated national production attributed to the farming system was 21 000 tonnes (22 percent) (MPEDA, 2009).

2.1.3 Modified extensive farming systems (MEFS)

The MEFS system is based on earthen ponds ranging in size from 0.5 to 1.5 hectares. The system employs low water exchange rates (tidal or pumped systems, with up to ten percent of water exchange per day), use intermediate stocking densities (4 to 8 PL/m^2), hatchery-produced PL, and manufactured feeds and some fertilization. Low labour inputs are required, and these systems are usually operated by family members. Partial aeration is used at night and in the early morning when dissolved oxygen levels in the pond waters are at their lowest. These farms tend to produce moderate shrimp yields of 1–2 tonnes/ha/year. In 2008, the estimated national production using this farming method was 29 000 tonnes (30 percent) (MPEDA, 2009).

2.1.4 Semi intensive farming systems (SIFS)

Typically SIFS farms use small to moderate-sized earthen ponds (0.3–1.0 ha), with moderate water exchange (pumping: 5–20 percent water exchange/week). Shrimp stocking densities range from 8–20 shrimp/m^2, and stocking is based on hatchery-produced PL. Manufactured pelleted feeds are used and the ponds are continuously aerated. Aeration rates increase during the final production phase. Fertilization and moderate labour inputs (one worker per 2 ha of ponds) are required. Semi-intensive farms produce shrimp yields of 2.0-4.0 tonnes/ha/crop. In 2008, the national production in SIFS was approximately 20 000 tonnes (21 percent) (MPEDA, 2009).

2.2 Hatchery production

Shrimp hatcheries comprise separate facilities for spawning, hatching, larval and PL rearing, indoor and outdoor algal culture (where applicable), and areas for hatching *Artemia* and feed preparation. Thirty percent of the larger hatcheries use separate biosecure production units for each production stage. Typically, the hatcheries comprise two to four production units with each unit comprising 10–20 separate tanks. Hatcheries attempt to stock all their tanks in each unit simultaneously in order to reduce biosecurity risks.

In addition, there is supporting infrastructure for the handling of water (facilities for abstraction, filtration, storage, disinfection, aeration, conditioning and distribution); there are diagnostic laboratories, areas for the maintenance and packing of nauplii and PL; and there are offices, storerooms and staff living quarters and facilities.

The *P. monodon* hatcheries in India primarily rely on wild shrimp broodstock; only two hatcheries are producing shrimp seed in maturation systems. Those hatcheries that mature their broodstock feed the animals with fresh squid (*Loligo* sp.) at 6–10 percent wet body weight/day, clams (4–8 percent wet body weight/day), polychaete bloodworms (10–12 percent wet body weight/day), and tuna fish eggs and goat liver at a combined total of 20–30 percent of wet body weight/day. All the maturation feed is procured from local sources. The exact quantity of feed provided is adjusted frequently, and is based on consumption rates within individual tanks. The feeding is to satiation and is continued until only a very small amount of uneaten food remains in the tank a couple of hours after each feeding.

3. RESULTS

3.1 Farming practices

For several decades, traditional farming has been practiced in the states of West Bengal (*Bheri* farmers) and Kerala. In February, ponds are filled during high tide, and PL that are either wild-caught or sourced from hatcheries are stocked at 15 000/ha. After two months of culture partial bi-weekly harvesting starts; 7 500 PL/ha are stocked immediately after each partial harvest and the final harvest takes place after approximately 10 months. *Bheri* farmers procure seed from commercial nurseries that are supplied with PL from the hatcheries. The dependence on commercial nurseries for seed in West Bengal is due to the small quantities that the farmers require to stock their ponds. Farmers feel it is not feasible for them to procure PL directly from the hatcheries because they would be required to purchase large numbers of animals. The production cycle in this system is approximately 10 months.

3.1.1 Pond preparation and Fertilization

The ponds in the traditional extensive production systems are not treated prior to stocking – they are large and they cannot be completely drained. In the other production systems, the ponds are drained and sun-dried for one to two months, and treated with lime in order to obtain the ideal soil pH. Ponds are filled to an average of one metre and fertilized with either inorganic or organic fertilizers. The inorganic fertilizers include urea, diammonium phosphate (DAP), superphosphate and potash. These are mixed in the water and spread throughout the pond. Organic fertilizers, such as fermented mixtures of molasses (locally known as *jaggary* – a by-product of the sugar industry), rice bran and yeast may be used. These are spread across the ponds at a ratio of 25:10:0.25 kg/ha.

Different fertilization regimes result in differential yields (Table 2). Seventy-eight percent of farms that were surveyed apply fertilizers to generate plankton blooms prior to shrimp seed stocking. These phytoplankton populations are maintained during the culture period. No inorganic fertilizers are applied after the first month of culture.

Fermented mixtures of molasses, rice bran and yeast are commonly used throughout the production cycle to maintain plankton blooms, and to keep the pH at acceptable levels (pH 7.5–8.5). Oil cakes are also used. The prices ranged from US$0.11–1.07/kg for inorganic fertilizers and from US$0.28-0.64/kg for organic fertilizers, except yeast, which was US$12.79/kg (Table 3).

TABLE 2

Use of fertilizers at different stocking densities and the resultant production of shrimp

Stocking density (PL/m^2)	No fertilization	Inorganic fertilization	Organic fertilization
	Production (kg/ha)		
1	154		
2	483	404	567
3		538	756
4		854	974
5	1 233	1 554	1 646
6	1 550	1 695	1 791
7			
8		2 500	1 883
9	1 733		3 087
10			2 781
11			3 186
12			3 280
13			2 908
14			3 409
15			1 516
17			4 178

Note: Inorganic fertilizers used are urea, DAP and superphosphate; organic fertilizers comprise a combination of molasses, rice bran, yeast and oil cakes.
Source: Field survey (2010).

TABLE 3

Prices and usage of fertilizers in study ponds

	US$/kg	Application rate (kg/ha)
Urea	0.14	12.5–25
DAP	0.22	50–125
Superphosphate	0.11	125
Ground nut oil cake	0.51	35
Rice bran	0.28	70
Molasses	0.64	2.5
Yeast	12.79	0.6
Potash	1.07	13

Source: Field survey (2010).

3.1.2 Shrimp seed procurement and stocking

The survey revealed that 93 percent of the farmers procured *P. monodon* seed through a contract system whereby farmers purchase quality seed in bulk. The farmers enter into an agreement with a hatchery operator one month in advance of delivery. Seventy percent of the seed used in the traditional extensive farming systems were procured from commercial hatcheries, and rest were sourced from the wild. In the modified extensive farming systems and the semi-intensive farming systems, the seed was sourced exclusively from commercial hatcheries. Hatcheries in the state of Andhra Pradesh supplied 90 percent of the seed to the study farms. Farmers procure seed from local hatcheries that are in close proximity to their farms (<8 hrs transportation time). When the transportation time exceeds four hours, the PL are stocked directly into the ponds during the early morning hours. When the transportation periods are less than four hours, the PL are stocked during the late evening. After 45 days, survival estimates are made. These are based on feed consumption rates (using feed trays), and cast net sampling. Until the survival estimations have been made, 80 percent of PL are assumed to have survived, and feed rates are adjusted accordingly.

3.2 Feed

3.2.1 Farm-made feeds

While twenty percent of the extensive farms reported using farm-made feeds (Figure 3, left), the study also revealed that 98 percent of the shrimp farmers used manufactured, sinking dry pellets (Figure 3, right) in combination with farm-made feed. Only 20 percent of the extensive farms (<2 percent of the total farming area in the country) were using farm-made feeds; the other 80 percent of the extensive farmers, and all of the modified extensive farms and semi-intensive farms used manufactured, sinking pelleted feeds.

The traditional extensive farms in West Bengal (*Bheris*) that are larger than two hectares do not use feeds, and the shrimp therefore rely on the natural productivity in the ponds for nutrients. The natural food is replenished by regular water exchange during high tide periods. On the smaller modified extensive farms, farm-made feeds are used and are primarily comprised of mixtures of boiled rice, maize and potatoes. During the first month of the production cycle there is no feeding, and the shrimp depend solely on natural pond productivity. In the second month feed is provided once per day, up to a maximum of 7.5 kg/ha. Groundnut, rice bran, wheat cake and egg yolk are used as ingredients (Figure 4). The average price of farm-made feeds is US$0.32–0.42/kg. From the third month, feeding is based on the size of the shrimp, and a minimum of 7.5 kg/ha is fed per day.

FIGURE 3
Aquafeed used for shrimp aquaculture in India

Note: Left: farm-made feed; right: commercially manufactured sinking pellets

FIGURE 4
Crumbled feed mixed with water to aid distribution in the pond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3.2.2 Industrially manufactured pelleted feeds

India has a well-established capacity to produce shrimp aquafeeds. Prior to 1990, when the manufacturing aquafeed industry was in its infancy, the country relied on farm-made feeds. In the early 1990s, large quantities of shrimp feeds were imported from Taiwan Province of China and Thailand. Over time, these imports have gradually been replaced by domestically produced feeds. Currently, domestic shrimp feed production capacity exceeds demand. Approximately 3 000 tonnes of shrimp feed is imported from Indonesia, China, Taiwan Province of China and South Africa to cater to the needs of niche markets (Suresh, 2007).

3.2.3 Quality Requirements for Shrimp Feeds

As farms in India evolve from low to high stocking densities, the quality of feed becomes increasingly important. Extensive farms use feed and also fertilize their pond waters to stimulate natural productivity. In semi-intensive farms, the shrimp primarily depend on pelleted feeds, and therefore the quality of the feed is more important because the shrimp derive their nutrition from exogenous feed inputs.

The respondents in the survey reported that the key factors that determine shrimp feed quality are its palatability, water stability and ingredient composition. The farmers assess the palatability of the feed quantitatively, based on feed intake, growth and FCR – an unpalatable feed would not be eaten, manifesting in a reduction in growth rates and poor FCR. Water stability is established by the farmers by placing a few feed pellets in a glass of water and establishing the condition of the pellets after 3 hours. If the pellets remain intact and do not disintegrate when the water is mildly stirred, it is considered as having good water stability. Farmers consider fishmeal to be one of the important ingredients in determining feed quality, and on receipt of a new batch of feed, the farmers smell the product to ascertain that it contains sufficient fishmeal. While this is not an accurate way to test the ingredient composition of the feed, it gives the farmers an idea of the quantity of fishmeal being used in the feed. Farmers reported that feeds with a good fishmeal odours provide good results in terms of growth and FCR.

The Marine Products Export Development Authority (MPEDA) has prescribed quality norms based on ingredient composition for shrimp feeds that can be sold in India (Table 4).

TABLE 4

Quality norms prescribed by the MPEDA for shrimp feeds sold in India (quantities stated as proportions of dry feed)

Proximate composition	**Starter**	**Grower**	**Finisher**
Crude protein (%)	40–45	30–35	30–35
Non-protein nitrogen (%)	<0.2	<0.2	<0.2
Crude lipid (%)	6–8	6–8	6–8
Crude fibre (%)	3–4	3–5	3–5
Digestible energy (10^3 calories/kg of feed)	3 200–3 600	3 200–3 600	3 200–3 600
Fatty acids			
Linoleic acid + linolenic acid (%)	0.5	0.5	0.5
Eicosapentenoic acid (EPA) + decosahexaenoic acid (DHA) (%)	0.5	0.5	0.5
Phospholipids (lecithin) (%)	1	0.4	0.4
Cholesterol (%)	0.5	0.2	0.2
Astaxanthin (ppm)	-	-	200
Essential amino acids			
Arginine (%)	2.03–2.32	1.74–2.03	1.74–2.03
Isoleucine (%)	1.225–1.4	1.05–1.225	1.05–1.225
Methionine (%)	0.84–0.96	0.72–0.84	0.72–0.84
Phenylalanine + tyrosine (%)	1.89–2.16	1.62–1.89	1.62–1.89
Phenylalanine (%)	1.4–1.6	1.2–1.4	1.2–1.4
Tryptophan (%)	0.28–0.32	0.24–0.28	0.24–0.28
Histidine (%)	0.735–0.84	0.63–0.735	0.63–0.735
Lysine (%)	1.855–2.12	1.59–1.855	1.59–1.855
Threonine (%)	1.26–1.44	1.08–1.26	1.08–1.26
Valine (%)	1.4–1.6	1.2–1.4	1.2–1.4

Source: MPEDA (2009).

3.2.4 Feed production

The aquafeed manufacturing industry has evolved significantly from the early 1990s, when small-scale shrimp feed manufacturers dominated the market. Prior to the white spot syndrome virus (WSSV) disease outbreaks in the mid-1990s, the market was dominated by small unorganized feed manufacturers. The sector comprised 30–40 feed mills that, in addition to producing shrimp feeds, also manufactured cattle and poultry feeds. During 1995–96, multinational companies, including CP, President, Gold Coin, and a few manufacturers from Taiwan Province of China, started importing feeds. From the mid-1990s, these feed manufacturers started developing large manufacturing plants that were dedicated to shrimp aquafeed production. Today, the feed produced from these plants dominates the market. India has 28 shrimp feed mills, both large and small, with an installed capacity of approximately 1 900 tonnes per day (Table 5) with a total installed production capacity exceeding 500 000 tonnes per year[2]. Out of these, six or seven manufacturers are manufacturing feeds in collaboration with overseas companies that provide technical assistance.

[2]Assumes >263 working days per year; normally there would be over 300.

TABLE 5

Distribution and installed capacity of shrimp feed manufacturing plants in India

State	Number of feed plants	Installed capacity (tonnes/day)
Andhra Pradesh	21	1 060
Tamil Nadu	6	720
Kerala	1	120
Total	28	1 900

Source: Suresh (2007).

3.2.5 Feed ingredients

The manufactured aquafeeds reported during the survey contain approximately 40 essential nutrients. About 20 to 40 percent of the ingredients used in commercial shrimp feeds are derived from marine capture fisheries, which include fishmeal, fish oil, shrimp/crustacean meal, squid meal and other miscellaneous products, such as fish, fish silage, fish/squid-liver meals and seaweed extracts (Table 6).

The principal classes of raw materials that are currently used in the shrimp aquafeeds can be classified as:

- Cereals and cereals by-products.
- Leguminous seeds.
- Vegetable oil residues.
- Animal by-products and oils.
- Miscellaneous ingredients, including vitamins and minerals.

TABLE 6

The key aquafeed ingredients used in the manufacture of shrimp feeds and their cost

Feed ingredient	Typical price	
	(INR/kg)	(US$/kg)
Fishmeal	51	1.10
Shrimp head meal/shrimp shell meal	27	0.58
Squid liver powder	280	6.05
Cod liver oil	33	0.71
Wheat flour	17	0.37
Wheat bran	13	0.28
De-oiled rice bran	8	0.17
Soybean meal	21	0.45
De-oiled groundnut cake	22	0.47
Cereals	12	0.26
Maize	12	0.26
Broken rice	11	0.24
Rape seed	15	0.32
Feed additives		
Soya lecithin	59	1.28
Cholesterol (95% pure)	2 311	50
Di-calcium phosphate	25	0.54
Vitamins and minerals	40	0.86
Lysine	127	2.75
Choline chloride	60	1.3
Antioxidant (ethoxyquin)	200	4.3
Binder – gluten	99	2.14

Notes: US$1.00 = INR 46.4 (2010 exchange rate).

Source: Field survey (2010).

In the past, feed manufacturers primarily depended on fishmeal imported from either Chile or Peru. Over the past few years, fishmeal produced in India is starting to be used by many feed manufacturers. With the assistance of the feed manufacturers, the quality of the locally produced fishmeal has been improved. Local fishmeal plants have invested in machinery, and are now producing good quality fishmeal with protein levels of up to 62 percent. Plant based ingredients, including soya flour, full fat soya and soya lecithin from India are also used. Various imported vitamins and minerals are added to the formulations.

3.2.6 Feed selection and availability

The respondents reported a number of factors that affected their choice of feed. The key factors included:

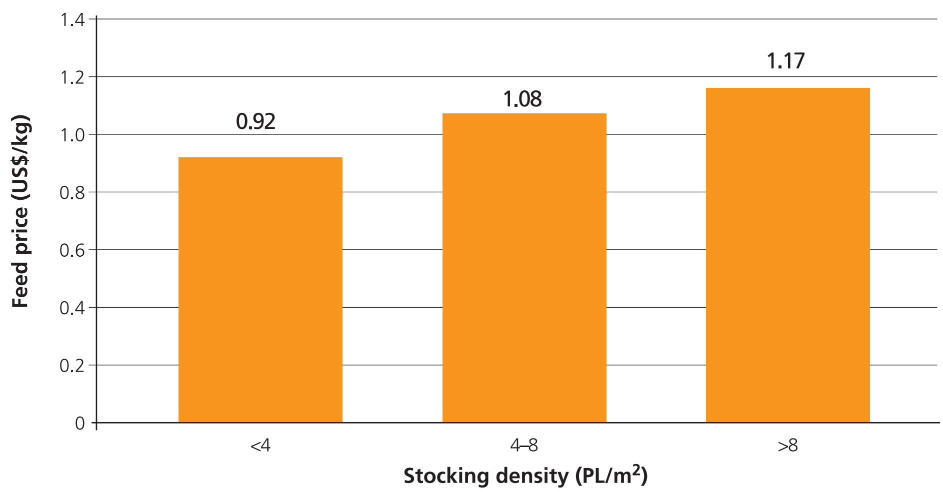
- Feed quality
- Previous experience of using the feed
- Feed price
- Reputation of feed manufacturer
- Availability of the feed
- After-sales service
- The opinion of neighbouring farmers

A network of local feed dealers ensures the availability of commercially manufactured aquafeeds throughout all the farming areas. All the major feed manufacturers supply feed to a network of feed dealers who buy feed in bulk from the factories. The dealers are either leading farmers in the area or private entrepreneurs (traders) who sell the feeds to the local farmers. The dealers usually maintain large feed stores from where the feed is distributed to the farmers. These dealers are located in towns close to the farming areas, and within a 10 to 20 kilometre distance from the farms. In some cases, where there is substantial farming activity taking place, they may also be located in villages.

3.2.7 Feed prices and financing arrangements

The price of pelleted feed ranges from US$0.5/kg to US$1.25/kg. The average unit price of the feeds used in extensive, modified extensive and semi-intensive farms are US$0.92, US$1.08/kg and US$1.17/kg, respectively (Figure 5). The feed cost in modified extensive farms contributes 57.5 percent of the total production cost while it is 65.5 percent in the semi-intensive farms (see Table 13).

FIGURE 5
Unit price of shrimp feeds used at different stocking densities



Source: Field survey (2010).

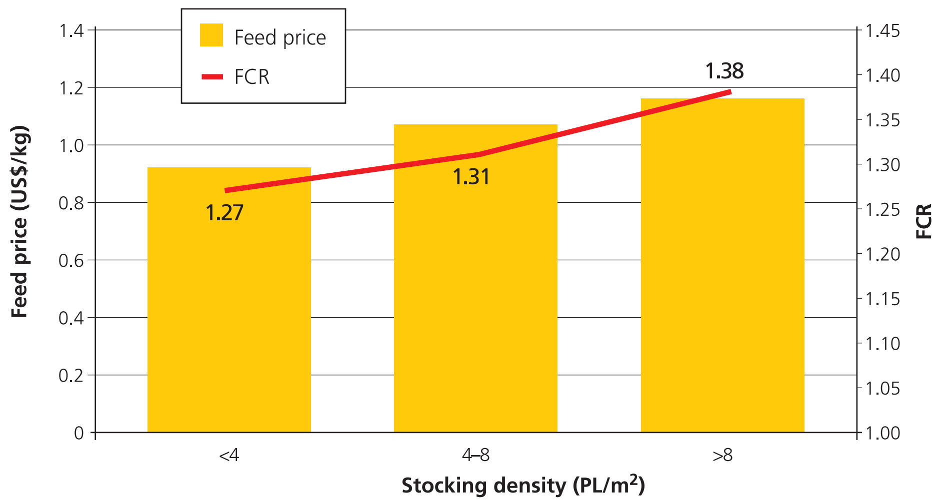
The feed price varies depending on the percentage of protein in the feed (Table 7) and the reputation of the feed manufacturer. A comparison of the average FCR and feed prices of the formulations used at different stocking densities (Figure 6) demonstrates that with an increase in stocking density there is an increase in both FCR and feed price. Many farmers prefer to keep production costs low, and by using low inputs in low stocking density systems they can use low protein feeds. In these systems, natural pond productivity assists in maintaining acceptable FCR.

TABLE 7
Average prices of feed containing different protein levels (data sourced from different feed manufacturers)

Protein content (%)	Average feed cost	
	INR/kg	US$/kg
30	30.50	0.64
32	30.67	0.64
36	51.83	1.09
38	54.68	1.15
40	49.40	1.04
42	54.75	1.15
44	62.00	1.30

Source: Field survey (2010).

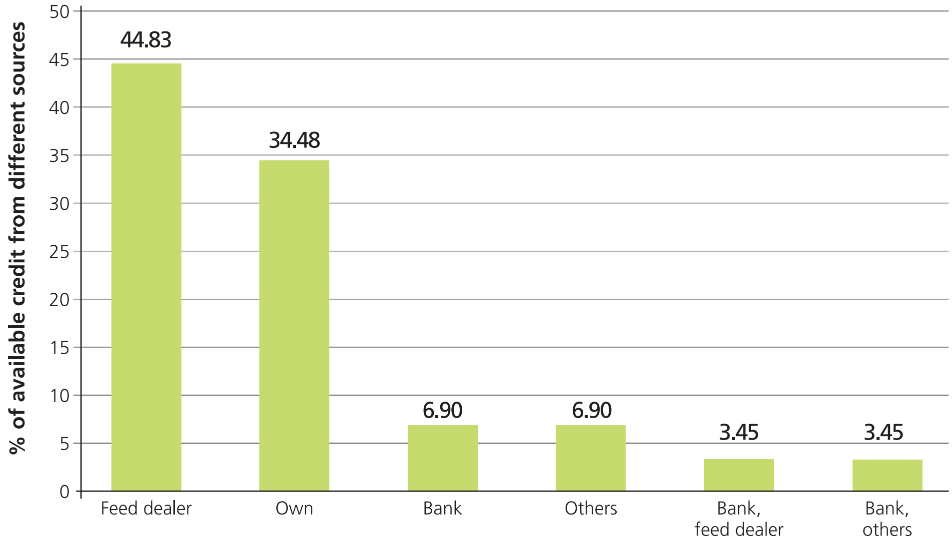
FIGURE 6
Average FCR and prices of feeds used at different stocking densities



Source: Field survey (2010).

Of the farmers surveyed, 45 percent purchase feed on credit from the feed dealers, 34 percent invest their personal savings, and the rest obtain their capital from banks and other financial institutions (Figure 7). Farmers have to pay the Maximum Retail Price (MRP) that is set by the feed manufacturers for those feeds that are purchased on credit. For those farmers who purchase with cash, the cost of the feed is reduced by 10 to 15 percent – depending on the quantity that the farmers purchase.

FIGURE 7
Available credit sources for shrimp farming in India



Source: Field survey (2010).

3.2.8 Feed transportation and storage

Farmers who purchase their feeds in bulk from feed dealers take responsibility for its transport to their farms. This is achieved by either hiring a truck or an auto rickshaw (small three-wheeler vehicle) (Figure 8). Small farmers who buy one or two feed bags at a time transport the feed on a bicycle/motorcycle (Figure 8). Farmers purchase enough feed to last for one or two weeks, and replenish the feed stock as and when required. Feed is stored in feed stores. Small farmers who do not have feed storage facilities at the farm site store their feed in their homes (Figure 9). Feed transportation and distribution is schematically presented in Figure 10.

FIGURE 8
Transportation of feed by an auto rickshaw (left) and motorcycle (right)

FIGURE 9

Storage of aquafeed: feed store of a feed dealer (left) and feed storage at the farm site (right)

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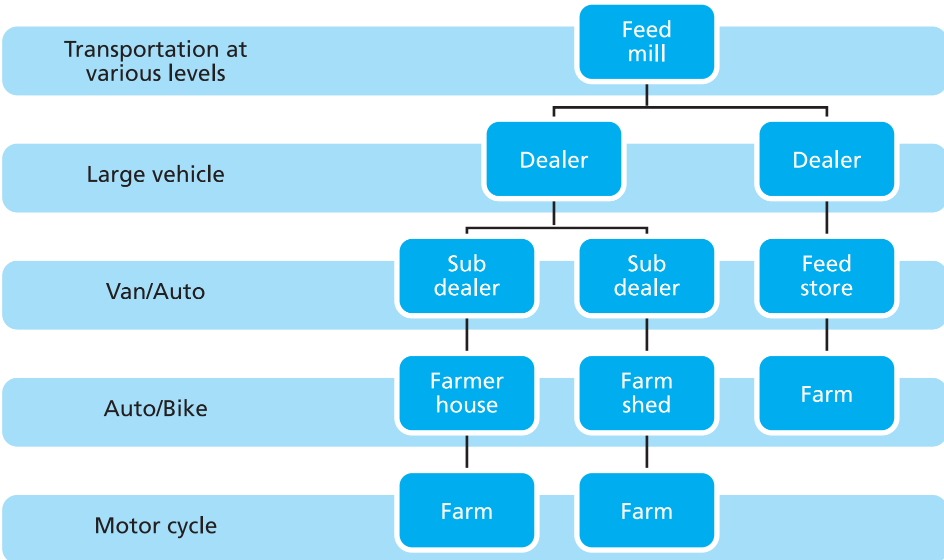
FIGURE 10

Schematic representation of feed transportation and distribution



Source: Field survey (2010).

3.2.9 *Feed management practices*

Successful shrimp farming is dependent on providing both good nutrition and maintaining good feed management practices. Feed management strategies must take into consideration several parameters, including the physiological processes that affect feed intake and digestion. They should be designed such that they promote optimal growth, feed conversion, reduce pollution and ultimately minimize feed costs (Molina, 2009).

The optimal feeding rate and frequency are determined at each farm and for different feeds by testing and comparing results in growth, survival and feed efficiency trials over several growth cycles. Farmers calculate feed rations based on the population size and biomass, survival estimates and the size distribution of the culture stock. Shrimp are benthic feeders, and it is difficult to estimate feed consumption rates unless check trays are used. Trays are currently one of the common options used by farmers to manage and adjust feed rations and prevent under- and over-feeding. Thirty days after stocking, farmers use feeding trays to monitor feed consumption. These enable them to adjust the daily ration according to apparent feed consumption. In addition, it allows for a quick health status check. Two to four check trays are installed in each pond for monitoring animal health and feed intake. The observations that are critical to the effective use of the check trays include the amount of feed remaining after the feed round, the number of shrimp on the tray, and the size of the shrimp. A standard feed table is applied to feed management. Under this system the rations are based on the size of the shrimp that are recorded during the weekly sampling. The amount of feed in that is placed in the check tray is based on a standard table (Table 8) or the experience of the farmer. The check tray factor provides an indication of the percentage of the ration that should be placed in the check tray for the following feeding. For example, if 10 kg of feed is the calculated amount to be fed to shrimp (with a mean weight of 10 g), and the amount remaining on the check tray from the previous feeding is 2.2 per cent (Table 8), the actual amount to be placed in the tray at the next feeding time should be reduced by 2.2 percent, namely to 9.78 kg (Figure 11). This amount would be divided evenly between all of the trays in the pond. The checking period provides an indication of the number of hours after feeding when the trays should be inspected. As the shrimp grow in size and the amount of feed required increases, the time delay between feeding and tray inspection is reduced from 2 hours post-feeding to 1½ hours (Figure 12).

Check trays are circular or rectangular and are made of iron/steel or PVC, and cost about US$2.50 to US$5.00. They are used after one month of stocking and placed on the bottom of the ponds in at least two to four locations, and between 3 to 4 m from the levees. In most cases catwalks are constructed to allow access to the check trays. From 45 days of onwards, the quantity of uneaten feed remaining on these trays is used to calculate the feed rations, as indicated in the previous paragraph. In ponds that have variable cohorts of shrimp at various sizes, farmers mix pellet sizes to ensure that all of the shrimp have access to the feed – if the feed is too big, the smaller shrimp may not be able to feed optimally and their growth rate will be reduced.

TABLE 8

Feeding regime for shrimp farming

Age (days)	Mean body weight (g)	Feed given per day (% of total shrimp biomass)	% feed remaining in check trays	Time of check tray observation after feeding (hours)
1–20	PL15–1.0	20.0–5.0		
20–35	1.0–4.0	5.0–4.0		
35–50	4–6	6.0–5.0		
50–55	6–7	5.0–4.5	2.0	2.0
55–60	7–8	4.8–4.2	2.0	2.0
60–65	8–9	4.2–4.0	2.1	2.0
65–70	9–11	4.0–3.8	2.2	2.0
70–80	11–14	3.8–3.6	2.3	1.45
80–90	14–17	3.6–3.3	2.4	1.45
90–100	17–21	3.3–3.0	2.5	1.45
100–110	21–25	3.0–2.5	2.7	1.30
110–120	25–30	2.5–2.1	3.0	1.30
120–130	30–36	2.1–1.6	3.5	1.30
130–140	36–43	1.6–1.5	4.0	1.20
140–150	43–50	1.5–1.4	4.5	1.15

Source: Field survey (2010).

FIGURE 11
Weighing feed rations and samples of feed (green bottles) for placing on the feed trays

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FIGURE 12
A farmer monitoring a feed tray

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Farmers keep complete records of the quantity of feeds applied to each pond. Shrimp are sampled every week after 45 days of culture. Cast nets are used to provide biomass estimates, which are used to adjust feeding rates. Farmers also check the pond bottom for deterioration. A deterioration in pond bottom condition (a blackening of the soil, hydrogen sulphide or ammonia production) could signify excess feeding. In such cases, farmers recheck and adjust the feeding rates accordingly.

The feed rations are adjusted daily, with minor adjustments between feeds that are dependent upon the consumption rates of the shrimp. This practice minimizes feed wastage. As shrimp are effectively scavengers, the most effective way to feed shrimp is to provide small amounts of feed frequently. The number of feed rounds per day is a trade-off between the optimal number of feedings that is ideal for the shrimp, and the labour (and hence cost) of providing these feed rounds. Farmers develop their feeding schedules based on the stocking density and number of days the shrimp have been stocked. During the initial 30 days post-stocking, feed is provided two to three times a day. This is increased to four to five times a day in subsequent months. From 30 days post-stocking, feed rations are adjusted. Ration adjustments are based on feed tray observations and cast net sampling.

The feed ration is roughly divided into four feeds a day of 25 percent, 25 percent, 20 percent and 30 percent, presented at 06.00 hours, 12.00 hours, 1600 hours and 21.00 hours, respectively. At low stocking densities (<4 PL/m^2) the feeding frequency ranges from two to three times a day (Table 9). At stocking densities of more than 4 PL/m^2, the feeding frequency ranges from three times a day for the first 60 days of the culture cycle to five times a day between days 91 and 120. Feed is distributed either by broadcasting (Figure 13) from the pond levee or by using polystyrene floats.

TABLE 9
The feeding schedule used by farmers in study ponds

Culture period (days)	Stocking density (PL/m²)	
	<4	>4
	Feeding frequency (times per day)	
1 to 30	2	3
31 to 60	2	3
61 to 90	3	4
91 to 120	3	5

Source: Field survey (2010).

Inefficient feed management practices commonly include inadequate handling and storage practices at farms – such as storing the feed in a metal container under hot conditions, feed spillage in the stores, and wastage of feed while feeding, particularly when inexperienced workers are used. Ineffective practices often include applying feed at times that are convenient to the farmer (during daylight hours), but not necessarily the optimal feeding time for the shrimp, feeding very close to the levees, and over-feeding as a result of over-estimating survival rates.

FIGURE 13
Feeding by broadcasting from pond levee during first month of rearing

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3.2.10 Feed additives

Seventy-five percent of the respondents reported using probiotics and feed additives. The use of these additives was dependent upon stocking densities (Table 10). There is an increase in the use of probiotics and feed additives as the stocking densities increased. No feed additives were used at stocking densities lower than 3-4 PL/m².

TABLE 10
Use and type of feed additives at different stocking densities

Stocking density (PL/m²)	Probiotics/feed additives used	% of ponds in the study
3–4	No feed additives	26.3
5	Feed probiotics	5.1
6	Feed probiotics, vitamin C	11.6
7	Feed probiotics, cod liver oil	13.5
8	Feed probiotics	4.1
9	Feed probiotics, yeast	12.5
10	Feed probiotics, vitamin C	11.6
11	Feed probiotics, vitamin C	15.3

Source: Field survey (2010).

3.2.11 Pellet size

Pellet size is based on the size of the shrimp. Generally, during the first month, a starter feed (0.4 to 1.4 mm crumble) is used. When shrimp reach 4–5 g, the feed is changed to pellets (1.8–2.3 mm diameter). Finisher feed (2.3 mm diameter) is used towards the end of the rearing period when the shrimp reach >20 g. The protein content and feed price varies according to the type of feed (Table 11).

TABLE 11

Specifications and price range of shrimp feeds manufactured in India

Feed class	Shrimp size (g)	Feed type	Feed size (mm diameter)	Crude protein (%)	Price (US$/tonne)
Starter	0.5–5	Crumble, short cut pellets	0.4–1.8	40–44	1 066–1 450
Grower	5–20	Pellets	1.8–2.3	38–40	959–1 429
Finisher	>20	Pellets	2.3	36–38	853–1 407

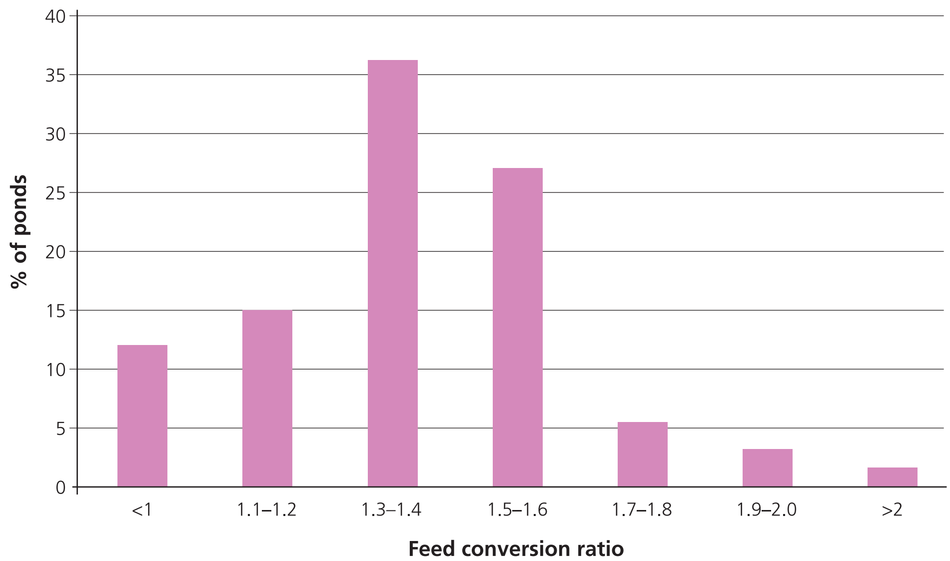
Source: Field survey (2010).

3.2.12 Feed conversion ratios (FCR)

All the study farms used commercially produced aquafeeds during the production cycle. These feeds were produced by 9 different manufacturers. Reported FCR ranged from <1:1 to 2.7:1 (Figure 14). The variability was attributed to different production conditions, feed management practices, and production protocols. An FCR below 1.5:1 is considered good by the farmers. About 63 percent of the ponds included in the survey were reported to achieve FCR ranging from 1.2:1 to 1.6:1 (Figure 14) but 1.6 percent had FCR of more than 2:1.

FIGURE 14

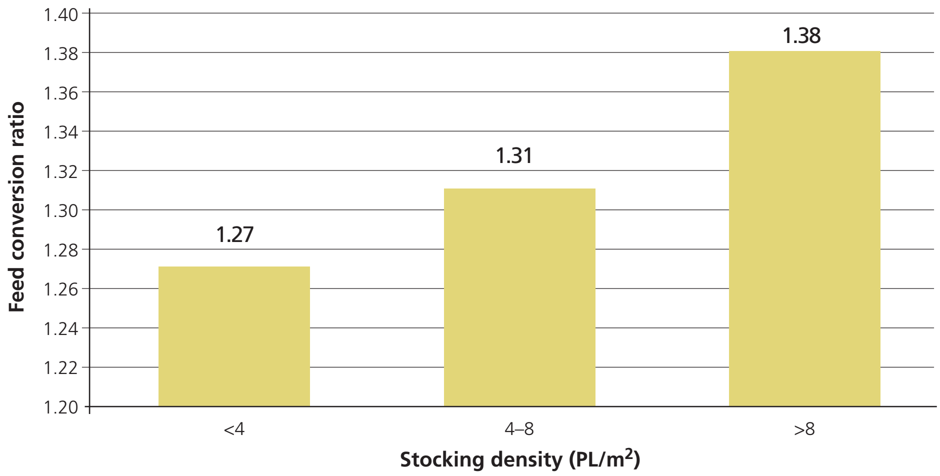
Percentage of variation in FCR in study ponds



Source: Field survey (2010).

With respect to stocking densities, the lowest FCR were observed at stocking densities below 4 PL/m^2 (FCR: 1.27:1, Figure 15). At stocking densities of 4–8 PL/m^2, the mean FCR was 1.31:1, and at 8 PL/m^2, the mean FCR was 1.38:1.

FIGURE 15
Variation in mean FCR in study ponds



Source: Field survey (2010).

3.2.13 Productivity

The survey revealed that the yields attained using the extensive farming systems ranged between 146 and 510 kg/ha/crop (Table 12). In modified extensive farming systems, they ranged from 870 to 1 656 kg/ha/crop. The yield in the semi-intensive farming systems ranged from 1 783–4 178 kg/ha/crop. In traditional farms (*Bheris*), yields ranged from 200–350 kg/ha during the crop period, with an average size range of 30–40 g shrimp being produced. Finfish are also harvested throughout the crop period in these *Bheri* systems.

TABLE 12
Stocking density and average yield per hectare

Stocking density (PL/m²)	Mean level of production (kg/ha/crop)
Extensive farming system	
1	145.7
2	488.9
3	510.3
Modified extensive farming system	
4	870.7
5	1 349.3
6	1 424.2
7	1 655.6
Semi-intensive farming system	
8	1 783.3
9	2 518.4
10	2 729.6
11	3 186.0
12	3 279.4
13	2 908.3
14	3 409.1
15	1 516.0
17	4 177.8

Source: Field survey (2010).

3.2.14 Cost-benefit analysis

Shrimp farming depends largely upon the use of commercially formulated high-energy feeds. Commercially produced pelleted feeds are provided in most of the extensive farms (<40 000 PL/m^2), all of the modified extensive farms (40 000–80 000 PL/m^2) and all of the semi-intensive farms (>80 000 PL/m^2); feed comprises 47.7 percent, 57.5 percent and 65.6 percent of the total operational costs respectively (Table 13). The second highest expense is for the fuel/energy that is required for pumping, pond filling, water exchange and aeration. The fuel/energy cost per unit of shrimp produced in extensive, modified extensive and semi-intensive farms are US$0.54/kg, US$0.56/kg and US$0.36/kg, respectively. The total expenditure was lowest in the modified extensive system (US$3.53/kg), while it was US$3.54/kg and US$3.89/kg in extensive and semi-intensive farming systems respectively. The profit margin per kilogram of shrimp production was highest at US$1.58/kg in the extensive farming system, followed by the modified extensive system (US$1.11/kg). The lowest profit margin was in semi-intensive farming system (US$0.53/kg).

TABLE 13
Summary of average production costs (US$/kg shrimp produced) at different stocking densities

		Stocking density (number/ha)		
	Totals	**<40 000**	**40 000–80 000**	**>80 000**
No. of ponds	183	59	68	56
Pre-stocking				
Pond preparation (drying + sludge removal + ploughing)	0.17	0.28	0.17	0.14
First water filling	0.06	0.11	0.07	0.05
Total pre-stocking expenses	0.23	0.39	0.24	0.19
Seed (including PCR and transportation)	0.44	0.62	0.35	0.41
Post-stocking				
Feed	2.37	1.69	2.03	2.55
Water exchange	0.33	0.39	0.42	0.15
Aeration	0.12	0.04	0.07	0.16
Feed additives	0.06	0.05	0.04	0.08
Chemicals	0.17	0.08	0.17	0.18
Agri lime	0.10	0.14	0.11	0.08
Total post-stocking expenses	3.15	2.39	2.84	3.20
Others				
a. Labour	0.09	0.13	0.09	0.08
b. Miscellaneous	0.01	0.01	0.01	0.01
Total other expenses	0.10	0.14	0.10	0.09
Total expenditure	3.92	3.54	3.53	3.89
Revenue	4.50	5.12	4.64	4.42
Profit	0.58	1.58	1.11	0.53

Source: Field survey (2010).

4. DISCUSSION

A feed management plan is designed to maximize growth, survival, total production and mean animal size, optimize feed conversion ratios (FCR), and minimize environmental impacts. More specific goals include providing the animals with a feed of the highest quality in the most cost-efficient way, and supporting the highest growth and production possible (Jory *et al.,* 2001). Farmers monitor and continuously adjust their feed rations according to changes in consumption rates that are caused by environmental variables, and the moulting cycle of the shrimp. Farmers always aim to minimize overfeeding, and its concomitant negative effect on production costs and the culture environment.

4.1 Feed selection

The modified extensive and semi-intensive farmers overwhelmingly indicated that they prefer to use manufactured feeds. The economics of using manufactured feeds combined with the low levels of pollution associated with their use and the concomitant reduction in costs associated with maintaining water quality, managing disease, and facilitating higher stocking densities and yields were seen as key advantages of their use. In addition, using these feeds also leads to a reduction in labour costs in terms of feed procurement, storage, preparation and administration.

Farmers select their formulated feeds to meet several criteria, including pellet size, uniformity of appearance, physical integrity, density, moisture, protein and lipid content, water stability, appearance and smell. The feed must fulfil the known nutritional requirements of the target species, be fresh and free of mycotoxins and pesticides, and have a low pollution potential. The feed should have attractants (natural or synthetic) to improve feed palatability and stimulate consumption (ASEAN, 2005). The feed must be water- stable, minimizing nutrient losses and wastage. Poor quality aquafeeds may leach nutrients rapidly after immersion, and thus it is important that feeds remain attractive to the target animal and maintain their form after immersion in water – this will maximise consumption rates, nutrient ingestion, and minimize wastage (Jory *et al.,* 2001).

When assessing the quality of their feeds, the farmers surveyed used the following criteria:

- ***Feed quality:*** Feed quality is the key criteria on which farmers make their purchasing decisions (pellet size, uniformity of appearance, physical integrity water, stability and smell).
- ***Previous experience:*** Farmers select their feeds based on their previous experiences and the resultant crop.
- ***Feed price:*** Extensive farmers tend to select lower protein (30 to 34 percent CP) low-cost feeds (US$0.63/kg). In contrast, the semi intensive farmers tend to select higher protein (36 to 40 percent CP), higher quality, more expensive feeds (US$1.05/kg).
- ***The reputation of feed manufacturer:*** The reputation of the feed manufacturer for supplying good quality feed consistently is an important consideration. Farmers cited examples where some manufacturers supplied good quality feed during the initial days of launching the feed. However, latterly there was a decline in its quality, which was reflected in poor growth and FCR. Farmers tend to experiment with different feeds from different manufacturers, and finally settle for one feed type that promotes good growth and an economical FCR.
- ***Availability of the feed:*** Feeds must be available to the farmers, and supply shortages result in farmers switching to alternative feeds.
- ***The opinions of other farmers:*** The farmers who are new to shrimp farming tend to take advice from neighbouring farmers about their experience with different feeds; they often decide which feed to use in their farms based on this information.

Farmers do not usually change feeds unless they encounter problems, such as poor growth rates, poor water stability or increased feed costs.

4.2 Feed cost and finance

Of the farmers surveyed, only 42 percent purchased their feed by paying cash. The others purchased their feed on credit. At present, there are no financial institutions that support the shrimp farmers. Access to institutional finance can reduce feed costs by 10 to 15 percent, and providing appropriate financial services is an area that needs to be addressed by the authorities. In many cases, farmers purchasing feed on credit are linked into buy-back agreements for their shrimp. In such cases, the farmers cannot sell the shrimp directly to processors/exporters, resulting in lower prices to the farmers.

The average feed price increases as the stocking density increase. This increase in price is related to the increase in the feed protein content as the density increases, which varies from 30 to 44 percent. The highest protein formulations are used during the first month of the production cycle, and the crop is subsequently changed onto to lower protein formulations. Those ponds that are fed with high protein feed during the initial stages of the culture period elicited good FCR, even when the percent protein decreased during last month of the grow-out phase. Those ponds which were fed with low protein formulations during the initial phase exhibited comparatively poorer FCR.

4.3 Feed transportation and storage

Appropriate feed handling and storage have immediate and significant consequences for shrimp production. The poor storage and handling of feeds results in product deterioration, increased fines, reduced feed attractability and palatability, possible nutritional deficiencies and disease outbreaks, and reduced growth rates and production (Jory *et al.,* 2001). Feed transportation employs a network of feed dealers who source the feed directly from the feed manufacturers in trucks, and store them in their warehouses. These warehouses are not air-conditioned.

4.4 Feed additives

In addition to the nutrients provided in the feed, farmers frequently top-dress their feeds with vitamins, minerals, immunostimulants, fish oil, probiotic bacteria and yeast, vitamin C and egg albumin. These feed additives are perceived by the farmers to be feed attractants and growth promoters (Hasan *et al.,* 2007). While some farmers top-dress all the feed that they use, many farmers top-dress their feeds only during specific phases of the culture period, when they feel that shrimp growth rates are slowing down or the culture environment is becoming unfavourable. No evaluation of the efficacy of top-dressing has been undertaken. Nevertheless, some preliminary investigations reveal that most water-soluble vitamins and minerals are lost when they are applied to the feeds. The study demonstrated that top-dressing typically increased feed costs by US$39/tonne.

4.5 Feed management and optimizing feed conversion ratios

Feed management is a critical aspect for cost-efficient, environmentally responsible shrimp production. Appropriate feed management practices maximize shrimp growth and survival, while reducing feed inputs and minimizing effluent streams. Poor feed management will lead to sub-optimal production, may promote the onset of various diseases and water quality related problems, and may adversely affect production (Jory *et al.,* 2001). During the 1990s, farmers generally fed during the night; shrimp tend to be most active then, showing peaks in feeding behaviour during the night and just before sunrise (Jory *et al.,* 2001) At high survival rates or when the biomass of the shrimp in the pond is high, these authors found that it was less important to feed at night, and thus many farmers started feeding at similar levels throughout the day.

Shrimp ponds are complex environments, where feed input is just one of the factors affecting yields. The generation of natural feeds through fertilizer use and the enhancement of natural pond productivity is of greater production importance at low stocking densities. Under semi-intensive culture, most, if not all, of the nutrients required for growth must be provided by formulated feeds. An important reason for the good FCR reported in this study is the promotion of beneficial bacteria in their culture ponds. Beneficial *in-situ* bacterial populations are promoted by regular mild stirring of the pond bottom using iron chains to suspend the organic matter. This is followed by the addition of a carbon source (molasses or a fermented mixture of molasses, rice powder and yeast) at 50 litres per ha to increase the C : N ratio in the pond. This practice is repeated every week after one month from stocking; it is economical and found to be useful in extensive and modified extensive farms (<8 PL/m^2). This observaion is supported by the trend of increasing FCR with increasing stocking density. Semi-intensive farms (>8 PL/m^2) tend to use commercially available probiotic preparations, which are supplied by the feed manufacturers and other retailers. This shift towards the promotion of heterotrophic bacteria in all three kinds of shrimp ponds could be one of the reasons why the farmers in the study ponds attained good FCR.

The FCR reported in this study demonstrate the positive impact of promoting better management practices in the sector. It was evident that with the use of good quality feeds and good feed management practices, FCR of 1.2:1 to 1.4:1 can be achieved. By improving feed management practices further, there would be scope to further reduce the FCR in extensive farms to below 1.2:1, and in modified-extensive and semi-intensive farms to below 1.4:1.

As feed intake patterns and consumption rates for shrimp vary under different agro-climatic conditions, a site-specific standardized feeding programme is essential for effective feed management. From the current study it is evident that both feed quality and feed management practices play an important role in governing production and feed conversion efficiencies, as well as minimizing pond bottom and water quality deterioration due to over- or under-feeding. Ration sizes need to take into consideration the environmental status of the pond waters, which varies on a seasonal basis, and the biomass in the pond. Maximum benefits from supplemental feeding can only achieved if the diet is ingested in its entirety, and supplied at a rate that is compatible with the quantity and quality of natural food available in the pond (Hasan *et al.,* 2007).

4.6 Development trends

The following developmental trends were observed in this study:

- An increase in the use of high quality seed and SPF seed from improved broodstock resources.
- An improvement in the sustainable, effective, and optimal use of water resources.
- A trend towards intensification.
- The application of Better Management Practices (BMP) to reduce the cost of production, and to fulfil the market requirement through organized farmer groups.

4.6.1 Stocking high quality seed and SPF seed from improved broodstock resources

The excessive reliance on wild broodstock poses problems in terms of the sustainability of the natural resource and ecosystem function. Moreover, the procurement of wild broodstock is becoming commercially unsustainable as increasing numbers of consumers from developed countries insist that their shrimp supply is derived from sustainable sources. In the coming years, the market will likely require that seed be obtained from domesticated Specific Pathogen Free (SPF) stock. The use of wild broodstock also poses serious risks for vertical disease transmission from the breeders to the offspring, and it is for this reason that viral diseases must be controlled at the broodstock level (Hoa, 2009). Indian shrimp hatcheries are totally dependent upon wild-caught gravid females. The high infection rates of the wild-caught broodstock with pathogenic viruses and bacteria lead to poor quality seed, diseases and stock losses in the hatcheries and farms. In India, data has shown that unhealthy and infected PL lead to frequent crop failures, with estimated losses of up to US$110–220 million per annum (FAO, 2007).

The availability and supply of high quality broodstock is vital to successful shrimp hatchery operations, and the production of high quality PL that can support the grow-out sector. With the emergence of a series of serious shrimp pathogens, disease-free wild broodstock have become rare around the Indian coast and across all other Asian countries. As a result, extreme care must be given to the collection, transportation, handling and maintenance of broodstock that are free of these pathogens, and to the biosecurity of the hatchery produced PL.

Disease free, good quality seed is the key to sustainable *P. monodon* aquaculture. Many countries in Asia are attempting to supply their farmers with SPF seed. Several research institutes and private companies have been involved in these developments. These include Aquacop in Tahiti (French Polynesia), the Southeast Asian Fisheries Development Center (SEAFDEC) in the Philippines, the National Center for Genetic Engineering and Biotechnology in Thailand, the Department of Fisheries of Malaysia, a commercial programme by a French group at Aqualma from Madagascar, a research programme by the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia, and a commercial project by Moana Technologies Inc, which was founded in Belgium and operates from Hawaii (Hoa, 2009).

The successful domestication of black tiger shrimp will ensure that sufficient quantities of good quality broodstock are available and, as a consequence, reliable seed production will be possible. Recently an Australian company reported that after eight generations of selective breeding, the Commonwealth Scientific and Industrial Research Organization (CSIRO) scientists and the Australian aquaculture industry have bred black tiger shrimp that produce record yields. One of the CSIRO partners, Gold Coast Marine Aquaculture, produced average yields of 17.5 tonnes per hectare, more than double the industry average. Several ponds produced 20 tonnes/ha and one produced a record yield of 24.2 tonnes/ha (www.seafoodsource.com).

In 2008, an agreement was signed between the National Fisheries Development Board of India and M/S Moana Technologies, Hong Kong to produce and supply genetically improved SPF shrimp. At full capacity, it is anticipated that the programme will produce approximately three billion PL per annum. This programme heralds a new approach to quality seed management, enhanced productivity and profitability in Indian aquaculture. Similarly, the Rajiv Gandhi Centre for Aquaculture (RGCA) of MPEDA is running a project in Andaman to produce SPF seed; this programme is expected to begin producing results by 2013.

The development of reliable domesticated broodstock to produce high quality and SPF seed represents an important development in the long-term sustainable development of *P. monodon* aquaculture. It will also assist in protecting natural resources of wild black tiger shrimp from over-fishing.

4.6.2 Sustainable, effective, optimal use of water resources

Production technologies are improving and systems requiring less water exchange are being adopted by the farmers. These systems require increased aeration, and improved water quality management that enhance beneficial bacteria in the ponds. To reduce input waters, minimal water exchange is now the preferred option. This reduces the risks associated with disease introduction and improves biosecurity at the farm level.

The system involves filling the pond with screened and chlorinated brackishwater/seawater. The shrimp are stocked and cultured for a period 120 days, attaining an average weight of 25–30 g. The system does not depend on frequent water exchange but simply maintains the water level in the pond by replacing water losses due to evaporation and seepage with screened/chlorinated seawater or brackishwater. Water exchange is only carried out in the event that water quality deteriorates, and when there are no disease outbreaks in the vicinity of the farm. In addition, ponds are being made deeper to increase their production capacities. Farmers are also reducing their use of antibiotics and chemicals, and are shifting their focus towards probiotic culture.

This trend towards increased intensification and productivity means that extensive and modified extensive farms are increasingly being converted to semi-intensive farms. The increased intensification requires well designed grow-out facilities. Typically, ponds are much smaller (0.1 to 1.0 ha) with increased depths (1.5-2.0 m). Water exchange is limited and stocking densities range from 100 000 to >200 000 PL per hectare. It is possible to produce two crops per year with output levels of 3–5 tonnes/ha/crop. Nutritionally complete artificial feeds, increased aeration and intensive monitoring are required for this type of farming system.

4.6.3 The adoption of farmer groups and the application of better management plans (BMP) and good aquaculture practices (GAP)

Small-scale shrimp farmers in India, Indonesia, Bangladesh and Viet Nam are increasingly becoming organised into groups or clusters. These promote economies of scale through collective bargaining, and their members have access to BMP/GAP that are designed to improve feed management. Grouping and clustering farmers is also used to encourage the farmers to address market requirements and gain access to international markets. This is often achieved through the promotion of private standards for food safety and quality, animal health, environmental sustainability and social responsibility, and the adoption of eco-labelling. The certification of shrimp aquaculture may become the norm in the very near future. Under such a scenario, the farmer groups will be able to attain cluster certification through the implementation of GAP and Internal Control Systems (ICS) which will reduce the costs of certification and help them meet future market requirements.

4.7 Key issues and recommendations

The major constraint to the use of commercially manufactured aquafeeds is their high cost. The increasing trend in feed prices is not reflected in increasing crop value, and thus the profits from many farming operations are increasingly being eroded. To remain profitable, feed utilization needs to become more efficient and, wherever possible, cheaper feeds will have to be adopted. To ensure the long term sustainability of the sector, there are five focus areas that require attention. These comprise:

- Improved capacity building and management through the clustering of small-scale shrimp farmers.
- The promotion of 'on-farm feed management practices'.
- A reduction in feed and feed ingredient costs.
- Ensuring that research is effectively translated into commercial realities.
- Improvements in the policy and regulatory environment

4.7.1 Improved capacity building and management through the clustering of small-scale shrimp farmers

While large scale farming operations have a high degree of control over input costs, smaller operations lack the critical mass required to exercise any meaningful degree of control over them. The relatively high input costs associated with small-scale farming activities inherently increase the financial risks associated with the farming operations.

This risk can be reduced if farms are clustered or if farmers organize themselves into groups (Hasan *et al.,* 2007). It should be recognized that the majority of the farmers operate at the household level and have relatively limited education, and thus the transfer of complex technical messages is problematic and requires continuous attention (Hasan *et al.,* 2007). As a component of a farmer level capacity building programme, NaCSA (National Centre for Sustainable Aquaculture) in India has facilitated the organisation of 16 760 small-scale shrimp farmers into 772 registered aquaculture societies (NaCSA, 2011). Each society comprises a group of 20 to 30 farmers in a farming cluster. This has enabled farmers to access information more effectively, and promotes training within the group.

4.7.2 Promotion of 'on-farm feed management practices'

There is a need to promote improved farm management practices, including the efficient use of feeds. The industry is developing rapidly and farmers need to keep abreast of new technologies and developments. Failure to do so will lead to greater inefficiencies (Hasan *et al.,* 2007). Farmer clusters provide a good opportunity for the rapid and efficient dissemination of good on-farm feed management practices; these in turn help to reduce production costs. Feed management guidelines for shrimp have been developed by NaCSA (NaCSA/MPEDA, 2013) and are outlined in Annex 1.

Black tiger shrimp culture is moving towards further intensification, and formulated feeds will play an increasingly important role in the long-term sustainability of the sector. Detailed studies are required to establish current feed utilisation and management practices in all the shrimp culture systems, and to develop recommendations to improve feed utilization and management practices. In addition, shrimp feeds are made of highly perishable ingredients, and it is important that farmers are taught to handle and store them appropriately.

4.7.3 Efforts to reduce the cost of feed and feed ingredients

The primary and immediate goal should be to address the high costs associated with shrimp feeds. This can be achieved by focusing on the following issues:

- The nutritive value of locally available ingredients such as soybean meal, fishmeal, fish oil and shrimp meal could be improved by upgrading local manufacturing processes. Policy-level initiatives such as providing technological assistance and incentives for ingredient processors could assist in this process.
- Feeds and feeding strategies based on feed ingredient sources from agriculture and fishery by-products/wastes need to be developed (Hasan, 2001).
- Access to finance – a significant constraint to small- and medium-scale farmers in managing the cost of feed and the lack of affordable credit. Efforts to improve access to credit should be made by the central and state government agencies.
- Improvements to traceability protocols within the shrimp production cycle need to be made. These interventions should also be included in feed manufacturing processes.
- Fishmeal replacements need to be included in shrimp feeds – Asia is a net importer and the largest global user of fishmeal and fish oil. It is therefore not immune to global issues in respect of fishmeal and fish oil use in aquafeeds. Although many studies have been undertaken to identify dietary protein sources that can act as fishmeal replacements, the results are rarely translated into practice, and there is a need to establish an effective dialogue between researchers and the feed industry. Throughout the region there are growing concerns with regard to feed quality, and consequently suitable guidelines and certification processes need to be introduced (De Silva and Hasan, 2007).
- It is likely that the formulations used in the commercial production of shrimp feeds have higher nutrient inclusion levels than required – especially those

feeds used in extensive and modified extensive systems. The results of the study demonstrate that there is little difference in the protein content of feeds used at stocking densities of 4 to 8 PL/m^2 and >8 PL/m^2. There is a need to reduce feed costs at lower stocking densities by reducing the protein and other nutrient levels, and increasing the nutritional contribution from natural food productivity.

- There is a need to study the impact of storing feed in air-conditioned or non air-conditioned stores, and to determine how storage conditions affect shrimp growth, FCR and other production indices.

4.7.4 Ensuring that research is effectively translated into commercial realities

There is a need to partner publicly funded research with the commercial feed manufacturing sector. Such an intervention could be used to promote the development of better feed standards and allow research results to be more effectively transferred to farmers (Hasan *et al.*, 2007). Feed management research is required to improve feed utilization indices and reduce the feed costs. The Central Institute of Brackishwater Aquaculture (CIBA) in India has developed low-cost feed formulae for shrimp, and close collaboration with the feed manufacturing industry is required to commercialize these feeds.

The role of natural pond productivity, particularly the heterotrophic bacteria, in the nutritional budget of the shrimp needs to be established, and the use of improved pond fertilization, substrate enhancement, water and pond bottom management techniques promoted. There is a need to assess the protein requirements of shrimp at different stocking densities, and to establish the efficacy of the feed additives that are commonly applied to the feeds.

4.8 Conclusion

The development and use of manufactured feeds has been a major factor in the successful expansion of *P. monodon* farming. Feed contributes 48 to 67 percent of the production costs, and it is important that efficient on-farm feed management strategies are developed to improve the economic efficiency of the farming operations. In this regard, better feed management practices are needed to maintain and improve the financial and environmental viability of the culture systems. Sustainable interventions are necessary to accelerate the growth in the sector.

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REFERENCES

ASEAN. 2005. Manual on ASEAN Good Shrimp Farm Management Practice, *ASEAN Cooperation in Food, Agriculture and Forestry Fisheries Publication Series* No. 1. 35 pp.

Chanratchakool, P., Turnbull, J.F., Funge-Smith, S.J., MacRae, I.H. & Limsuwan, C. 1998. *Health Management in shrimp ponds.* Thailand, Aquatic Animal Health Research Institute, DOF. 152 pp.

De Silva, S.S. & Hasan, M.R. 2007. Feeds and fertilizers: the key to long-term Sustainability of Asian aquaculture. *In* M.R. Hasan, T. Hecht, S.S. De Silva and A.G.J. Tacon, eds. *Study and analysis of feeds and fertilizers for sustainable aquaculture development*, pp. 19–47. FAO Fisheries Technical Paper No. 497. Rome, FAO. 510 pp.

De Silva, S.S. & Davy, F.B., eds. 2010. *Success Stories in Asian Aquaculture*, Dordrecht, the Netherlands, Springer Science. Dordrecht, Springer. 214 pp.

FAO. 2005a. *National Aquaculture Sector Overview*. India. Rome, FAO. www.fao.org/fishery/countrysector/naso_india/en

FAO. 2005b. *National Aquaculture Legislation Overview*. India. Rome, FAO. www.fao.org/fishery/legalframework/nalo_india/en

FAO. 2007. *Improving* Penaeus monodon *hatchery practices*. Manual based on experience in India. FAO Fisheries Technical Paper No. 446. Rome, FAO. 101 pp.

FAO. 2009. *The Status of World Fisheries and Aquaculture 2008*. Rome, FAO. 176 pp.

FAO. 2012. *Fishstat Plus, Vers. 2.32*. Rome, FAO. (available at www.fao.org/fishery/statistics/software/fishstat/en).

Hasan, M.R. 2001. Nutrition and feeding for sustainable aquaculture development in the third millennium. *In* R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. *Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20–25 February 2000*, pp. 193–219. NACA, Bangkok and FAO, Rome. 471 pp.

Hasan, M.R., Hecht, T., De Silva, S.S. & Tacon, A.G.J., eds. 2007. *Study and analysis of feeds and fertilizers for sustainable aquaculture development*. FAO Fisheries Technical Paper. No. 497. Rome, FAO. 510 pp.

Hoa, N.D. 2009. *Domestication of black tiger shrimp* (Penaeus monodon) *in recirculation systems in Viet Nam.* PhD thesis. Ghent, Ghent University. 186 pp.

Jory, D.E., Cabrera, T.R., Dugger, D.M., Fegan, D., Lee, P.G., Lawrence, A.L., Jackson, C.J., McIntosh, R.P. & Castaneda, J. 2001. A global review of shrimp feed management: status and perspectives. *In* C.L. Browdy & D.E. Jory, eds. *The New Wave. Proceedings of the Special Session on Sustainable Shrimp Culture*. pp. 104–152. Baton Rouge, Louisiana, World Aquaculture Society.

Jory, D.E. 2010. GOAL Production Data Projects Tempered Aquaculture Growth. *Global Aquaculture Advocate*, 1: 8–10.

Molina, C. 2009. Feed programs: maximizing feed and feeding efficiency in shrimp farming. *In* C.L. Browdy & D.F. Jory, eds. *The Rising Tide – The Proceedings of the Special Session on Sustainable Shrimp Farming, Veracruz.* Baton Rouge, World Aquaculture Society, 316 pp.

MPEDA. 2008. *MPEDA Newsletter, June 2008.* Kochi, MPEDA. 1 p.

MPEDA. 2009. *Statistics of Marine Products*. Kochi, MPEDA. (available at www.mpeda.com).

MPEDA. 2010. *Statistics of Marine Products*. Kochi, MPEDA. (available at www.mpeda.com).

Naylor, R., Goldberg, R., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubchenco, J., Mooney, H. & Troell, M. 2000. *Effect of aquaculture on world fish supplies*. Nature, 405: 1017–1024.

NacSA. 2011. NaCSA Annual Report 2010–11 presented during NaCSA AGM 27th September, 2011. National Centre for Sustainable Aquaculture, Rajendra Nagar, Kakinada, India. 1 pp.

NacSA/MPEDA. 2013. NaCSA/MPEDA BMP manual for shrimp farming. National Centre for Sustainable Aquaculture, Rajendra Nagar, Kakinada, India. (*in press*.).

Neil, A.E., Neill, S., Varley, J.B. & Whitmarsh, D.J. 2001. *Shrimp aquaculture: economic perspectives for policy development*. Marine Policy, 25: 265–279.

Suresh, A.V. 2007. Development of the aquafeed industry in India. *In* M.R. Hasan, T. Hecht, S.S. De Silva and A.G.J. Tacon, eds. S*tudy and analysis of feeds and fertilizers for sustainable aquaculture development*, pp. 221–243. FAO Fisheries Technical Paper No. 497. Rome, FAO. 510 pp.

Wyban, J. 2007. *Thailand's white shrimp revolution*. Global Aquaculture Advocate, 10(3): 56–58.

Xinhua, Y. 2008. *Comparative advantage analysis of shrimp production*. Asia Aquaculture Asia Magazine, 8 (1): 33–36.

ANNEX 1
NaCSA feed management guidelines for shrimp

1. Feed storage guidelines

1. Feed should be stored in clean, cool and ventilated area, well protected from sunlight
2. Bags must be stacked neatly on pallets away from walls to prevent feed from being in direct contact with damp floor.
3. Farmers are advised to avoid excessive handling of feed bags, and to handle with care.
4. Different types of feeds must be kept separate and clearly demarcated.
5. Feed stock must be rotated using older feed first, feed that has been stored the longest. 'First in, first out' principle must be followed. Feed should not be stored for more than 2–3 months.
6. Precautions must be taken to prevent the entry of animals through doors and windows to the storage areas. This can be achieved by blocking with entrances with meshes. Stores must be kept clean.
7. Fuel items should not be stored in the feed store.
8. On farms that feed several times in a day, the total feed ration is transported from the warehouse to the ponds once, usually early in the morning. In such cases, feed bags should be protected from sunlight and rain, by storing them off the ground in simple, pond side storage sheds.
9. During the rain, proper care should be taken to prevent feed bags getting moist by ensuring there is no leakage in to the feed store and covering the feed bags with an extra layer of plastic cover.
10. Empty feed bags may be used as a cover over farm sheds or sold to local traders who recycle them for other purposes.

2. Feed management guidelines

1. Date of manufacture on the feed bag should be checked upon its arrival. Farmers should ensure that the feed is not more than 90 days old form date of manufacture. Farmers should not use feed older than 90 days, if found to be older than 90 days, it should be returned back to feed dealers.
2. Shrimp should be fed from the day stocking. The starter feed (crumble) should be mixed with a little water to distribute easily and ensure that it sinks rapidly.
3. Appropriate pellet sizes should be determined based on the size of the shrimp. A mix of two feed sizes should be used for at least 4 days while switching from one feed size to the next.
4. The feed fed on daily basis should not exceed the quantity that is indicated in the feed scheme provided in NaCSA BMP manual (Annex 2. The feed quantity to be given should be recorded accurately in the pond record book.
5. Feeding should be reduced during periods of low dissolved oxygen, plankton crash, rainfall, moulting, and extremes of temperature when feed consumption normally reduces.
6. When active swimming of shrimp are observed around the edge of the pond during daylight hours (but not at the water surface) it could indicate under feeding. If this is observed consistently, the feeding rate should be checked and increased accordingly.
7. Check trays should be installed from 30 days onwards for monitoring the feeding.
8. Regular sampling of shrimps should be done once a week after 45 days to determine growth rate and to calculate the FCR.
9. Slightly underfeeding is preferable to overfeeding, this saves money, maintains water quality, and reduces pond pollution.
10. Antibiotics should not be mixed with the feed. Ensure the feed is fresh and of a good quality so that there is no need to add additives.

3. Better feed distribution practices

Different feeding methods are used to deliver feed. The most common method is through broadcasting feeding (by hand) from pond levees, and in the middle of the pond where ropes are tied a few meters inside the pond, parallel to pond levees, and feed is broadcast with the help of floating device (small feeding boat, thermocol or large tube) which helps to disperse the feed uniformly over the pond surface.

1. During the first 30 days of culture, feed should be spread within 2 to 4 m from the edge of the pond as the smaller juveniles prefer shallower areas of pond slope.
2. The normal practice is to spread feed by hand. A simple plastic hand scoop can be used, which helps promote a wider distribution of the feed.
3. After the first month, the feed should be spread all over the pond using a boat/ floating device as the shrimp move in to the inner part of the pond.
4. Pond bottom soil should be checked on a regular basis and feeding should be avoided in areas with black and badly smelling soil (hydrogen sulphide) and in pond corners. Feed is supplied to clean areas in the pond.
5. In the ponds with aerators, feeding is should be done in the areas cleaned by the water movement. Aerators should be switched off just before feeding until 1 to 2 hours after feeding to prevent feed being carried away by the water current.

4. Check tray monitoring guidelines

1. Use 4 check trays (round shape with 80 cm diameter or square of 0.64 m^2) per ha pond to monitor the feed consumption from day 30 of the culture period.
2. Check trays should be placed on the pond bottom 2 m away from the slope of the pond banks, aerators, sluice gates and pond corners.
3. Feed should be provided in check trays and checked as per the feed chart (Table 11).
4. The check tray should be released slowly in to the water to prevent the feed from dispersing and to ensure that check tray settles on the pond bottom by pulling up the check tray few cm when it reach the bottom and again dropping it down.
5. If more than 25 percent of feed remains on the tray, the feed quantity should be decreased by 50 percent for the next feeding; if less than 10 percent of the feed remains on the tray, feeding is continued as scheduled. If no feed is found remaining in the trays the feed should be increased approximately 5 to 10 percent for the next feeding. Feeding should be suspended when farmers find most of the feed provided in the tray is left uneaten in all check trays.
6. There are several factors, other than survival which affect feed consumption in trays; when the reduction in feed consumption is noticed farmers should check for:
   - Deteriorating water quality and pond bottom;
   - Competitors in the pond;
   - Quality of the feed;
   - Moulting cycle;
   - Temperature, salinity and rainfall;
   - Diseases; and
   - Corrective actions should be taken based on these observations.
7. When feed consumption drops dramatically and does not improve within two to three days, the shrimp should be checked for health problems.
8. After check tray observation, check trays must be kept clean and dry.
9. Feed brand, type and quantities must be recorded in the pond record book.
10. Gut content, colour of the shrimp or of its faeces in the check tray should also be examined and corrective actions should be taken (Table A1).

TABLE A1

Gut colour content observation

Gut content colour	Probable food item	Probable cause(s)	Corrective action
Black Dark brown	Benthic detritus, sediment	Under feeding; inadequate feeding frequency	Increase feeding and frequency
Red Pinkish	Cannibalized body parts from dead shrimp	Disease event in pond	Check for dead shrimp in the pond
Green	Benthic algae	Under feeding	Increase feeding
Pale Whitish	Manufactured feed or natural food	Gut infection	Reduce feeding
Golden Brown	Manufactured feed	Normal	-

In addition to the above recommended practices farmers should be provided with a quick chart to trouble shoot any problems with feed management (Table A2).

TABLE A2

Common problems and solutions in shrimp feeding

Observation	Detailed observation	Action required
Shrimp not feeding in the feed net	• Shrimp not yet used to feeding in net	• Use feed nets from 20 days after stocking
	• Over feeding	• Reduce the feed by 50 percent and re-calculate survival
	• Wrong positioning of check tray	• Check the pond bottom near check tray
	• Deterioration in the water quality	• Improve the water quality (pH and DO)
	• Disease outbreak	• Examine shrimp from cast net for signs of disease
	• During moulting period	• Examine pond for presence of shrimp shells. Adjust the feed according to consumption (reduce to approximately 50 percent) until shrimp return to normal appetite
	• Other animals present in the pond	• Apply tea deed cake if there are too many fish
	• Poor water quality	• Check water quality and improve aeration
All the feed i n the net gone but no faeces	• Feed not put in the net • Net dropped into the pond too quickly	• Check on workers
	• Net incorrectly placed, rope too short or net not flat	• Check nets
Increasing numbers of shrimp in the net	• Deteriorating pond bottom causes shrimp to move to edge of pond	• Check condition of pond bottom
		• Move nets to clean areas if necessary
		• Feed only in clean part of pond
	• Underfeeding	• Check survival and re-calculate the feed
Feed disappears from the net too quickly	• Deteriorating pond bottom causes shrimp to move to edge of pond	• Check condition of pond bottom, move nets to clean areas if necessary • Feed only in clean part of pond
	• Underfeeding	• Check survival and re-calculate the feed
	• Tray incorrectly placed	• Check nets
	• Fish in pond	• Look for fish in cast nets or large faeces in check trays • Kill the fish with tea seed cake

Source: Modified from Chanratchakool *et al.* (1998).

ANNEX 2
Feeding scheme for shrimp farming

Age (days)	Mean body weight (g)	Daily feeding rate (% of mean body weight)	Check tray (%)	Time of feed tray checking (hours)
1–20	PL15–1.0	20.0–5.0		
20–35	1.0–4.0	5.0–4.0		
35–50	4–6	6.0–5.0		
50–55	6–7	5.0–4.5	2.0	2.0
55–60	7–8	4.8–4.2	2.0	2.0
60–65	8–9	4.2–4.0	2.1	2.0
65–70	9–11	4.0–3.8	2.2	2.0
70–80	11–14	3.8–3.6	2.3	1.45
80–90	14–17	3.6–3.3	2.4	1.45
90–100	17–21	3.3–3.0	2.5	1.45
100–110	21–25	3.0–2.5	2.7	1.30
110–120	25–30	2.5–2.1	3.0	1.30
120–130	30–36	2.1–1.6	3.5	1.30
130–140	36–43	1.6–1.5	4.0	1.20
140–150	43–50	1.5–1.4	4.5	1.15

Source: NaCSA/MPEDA (2013).