Development of the aquafeed industry in India

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SUMMARY

India is the second largest aquaculture producing country after China. The current annual aquaculture production exceeds 2.47 million tonnes of fish, freshwater prawns and marine shrimp. Production of carps dominates Indian aquaculture with an annual production exceeding 2.11 million tonnes, while the total shrimp and prawn production is over 172 000 tonnes. The terrestrial and aquatic animal farming sectors are rapidly expanding and intensifying in India. However, industrial feed manufacturing in India still lags behind other rapidly developing economies in size and sophistication. The current level of industrial feed production for terrestrial livestock is estimated to be about 5 million tonnes, though requirements exceed 42 million tonnes. Similarly, aquaculture requires at least 2.59 million tonnes of manufactured feeds but, at present, only about 200 000 tonnes are manufactured. Semi-intensive and intensive carp and other freshwater fish production systems in India are predominantly based on farm-made feeds. An estimated 6.83 million tonnes of feed ingredients are used for producing farm-made feeds, while only 10 000 tonnes of industrially manufactured feeds are used in freshwater aquaculture. Preliminary data suggest that the use of manufactured feeds could bring about significant savings in carp production. Food conversion ratios could be reduced from 3 to 1:1 when manufactured feeds replace farm-made feeds. There are additional benefits associated with manufactured feeds in the form of cleaner ponds and less labour for feed preparation and feeding. The principal constraint to the use of manufactured feeds in fish production is the perception that such feeds are not cost effective. Once feed manufacturers and farmers realize that it is possible to produce profitably and use feeds in fish farming, the use of manufactured feeds will increase. It is likely that the use of manufactured feeds in freshwater fish farming will increase from the present 10 000 tonnes to at least 250 000 tonnes within the next five years.

The use of industrially manufactured feeds in Indian aquaculture started in the early 1990s when feeds were imported from Taiwan Province of China, Southeast Asia and the United States of America for shrimp production. Currently, India has more than sufficient capacity to produce adequate volumes of feed for freshwater prawn and marine shrimp farming. Annual production of prawn and shrimp feeds is around 190 000 tonnes against an installed capacity of around 500 000 tonnes per year. Other than in the traditional, extensive production systems in Kerala and West Bengal that are not designed to use feeds, industrially manufactured feeds are used in almost all prawn and shrimp farms in India. Falling prices of prawns and shrimps in the global market have meant lower profitability for the farmers and the high cost of feed has become a constraint. While market forces will no doubt correct this imbalance over a period of time, opportunities exist in research and policy-making to achieve efficiencies that would lower the cost of feed per unit of production.

There is an adequate domestic feed ingredient resource base for most of the animal feed requirements by the aquaculture and animal production sectors. For example, India produces 3.5 million tonnes of rice bran, the chief ingredient in fish feeds, which is sold at Rs 3 200/tonne (US$71.11). However, maize has to be imported to meet the needs of the poultry sector and fishmeal and marine oils are imported for the shrimp farming sector. Fortunately, India is one of the biggest exporters of soybean meal in the world and enjoys a competitive position as far as most aquafeed ingredients are concerned. However, the high import tariff imposed on feed additives is a constraint, although this will probably change with the implementation of global trade reforms.

1. INTRODUCTION

This report reviews the development of the aquafeed industry in India. It is principally based on secondary information and data derived from the published literature, unpublished reports and some primary data collected in the field. The report provides:

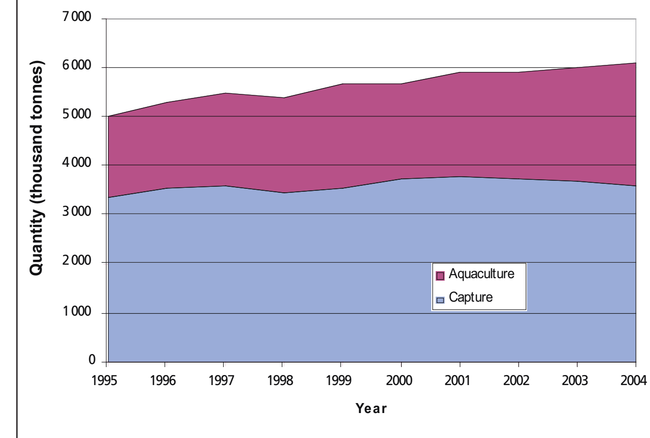
- a brief overview of aquaculture practices and farming systems, with production data (weight and value) of major species groups;
- an overview of the animal feed manufacturing sector including total compound animal feed production, production capacity and potential, feed manufacturing associations as well as the relevant regulations and controls;
- a review of availability, nutritional value and cost of feed ingredients including feed additives (e.g. vitamins, minerals, antioxidants and binders) including summary information on current feed and feed ingredient imports and exports;
- a summary of feed production for major species group and farming systems;
- a summary analysis of constraints on the use of commercially manufactured feed for small- and medium-scale aquaculture enterprises, including a comparative assessment of the economics of small-scale aquaculture based on industrially manufactured complete/semi-complete feed and farm-made feeds; and
- recommendations and suggested policy guidelines for improved utilization of industrially manufactured feed.

2. AQUACULTURE IN INDIA: A BRIEF OVERVIEW

In 2004 India was estimated to have harvested about 6.09 million tonnes of aquatic products, mainly finfish and shellfish (FAO, 2006). This is slightly lower than the figures provided by Ayyappan and Ahamad Ali (2007), who estimated that India's total aquatic food production was 6.4 million tonnes in 2004 and that aquaculture contributed about 2.37 million tonnes of this production. The FAO data show that roughly 59.5 percent was from capture fisheries and the remaining 40.5 percent was from aquaculture. Figure 1 shows that the contribution by capture fisheries has almost stagnated at about 3.5 million tonnes in the last 10 years, whereas aquaculture has grown from 1.66 to 2.47 million tonnes during the same period. Ayyapan and Diwan (2004) predicted that Indian aquaculture would continue to grow at an average annual growth rate of about 8 percent in the next five years.

Freshwater aquaculture accounts for the bulk of production and amounts to around 2.34 million tonnes per year. In comparison, the average annual brackish-water and marine shrimp production over the last five years has been around 100 000–170 000 tonnes. Even though this represents only a small fraction of the total marine harvest in India, the proportional contribution to total value is high.

FIGURE 1
Aquatic food production in India from 1995 to 2004



Source: FAO (2006)

2.1 Freshwater aquaculture in India

As stated earlier, current freshwater aquaculture production in India is 2.34 million tonnes. Most of this production is attributed to carps which accounted for 90.5 percent of the total freshwater production in India (Table 1). In 2004, the three Indian major carps (catla, rohu and mrigal) contributed 59.7 percent, common carp 19.4 percent and the two Chinese carps (grass and silver carp) 11.3 percent to total freshwater production.

TABLE 1
Aquaculture production by species groups in 2004

Species groups	Tonnes
Indian major carps	**1 396 855**
Catla	467 962
Rohu	486 113
Mrigal	442 780
Chinese & common carps	**719 472**
Grass carp	100 641
Silver carp	165 084
Common carp	453 747
Snakeheads	29 949
Catfishes	42 160
Other fishes	108 958
Freshwater prawns	**38 965**
Monsoon river prawn	245
Giant freshwater prawn	35 720
Total freshwater aquaculture	**2 336 359**

Source: FAO (2006)

There are three broad types of carp farming systems in India (Table 2). The most traditional of the three are the stock-and-harvest systems, in which fish seed is the only input and in which the fish are totally dependent on natural productivity. This is practised in larger water bodies, particularly reservoirs. Based on current yields that range from 11 to 48 kg/ha in large-to-medium and small reservoirs, respectively (Nath and Das, 2004), the estimated total annual production of fish from these systems is about 90 000 tonnes. Currently, there is little scope for feed use in reservoirs and other extensive waterbodies. However, should cage culture in reservoirs ever become a reality in India, there is a vast potential for increasing fish production and feed use.

The second type of carp farming practice is generally referred to as low input, extensive culture. This is practised in a variety of waterbodies that may not necessarily have been excavated for fish farming. Examples are rice paddies and seasonally flooded pools. Fish are stocked at low densities (<5 000/ha) and the water may be fertilized with organic manures such as cow dung. A limited quantity of feed, in the form of crop residues, is provided. Yields typically range from 1 to 2 tonnes/ha/year. The production data are unreliable, but it is likely that at least 1 million tonnes are produced annually from this sector.

The third type is intensive pond culture in which fish stocking densities exceed 5 000/ha. The ponds are fertilized and the fish are fed, the yield normally exceeds 5 tonnes/ha/year. There are no reliable production data from this sector but it is likely that at least 750 000 tonnes are produced by intensive pond culture.

Carp culture in India has evolved over the past 50 years, with some regional disparities – predominantly from stock-and-harvest fisheries to more intensive forms of production. Stock-and-harvest fisheries and low-input, extensive pond culture of several species still exist in almost all parts of the country. A variety of farming systems including sewerage-fed aquaculture exist in states such as West Bengal. Intensification has mainly occurred in the southern states, particularly Andhra Pradesh, Karnataka and Tamil Nadu, and in the northern states of Punjab and Haryana. Carp farming is still predominantly polyculture, though there has been a decline in the use of Chinese carps, particularly silver carp. The poor eating quality of this species and difficulties in spawning this fish are cited as the reasons. Intensive farmers increasingly prefer catla and rohu as the only two species for carp farming because of their relatively high market value. Common carp is preferred in some areas (e.g. Karnataka). Other herbivorous species such as *Puntius* spp. are included with carps in the eastern states (Orissa and West Bengal).

TABLE 2
Summary of carp farming systems in India

System type	Inputs	Farm production (tonnes/ha/year)	Estimated national production (tonnes/year)
Stock and harvest in reservoirs	Fingerlings only	0.02–0.03	90 000
Rice paddy, seasonally flooded pools, temple ponds, water storage reservoirs for agriculture, sewerage-fed pools	Fingerlings, manure, occasional feeding with agricultural by-products and household waste	1.00–2.00	1 000 000
Ponds with proper embankments and drainage	Fingerlings, manure, systematic feeding with ingredients such as rice bran and oil seed residues	>5.00	750 000

Commercially successful intensification of carp culture started in the southern state of Andhra Pradesh in the mid- to late 1980s (Veerina *et al*., 1999). The intensification was characterized by:

1. an increase in the stocking density from 5 000 to about 8 000/ha;
2. a shift towards polyculture of Indian carps only and in particular catla and rohu at a ratio of 1:4-1:15;
3. establishment of effective nursery systems for the fry and advanced fingerlings. When fingerling and grow-out production cannot be synchronized, fingerlings are provided with a maintenance ration until they are needed. Compensatory growth is rapid and the fish reach 1.5–2.0 kg in one year;
4. their fertilization. Though ponds are large (10–20 ha), they are fertilized with poultry manure throughout the production cycle. Fertilization is well managed and farmers routinely sample pond water to observe plankton production (Figure 2) and add fertilizers when necessary; and
5. feeding practice. The fish are fed with de-oiled rice bran (90 percent) and groundnut and/or cotton oilseed cake. The feedstuffs are blended and packed in plastic bags with holes (Figure 3) and these are suspended in the ponds (Figure 4). Further details of the ingredients and feed composition are provided later in the report.

The market value of carps varies within and between states. West Bengal as a whole, and Kolkata in particular, is the biggest market for carps in India, where the current price varies from Rs 45 to 60/kg (US$1–1.3).[1] Similar prices are obtained in urban markets in the states of Punjab and Haryana. Andhra Pradesh is the biggest intensive carp farming area in the country. However, because marine fish are preferred here the market price for carp is considerably lower, at around Rs 26–30/kg (US$0.57–0.66), hence most of the fish are transported to the market in West Bengal. Intensive carp farming in Tamil Nadu occurs in the Cauvery delta region. Though also a coastal region, carp is readily accepted on the market and currently fetches around Rs 40–45/kg (US$0.9–1.0).

Carnivorous snakeheads, clariid and pangasiid catfish are also produced in India. Snakeheads, locally known as murrels, are cultured throughout the country in areas where seed availability is not a constraint. Snakeheads fetch a high market price

[1] US$1.00 = Rs 44.00 (Indian Rupee, INR)

FIGURE 2
Sampling of pond water to check plankton density

Farmers of intensive carp culture system in Andhra Pradesh routinely sample ponds to determine plankton density and adjust the fertilization schedule accordingly.

FIGURE 3
Bags used for feeding of fish in intensive carp culture in India

The bags are packed with supplementary feed before placing them in the pond. Bag feeding method is commonly used in intensive carp culture in Andhra Pradesh. The bag has several holes through which the fish access the feed packed into the bag.

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FIGURE 4
Bag feeding method in intensive carp culture in India

Bags filled with feed are tied to bamboo poles placed at the edge or centre of ponds.

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of Rs 120–180/kg (US$2.67–4.00). As air-breathing fish they are stocked at a high density; however the lack of seed supply, their high protein requirement, slow growth and susceptibility to disease constrain the expansion of murrel farming. Wet trash fish and poultry processing waste (mainly guts and heads) combined with rice bran and oil seed residues are fed to the fish.

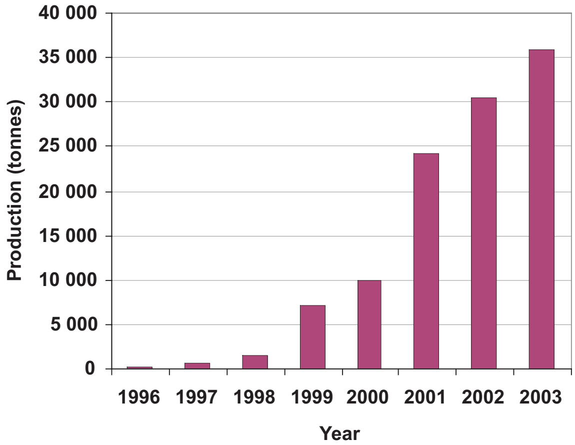
Catfish culture has recently expanded. While India has a number of endemic catfish species including *Clarias batrachus* and *Pangasius pangasius*, the faster growing African catfish, *Clarias gariepinus,* and sutchi catfish, *Pangasius hypopthalmus,* imported from Southeast Asia, have become the most widely farmed species in recent years. Legally these two species are not permitted to be farmed in India, hence production data are unavailable. Farmers typically use high stocking densities (>40 000/ha) and mixed feeds composed of rice bran, oilseed cake residues, kitchen waste, poultry processing waste and others. The fish grow to 1 kg within six months.

India is one of the few countries in Asia without tilapia in aquaculture. *Oreochromis mossambicus* was first introduced to India some 50 years ago and the species has now been established in reservoirs and lakes throughout the country. Owing to its unpleasant looking dark skin and peritoneum pigmentation, it does not have a broad market appeal and is considered to be a pest species in capture fisheries and aquaculture. Farming trials with red hybrid tilapia showed that the hybrid fish was well accepted by the market. The introduction of species into India requires an exotic species import permit and importers have to comply with quarantine requirements. Currently there is an initiative to introduce Nile tilapia (*O. niloticus*) into India, although there are unconfirmed reports that *O. niloticus* and the genetically improved farm tilapia (GIFT) have already been introduced via Bangladesh into West Bengal. The prospects for tilapia farming in India are good once appropriate candidate species have been introduced.

Extensive freshwater prawn farming has been practised for many years in floodplains and rice paddies in West Bengal and Kerala. Semi-intensive prawn farming only commenced in the mid-1990s in Andhra Pradesh when marine shrimp farming was severely affected by white spot syndrome virus (WSSV). Prawn farming was also facilitated by the available shrimp farming infrastructure. The species of choice is the giant freshwater prawn (*Macrobrachium rosenbergii)* that is locally and incorrectly referred to as "scampi". Prawns are produced in ponds both under monoculture and polyculture conditions with Indian major carps. Grow-out stocking densities range from 0.5 to 2.5 prawns/m^2 in polyculture and 1 to 5/m^2 in monoculture and the grow-out period is 6–8 months. Average pond production is about 600 kg/ha; however, well-managed ponds produce up to 2 tonnes/ha/crop cycle. Freshwater prawns (average weight of 50 g) fetch approximately Rs 225/kg (US$5.10).

Prawn production in Andhra Pradesh, particularly in the district of Nellore, grew rapidly from 1996 to 2002 and this area now contributes approximately 80 percent of the country's total prawn production. Low rainfall, disease problems during seed production and grow-out and lower export prices significantly affected prawn production in this district in 2003–04. This has been compensated for by increased production from other areas in Andhra Pradesh and elsewhere (Figure 5). India produces an estimated 25 000–30 000 of

FIGURE 5
Freshwater prawn production in India from 1996 to 2003



Source: Marine Products Export Development Authority brackish-water shrimp in inland waters (Figure 6), mainly in the districts of East and West Godavari in the state of Andhra Pradesh. The production systems, methods and feeds are not considerably different from those used in coastal waters (see below for details).

FIGURE 6
Brackish-water shrimp production in inland waters

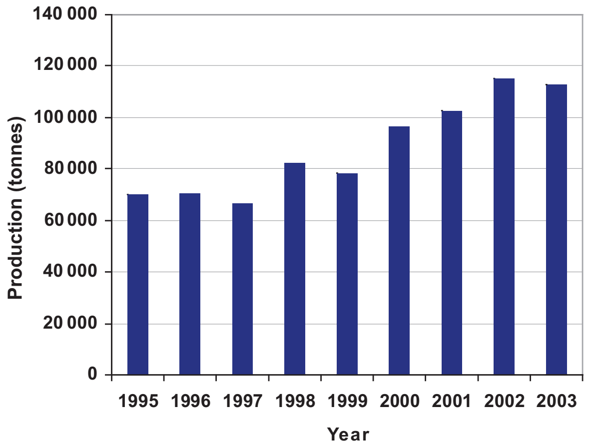
The pond represents low salinity (<5 ppt) systems in the Godavari and Krishna districts of Andhra Pradesh. Though trench-type ponds in a coconut grove as shown here are atypical, it is common to find shrimp ponds coexisting with rice paddy fields and coconut groves in the area.

2.2 Brackish-water and marine aquaculture

India's brackish-water and marine aquaculture sector produces only marine shrimp, mainly black tiger shrimp, *Penaeus monodon,* and smaller proportions of Indian white shrimp, *Fenneropenaeus indicus,* and Pacific white shrimp, *Litopenaeus vannamei.* Production of marine fishes, including Asian seabass/barramundi (*Lates calcarifer*), is negligible.

Extensive shrimp farming has been practised in India, particularly in Kerala and West Bengal, for several decades. Semi-intensive farming emerged in the late 1980s and grew rapidly in the early 1990s (Figure 7). The outbreak of WSSV stemmed the sector's growth in 1995. The sector was also affected by the Indian Supreme Court's decision to ban intensive and semi-intensive aquaculture practices within 500 metres of the high tide mark. Subsequently, the sector has experienced a revival and total production in 2004 reached approximately 116 000 tonnes. Recent setbacks to the sector include (i) imposition of anti-dumping duty on shrimp exported from India to the United States of America; (ii) low prices of shrimp due to global oversupply and anti-dumping duty; and (iii) the 2004 tsunami that affected hatcheries and farms in Tamil Nadu. WSSV still persists and new problems such as loose shell syndrome threaten the profitability of the sector. Loose shell syndrome is a unique disease problem in India that results in severe atrophy of the muscles. The etiology of the problem remains largely unknown, although a number of factors such as blue-green algae and poor pond bottom are thought to be causative factors.

FIGURE 7
Marine shrimp production in India from 1993 to 2003



Source: Marine Products Export Development Authority

There are three types of shrimp farming systems in India, i.e. traditional extensive, modified extensive and semi-intensive (Table 3). Traditional and extensive farmers in Kerala and West Bengal use large (>5 ha), irregular shaped ponds that are filled during flooding or through tidal exchange. Stocking densities are low (<5 PLs/m^2) and shrimps are either fed with farm-made feeds or receive no food at all. Typical yields are in the range of 200–400 kg/ha/crop cycle. There are no reliable estimates of production from these systems. Production in West Bengal and Kerala amounts to approximately 36 000 tonnes of shrimp and it is estimated that some 28 800 tonnes are produced in extensive systems.

TABLE 3
Summary of shrimp farming systems in India

System type	Inputs	Farm production (tonnes/ha/cycle)	Estimated national production (tonnes/year)
Traditional, extensive	Post-larvae/juveniles (hatchery or wild source), 2–5 animals/m²; farm-made feeds or no feeds	<0.5	30 000
Modified, extensive	Hatchery-produced post-larvae, 5–10 animals/m²; manufactured feeds	1.0–-1.5	50 000
Semi-intensive	Hatchery-produced post-larvae, 15–20 animals/m²; manufactured feeds	>2.0	30 000

Manufactured feeds are used in the other two shrimp farming systems. In semi-intensive systems, stocking densities exceed 15 PLs/m^2 and yields exceed 2 tonnes/ha/crop cycle. In the modified extensive systems, stocking densities are in the range of 7–10/m^2 and yields are about 1.0–1.5 tonnes/ha/cycle. Typical pond size is in the range of 0.8–1.0 ha each.

There are two distinct shrimp cycles (crops) in India. The first cropping starts in February/March and ends in May/June. The second cropping starts in August/September and ends in November/December. Typically, the first crop produces a higher yield than the second crop. Better water quality following the 2–3 months "between crop holiday" is cited to be the reason for such a difference. However, in recent years and with better management, this is becoming less common. The average duration of each crop cycle is 130 days. The average size of shrimp at harvest is 25–30 g and the farm-gate price of shrimp in the 25–30 g range varies between Rs 210 and 280/kg (US$4.88–6.22).

3. THE ANIMAL FEED MANUFACTURING SECTOR IN INDIA

The farm animal population of India in 2003 was estimated to be about 974.01 million (see Table 4). It is further estimated that in 2003 India produced a total of 5.98 million tonnes of meat, 88 million tonnes of milk and 40 billion eggs. Despite this large volume from the livestock sector, animal production in India is largely comprised of small- and medium-size farming enterprises. Most of the feeds used for animal production consist of natural pasture, farm-made feeds and some measure of scavenging. In comparison with other developed nations and fast-developing economies of the world the feed manufacturing industry is in the early stages of development.

The current volume of compounded feed production for the dairy, poultry and aquaculture sectors is about 5 million tonnes (CLFMA, 2005). It has been estimated that India would require about 42 million tonnes of balanced feed if livestock farming were to be primarily feed-based. By 2010, this demand is expected to increase to about 60 million tonnes (CLFMA, 2005). Table 5 summarizes the current production and estimated demand for feeds.

- **Dairy cattle.** The dairy cattle industry in India, though the largest in the world in terms of number of cows and milk production, is highly fragmented and widely distributed throughout the country, and is in the hands of millions of small farmers. Most farmers mix their own feed formulations and rely on

TABLE 4
Farm animal population of India in 2003

Species	Number (million)
Cattle	185.18
Buffalo	97.92
Small ruminants	185.83
Pigs	13.52
Other draught animals	2.55
Poultry*	489.01
Total	**974.01**

*Poultry population may have been underestimated. The Compound Livestock Feed Manufacturers Association (CLFMA) estimated that there were 150 million layer birds and 650 million broiler birds in 2003.

Source: Directorate of Economics and Statistics, Ministry of Agriculture (2003).

TABLE 5
Demand and current production of animal feeds in India (million tonnes)

Sector	Feed demand	Current feed production	Information source
Dairy cattle	45.00	2.00	CLFMA
Poultry, broiler	6.21	3.00	CLFMA
Poultry, layer	8.13	Not significant	CLFMA
Aquaculture, fish	2.31	0.01	Author
Aquaculture, prawn	0.27	0.19	Author

grazing or stall-feeding, using crop residues. Owing to the poor genetic make-up of the stock and management practices, use of manufactured feed may not improve productivity. Experts consider that manufactured feeds would be best utilized for only about 10–15 percent of dairy cattle in India that are cross-bred and optimally managed. The potential demand for dairy cattle feed is estimated at 45 million tonnes, assuming that only 50 percent of milk production in the country is from cattle that are fed manufactured feeds (CLFMA, 2005). The current estimated production of cattle feed is about 2 million tonnes indicating the high potential for the animal feed manufacturing industry. The major markets for dairy cattle feeds are Punjab, Haryana, Uttar Pradesh, Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu and Andhra Pradesh.

- **Poultry.** Over the last decade, consumption of broiler meat has grown at an annual rate of almost 15 percent. The broiler production sector is technologically advanced, relies on balanced feeds and uses most of the animal feeds manufactured in India. Nearly 3 million tonnes of manufactured feeds are used by the sector. CLFMA (2005) reported that the feed requirement for the broiler sector was 6.21 million tonnes in 2004, while some 8.13 million tonnes are required for layers. Increased use of manufactured feeds in the poultry sector is constrained by cost.
- **Aquaculture.** See later.

Table 6 provides a summary of manufactured feed types, feed composition and costs of broiler feeds and various aquafeeds. The data suggest that feed costs as a percentage of market price for broilers and carps are quite similar. However, better resource efficiencies are possible if carps are fed on manufactured feeds (see later for further discussion). Prawn and shrimp feeds are more expensive than other feeds but, because of the high price of shrimp and prawns, production is relatively cost effective.

TABLE 6
Type of broiler and aquafeeds manufactured, composition and their cost

Animal	Broiler	Carp	Prawn	Shrimp
Type of feed	Pellet	Mash	Pellet	Pellet
Proximate composition				
Crude protein (%)	18	20	28	40
Crude lipid (%)	5.5	2.0	4.0	6.0
Crude fibre (%)	4	15	4	3
Costs				
Unit cost of feed (Rs/kg)	12	4	28	42
Unit cost of feed (US$/kg)	0.27	0.09	0.64	0.95
Feed conversion ration (FCR)	1.8	3.5	2.5	1.6
Feed cost/kg of animal produced (Rs)	21.6	14.0	70.0	67.2
Feed cost/kg of animal produced (US$)	0.49	0.32	1.59	1.53
Market size (g/animal)	2 000	1 000	70	33
Time to market size (day)	40	365	180	140
Sale price (Rs/kg)	40	30	270	250
Sale price (US$/kg)	0.91	0.68	6.14	5.68
Feed cost (% of sale price)	54.00	46.67	25.93	26.88

The Compound Livestock Feed Manufacturers Association (now simply known as CLFMA) is the only association that is widely recognized by the feed industry. Nearly 50 percent of manufactured feed in India is produced by members of the association. CLFMA has recommended quality norms for various livestock feed (Appendix, Tables A.1 and A.2). The Bureau of Indian Standards has also recommended specifications for various livestock feeds (Appendix, Tables A.3 and A.4). The Marine Products Export Development Authority (MPEDA) has similarly prescribed norms for marine shrimp feeds (see later for more detail). These standards and quality norms are adopted on a voluntary basis and are not enforceable.

4. AVAILABILITY OF FEED INGREDIENTS

India is primarily an agricultural economy and is one of the biggest producers (Table 7) of rice, wheat and many oilseeds, including soybean.

The broad agricultural base provides coarse grains, grain by-products (brans), and oilseed cake or meals for the manufacture of animal feeds. Ayyappan and Ahamad Ali (2007) provided a detailed estimate of agricultural products and by-products that could be used in animal feeding. CLFMA (2005) estimated the feed resources that are currently available from domestic agricultural production for livestock feeding (see Table 8).

In addition to by-products from crop production, India also produces some animal by-products such as meat and bone meal, blood meal, feather meal, fishmeal, fish oil, *Squilla* meal and shrimp waste meal. Production volumes of terrestrial animal proteins are not known. Ayyappan and Ahamad Ali (2007) estimated that nearly 340 000 tonnes of marine animal proteins are potentially available for feed use in India. India produces nearly 4 million tonnes of soybean meal a year, of which about 65 percent (2.6 million tonnes) is exported mainly to the Republic of Korea, Japan, Thailand, Indonesia, Malaysia, Viet Nam and the Philippines.

TABLE 7
Estimates of agricultural outputs in 2003

Commodity	Quantity (million tonnes)
Rice	87.0
Wheat	72.0
Corn (maize)	14.7
Pearl millet *(bajra)*	11.8
Sorghum *(jowar)*	7.3
Finger millet *(ragi)*	2.0
Barley	1.3
Pulses	15.2
Soybean	5.5
Groundnut	8.3
Rapeseed/mustard seed	5.8
Sunflower	1.0
Cassava	6.0

Source: Hindu Survey of Indian Agriculture (2004).

Given the current estimated feed requirement of 42 million tonnes, the feed resource base is perhaps just sufficient to meet the requirements. Indian international trade in animal feed ingredients is rather small except for maize and soybean meal. India imports maize when local production is not sufficient to meet domestic demand. Concerned about the economic effects of cheaper subsidized maize produced in western countries, particularly the United States of America, on domestic maize, India imposed a tariff of 15 percent on the first 500 000 tonnes of maize imported into the country. Imports above 500 000 tonnes attract a tariff of 65 percent. Import tariffs for major feed ingredients in India are listed in Table 9.

TABLE 8
Available resources for animal feeds in 2004

Commodity	Quantity (million tonnes)
Oilseed cake and meals	15.76
Brans	13.26
Coarse grains*	5.74
Others	0.53
Total	**35.32**

*Coarse grain production may have been underestimated considering the fact that nearly 7.0 million tonnes of domestically produced maize is used by the feed industry.

Source: CLFMA (2005).

India imports fishmeal primarily for use in shrimp feeds. Small quantities may also be used in poultry and freshwater prawn feeds. India is not considered to be a significant importer of fishmeal or any other animal by-product. The total import of marine and animal by-products into India is unlikely to exceed 10 000 tonnes per year. There is an official ban on the importation of animal and poultry by-products due to fear of introduction of pathogenic factors responsible for bovine spongiform encephalopathy (BSE) and highly pathogenic avian influenza (HPAI), respectively.

Ingredients and additives, imported and of domestic origin, do not require any form of registration in India, although the Ministry of Agriculture now requires an import certificate for all animal feed ingredients and finished feeds. The requirements vary from ingredient to ingredient and are not standardized. Unrealistic requirements are imposed from time to time, for example, the requirement that all fishmeal is free of WSSV. The certification process is considered by many in the feed industry to be a trade barrier.

Table 10 presents a list of ingredients that are commonly used in feed manufacturing in India and their typical nutritive composition and price. Because of their importance in aquafeeds, several of the available ingredients are discussed in greater detail below. Complementary information on the availability of an ingredient for and use in aquafeeds may be found in Ayyappan and Ahamad Ali (2007).

1. **Rice bran.** India produces 3–3.5 million tonnes of rice bran annually. Full-fat rice bran or rice polish is used for the extraction of rice bran oil and is therefore relatively expensive for use in feeds. If the oil is not extracted or the polish is not heat treated, the oil becomes rancid and the quality of the bran is reduced. De-oiled rice bran is the most important ingredient in carp feeds and is also used in prawn feeds. The quality of rice bran varies considerably. Mixing of rice husks with the bran is a serious quality issue. This can be detected by the ash and fibre content of the bran. High ash and fibre contents are indicators of poor quality. The relatively high level of protein and starch in rice bran makes it a valuable feed ingredient.
2. **Coarse grains.** Coarse grains are not used widely in Indian aquaculture. However, they have a high nutritive value in relation to cost, particularly in fish feeds. Maize, sorghum, finger millet and broken rice are good sources of starch. Once extrusion becomes more widely adopted in aquafeed production, the use of coarse grains will increase.
3. **Soybean meal.** Soybean meal with hulls (44 percent crude protein) and de-hulled soybean meal (48 percent crude protein) are available in large quantities in India. Currently, these products are used only in shrimp and prawn feeds. Fish farmers do not use soybean meal due to its high cost. However, once fish feeds are commercially manufactured, the use of soybean meal will increase.
4. **Groundnut cake.** Mechanically extracted groundnut cake has been traditionally used for the feeding of fish. Solvent extracted groundnut cake is now more commonly available on a commercial scale. Due to concerns about mycotoxins, groundnut cake is not used in shrimp feeds.

TABLE 9
Import tariffs (%) on feed ingredients imported into India (effective as from 24 August 2005)

Item	Basic duty	Counter veiling duty	Cess	Total
Fishmeal	5	0	0.10	5.10
Other marine protein meals and by-products*	30	0	0.60	30.60
Terrestrial animal protein by-products	30	0	0.60	30.60
Bran, rice (raw or de-oiled)	15	0	0.30	15.30
Bran, other grains (maize, wheat, etc.)	30	0	0.60	30.60
Residues of starch manufacturing**	30	0	0.60	30.60
Oilseed cakes and solid residues from oil extraction	15	0	0.30	15.30
Concentrates for feed preparation	30	0	0.60	30.60
Compounded feeds	30	0	0.60	30.60
Brewers' yeast	30	16	0.92	46.92
Cholesterol	15	16	0.62	31.62
Lecithin	15	16	0.62	31.62
Monocalcium phosphate	15	16	0.62	31.62

* Includes fish solubles, hydrolysate, etc.
** includes wheat gluten

5. **Cotton oilseed cake.** Solvent-extracted cottonseed cake is used in fish feed.
6. **Other oilseed residues.** Oil cakes of sunflower, coconut (copra meal), sesame and rapeseed are presently not commonly used in aquafeeds. These have high potential for use in fish feeds because of their low cost relative to nutritive value.
7. **Residues of starch manufacturing.** Locally produced maize gluten meal has now become available in India. Its potential for use in aquafeeds, especially shrimp feeds, is good due to its high nutritive value relative to cost. Wheat gluten is only available in small volumes. However, significant quantities are imported from Europe and China for use in the food industry. It is used in small quantities (<2 percent) in shrimp feeds as a binder.
8. **Wheat flour.** This ingredient is used only as a binder in pelleted shrimp and prawn feeds. India is one of the world's largest wheat producers and processors. Second-grade wheat flour, which is only marginally fit for human consumption, is used in animal feeds. Indian wheat has a low wet gluten index (<28 percent) relative to the ideal index for shrimp feed pelleting (32 percent).
9. **Fishmeal.** The shrimp feed industry mainly uses premium grade (prime or super prime) fishmeal imported from Chile or Peru. There are two types of locally available fishmeal, one of which is produced mostly from oily, small-pelagic fish such as sardines and mackerel. Typically, the fish are cooked and pressed to extract the oil. The press cake is then dried in a flame drier to produce a meal of about 55 percent crude protein. The factories may also use species such as leognathids and carangids. The meal has high ash levels. The other is made from fish that is unfit for human consumption. This fish is sun-dried and ground for use in feeds. The meal has high levels of ash and silica (the latter originating from the sand on which the fish are dried). Sun-dried meals are not commonly used in aquafeeds, but find use in poultry feeds. The factory-produced local fishmeal is used in prawn feeds. Most fishmeal factories are located on the west coast of India.
10. **Marine by-product meals.** Shrimp head and shell meal are produced by cooking and drying or simply drying shrimp processing waste. Clam and other mollusc meals are made by simple cooking, drying and milling methods. A small quantity of squid meal is produced and exported from India. Squid liver paste and meal and fish solubles are imported from the Republic of Korea and the Americas, respectively. Small quantities of fish hydrolysates are imported from Europe.
11. **Yeast.** Yeast is used in shrimp feeds. Currently, most of this product is imported from Brazil in the form of spray-dried, molasses yeast. The large brewing and distilling industry in India is not yet adequately organized to supply yeast and other brewery/distillery by-products.
12. **Fats and oils.** Fish and squid oils are primarily used in shrimp and prawn feeds. Squid oil is imported from the Republic of Korea, while fish oil is imported from the Americas. Crude fish oil is produced locally, but the method of production leads to poor quality oil. The presence of a high level of peroxides and free fatty acids prohibits their wider use. Soya lecithin is produced locally and used in shrimp and prawn feeds as a source of phospholipids. Indian manufacturers of lecithin supply only the dark, viscous lecithin variety. The lecithin, however, matches the phospholipid content (at least 65 percent) of imported liquid lecithin products. The meals produced from solvent extraction have less than 1 percent residual oil. Commercially manufactured fish feeds therefore require supplementation with fats and oils as a source of essential fatty acids and energy. The possibility of using crude forms of or by-products of soybean, palm and other edible oils in fish feeds requires investigation.

Table 11 presents a list of micronutrients and non-nutritive feed additives that are commonly used in feed manufacturing in India. Most preservative and mineral feed additives are now locally manufactured.

TABLE 10

Composition and price of aquafeed ingredients commonly available in India

Ingredient	Typical composition (percent as fed basis)				Typical price/tonne	
	Crude protein	Crude lipid	Crude fibre	Ash	Indian Rs	US$
Grains						
Finger millet	6.5	1.2	6.0	7.0	3 500	77.78
Sorghum (white)	8.0	2.5	3.0	2.8	5 000	111.11
Maize	8.5	3.5	2.0	1.9	6 000	133.33
Broken rice	8.5	0.4	0.6	0.8	7 000	155.56
Wheat flour	11.0	0.4	0.1	0.7	10 500	233.33
Grain by-products						
Wheat bran	12.8	3.2	11.1	8.4	5 000	111.11
Rice polish	13.0	15.8	6.6	9.8	5 500	122.22
Rice bran, de-oiled	15.2	0.2	17.0	10.1	3 200	71.11
Corn gluten meal	61.2	2.2	1.5	1.0	12 500	277.78
Wheat gluten	80.0	0.8	0.1	0.8	46 000	1022.22
Oilseed residues						
Copra meal (solvent extracted)	23.4	1.2	13.0	8.0	6 500	144.44
Sunflower meal (solvent extracted)	28.2	0.6	16.0	7.2	5 000	111.11
Cotton seedcake (solvent extracted)	36.8	2.5	9.8	6.2	7 500	166.67
Rapeseed meal (solvent extracted)	37.0	0.85	6.7	8.3	6 500	144.44
Soybean meal, 44% (solvent extracted)	44.5	1.6	6.0	8.0	11 400	253.33
Soybean meal, 48% (solvent extracted)	49.0	1.6	4.9	7.3	13 400	297.78
Groundnut cake (solvent extracted)	47.0	0.5	6.0	7.0	9 500	211.11
Animal by-products						
Fish soluble	26.0	4.0	NA	12.0	28 000	622.22
Shrimp meal	44.0	7.2	15.2	25.0	14 000	311.11
Squid liver powder	47.5	21.2	1.0	4.6	26 000	577.78
Fishmeal, local	57.8	10.9	NA	17.9	21 000	466.67
Fishmeal, imported	68.0	8.9	NA	13.0	33 000	733.33
Single cell protein						
Yeast	37.0	0.4	0.1	5.0	26 000	577.78
Oils and fats						
Fish oil, imported	NA	100.0	NA	NA	32 000	711.11
Fish oil, local	NA	100.0	NA	NA	26 000	577.78
Soy lecithin	NA	100.0	NA	NA	38 000	844.44

TABLE 11

Additives and other components used in the aquafeed industry in India

Additive/microingredient	Composition/details	Typical price/kg		Imported/local
		Indian Rs	US$	
Cholesterol	95 percent purity, used in shrimp feeds	2100	46.67	Imported
Mould inhibitor	Mixture of propionic acid and other organic acids and salts	100	2.22	Imported and local
Antioxidant	Mixture of BHT, BHA, ethoxyquin, etc	160	3.56	Imported and local
Pellet binder	Modified urea formaldehyde	120	2.67	Imported
Monocalcium phosphate	21-23% phosphorus	55	1.22	Imported
Dicalcium phosphate	18% phosphorus	16	0.36	Local
Limestone powder	Mostly used as a filler	2	0.03	Local
Mineral premix	Typical micromineral premix for fish feeds	22	0.49	Local
Salt	Feed grade	1	0.02	Local
Potassium chloride	KCl 50%	20	0.44	Local
Magnesium sulphate	$MnSO_4$ 31%	15	0.33	Local
Vitamin premix	Typical premix for fish feeds, without Vitamin C	220	4.89	Imported and local
Choline chloride		40	0.89	Imported
Vitamin C, coated	35% active ascorbic acid	360	8.00	Imported
Inositol		400	8.89	Imported

5. AQUAFEED PRODUCTION

It has been estimated that there is a need for approximately 2.59 million tonnes of aquafeeds in India (Table 12), although currently only some 200 000–250 000 tonnes are industrially manufactured. FCRs using farm-made feeds are 2–3 times higher than those achieved with manufactured feeds. On this basis, it was estimated that about 7.11 million tonnes of feed ingredients are used for the production of aquafeeds in India.

5.1 Feeds for freshwater fish farming

Almost all freshwater fish in Indian aquaculture are raised on farm-made feeds. Industrially manufactured feeds for carps are marketed by one major feed company (Godrej Agrovet Ltd) in Andhra Pradesh, Punjab and Tamil Nadu, on a trial basis. Limited experimental results are available, but at least one trial with grass carps indicates that FCRs of less than 1 are possible with manufactured feeds. The total volume of manufactured feeds sold for freshwater fish culture is estimated to be 10 000 tonnes/year.

As shown in Table 12, an estimated 6.83 million tonnes of ingredients are used to make farm-made feeds for fish production. Of this volume, at least 3 million tonnes are used to produce farm-made feeds for intensive carp production. In the Kolleru area of Andhra Pradesh, some 1.8 million tonnes of ingredients are used for the manufacture of farm-made carp feeds.

De-oiled rice bran is the major ingredient of all fish feeds in India and is used either singly or in combination with other ingredients. In the Cauvery delta, maize is ground and mixed with rice bran and groundnut cake to feed carps. The typical ratio of mixing is 2:1:1 of rice bran, maize and groundnut cake. In Andhra Pradesh, one or more of the following seven ingredients are mixed with rice bran to feed carps: rice polish, broken rice, groundnut cake, cottonseed cake, sunflower cake, meat meal and soybean meal. Veerina *et al*. (1993) observed that a combination of groundnut oilseed cake and rice bran was used by about 75 percent of farmers in the Kolleru area. A more recent survey indicated that the majority of farmers use a blend of rice bran, groundnut oilseed cake and cotton oilseed cake. The formulation and proximate composition of this feed are shown in Table 13.

TABLE 12
Estimated feed requirements based on aquaculture production in India in 2004

	Production (tonnes)	Type of Feed	Current FCR	Current volume of feed use (tonnes)	FCR of manufacured feed	Potential volume of manufactured feed (tonnes)
Fish						
Carps	2 026 327[1]	Farm-made[2]	3	6 078 981	1.0	2 026 327
Snakeheads	29 949	Farm-made	5	149 745	2.0	59 898
Catfishes	42 160	Farm-made	4	168 640	1.5	63 240
Other fishes	108 958	Farm-made	4	435 832	1.5	163 437
Total fish feeds				6 833 198		2 312 902
Crustaceans						
Freshwater prawns	38 965	Manufactured[3]	1.6	62 344	1.6	62 344
Penaeid shrimp	133 020	Manufactured[3]	1.6	212 832	1.6	212 832
Total crustacean feeds				275 176		275 176
Total aquafeeds				**7 108 374**		**2 588 078**

[1] Carp production data modified by subtracting 90 000 tonnes from FAO data for 2004 on the assumption that 90 000 tonnes are produced from stock-and-harvest fisheries that are not fed.
[2] About 10 000 tonnes of manufactured feeds are used in freshwater fish culture.
[3] Farm-made feeds are used in some prawn and penaeid shrimp farms in extensive farms in Kerala, Orissa and West Bengal. The exact volume of use is not known, but it is not likely to exceed 30 000 tonnes.
Source: FAO (2006) and as modified.

Many carp farmers in the Kolleru area feed their fish only with de-oiled rice bran and rice polish up to a size of 500 g, whereafter oil seed residues and other protein concentrates are added to the feed. The daily ration depends on fish body weight as shown in Table 14. More details on the composition of farm-made feeds and feeding practices may be found in Ayyappan and Ahamad Ali (2007).

The American Soybean Association (ASA) has been conducting trials in the Cauvery delta region of Tamil Nadu (Thanjavur district) to compare the performance of carps fed traditional farm-made feeds and an extruded floating feed. It is reported that the fish on extruded floating feeds reached market size (~450 g) earlier than fish on farm-made feeds and achieved a FCR close to 1:1, while the fish on farm-made feeds had a FCR of 2-3:1 (P.E. Vijay Anand, pers. comm.) The typical FCR of intensive carp culture systems using farm-made feeds ranges from 3 to 4:1. The cost of feed is typically Rs 13.5–15.75/kg of fish (US$0.3–0.35).

TABLE 13
Composition and estimated cost of farm-made feeds used in carp farms in the Kolleru area of Andhra Pradesh

Ingredient composition	Percent
De-oiled rice bran	80
Groundnut cake	10
Cottonseed cake	10
Proximate composition	
Crude protein	20
Crude fat	2
Crude fibre	15
Ash	17
Estimated cost (Indian Rs/kg)	4.5
Estimated cost (US$/kg)	0.1

Source: R. Ramakrishna, pers. comm. (2005).

TABLE 14
Daily ration for intensive carp farming systems in the Kolleru area of Andhra Pradesh

Fish size (kg)	Ration (% body weight/day)
<0.5	4.0
0.5–1.0	2.5–2.0
1.0–2.0	2.0–1.5
>2.0	1.5

5.2 Feed production for shrimp and prawns

India has a well-established capacity to produce feeds for shrimp and prawn culture. Until 1990 the sector relied solely on farm-made feeds. With the advent of large-scale semi-intensive shrimp culture in the early 1990s, vast quantities of shrimp feeds were imported from Taiwan Province of China and Thailand. However, imports have gradually been replaced by domestically produced feeds. Currently, the domestic shrimp feed manufacturing capacity exceeds demand. However, about 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. Additionally, about 30 tonnes of larval shrimp feeds are imported as India lacks the capacity to produce these specialty diets.

Many of the traditional, extensive shrimp and prawn farms in Kerala and West Bengal either provide no feed or only use farm-made feeds. Production from these systems is likely to be about 30 000 tonnes a year. However, the bulk (130 000–140 000 tonnes) of freshwater prawn and shrimp production is reliant on manufactured feeds. In 2004, an estimated 193 500 tonnes of prawn and shrimp feeds were manufactured and sold in India.

India has about 28 feed mills dedicated to the production of freshwater prawn and shrimp feeds (Table 15). Ten of these mills are subsidiaries to international aquafeed companies. Collectively, these companies account for 90 percent of shrimp and prawn feed sales in India.

Table 16 details the regional distribution of shrimp and prawn feed mills. It is apparent from this table that India has an excess shrimp and prawn feed manufacturing capacity. The installed capacity exceeds 500 000 tonnes per year, twice the current annual requirement. However, the shrimp feed business is highly seasonal (Figure 8). As a result, in the past disruptions in feed distribution have occurred periodically during the peak season (May–July). It is estimated that at the peak of shrimp production, the country requires about 1 100 tonnes of feed per day. The current installed capacity of 1 900 tonnes/day implies that supply disruptions are now less likely to occur. In spite of the adequate to excess capacity, many foreign feed manufacturers still consider India as a growing market in the shrimp feed business and are investigating the possibility of entering it directly or through a local partner.

TABLE 15
Companies involved in the production of freshwater prawn and marine shrimp feeds in India

Company	No. of plants	Description
CP India	2	Thailand-based multinational feed company
Avanti	1	Local company that has technology partnership with Thai Union, a leading feed company in Thailand
Waterbase	1	Local company that has technology partnership with INVE, a Belgian company specializing in *Artemia* and larval feeds
Higashimaru	1	Local company that bought technology and brand name licence from Higashimaru, Japan
Grobest	1	A multinational feed company based in Taiwan Province of China
Godrej Agrovet	1	The largest livestock feed company in India that has recently entered into a collaboration agreement with Uni-President of Taiwan Province of China, a multinational shrimp feed company
Gold Mohur	1	A subsidiary of Godrej Agrovet (previously owned by Hindustan Lever) that uses the brand licence of Hanaqua Feeds, Taiwan Province of China
Laila Global	1	Local company that has partnered with Global Feeds of Indonesia
Cargill Matrix	1	The largest livestock feed company in the world that has recently entered into a partnership arrangement with a local company
Local	18	Small-scale feed mills (average capacity 1 tonne/hour) that produce their own formulations or formulations provided by the farmers

Steam pelleting technology combined with post-pellet conditioning is used to manufacture prawn and shrimp feeds in India. Most feed mills have installed capacities for fine grinding, extended pre-conditioning (multipass, steam-jacketed conditioners with 1–2 minutes of retention time) (Figure 9), pelleting through die holes down to 1.8 mm and live-steam post-conditioning. Crumblers are used to produce particles for feeding PLs stocked in ponds.

Specifications used by manufacturers of prawn feeds are shown in Table 17. Nutrient density of freshwater prawn feeds is lower than that of marine shrimp feeds (Table 18). Indian shrimp farmers have high quality expectations. The feeds are expected to have at least three hours of water stability and low levels of fines. Farmers expect shrimp to grow to about 3 g in size after the first four weeks of stocking; thereafter they are expected to grow at a rate of 2 g/week until they reach about 25 g. After reaching 25 g, they are expected to grow at a rate of 3 g/week. In 2004, MPEDA released a set of quality specifications for shrimp feeds in India (Table 19). Compliance is voluntary at present. The specifications are considered incomplete because many key nutrients such as phosphorus and vitamin C have not been specified.

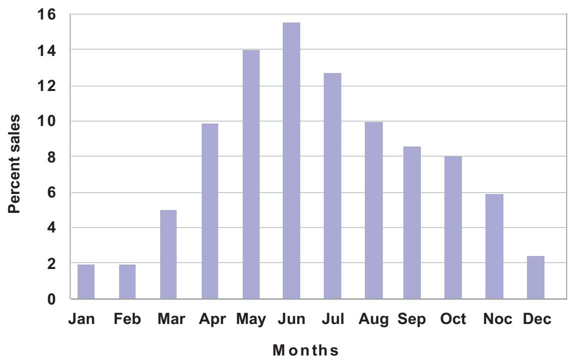
Farmers frequently topcoat the feeds with vitamins, minerals, squid oil, lecithin, *Spirulina*, probiotic bacteria and yeast, immuno-stimulants and feed attractants. Some farmers topcoat every feed they use. However, the majority only topcoat their feeds for use during specific production phases when they consider growth rates to be declining or when environmental conditions are unfavourable. Evaluation of the effectiveness of topcoating is lacking,

TABLE 16
Regional distribution of shrimp and prawn feed manufacturing plants in India

Region	Number of feed plants	Installed capacity** (tonnes/day)
Andhra Pradesh, northern*	10	740
Andhra Pradesh, southern	11	320
Tamil Nadu	6	720
Kerala	1	120
Total	**28**	**1 900**

* One feed plant located in the Union Territory of Pondichery has been included in the northern Andhra Pradesh .
** Estimate based on 20 work hours per day.

FIGURE 8
Monthly sales of shrimp feed in India



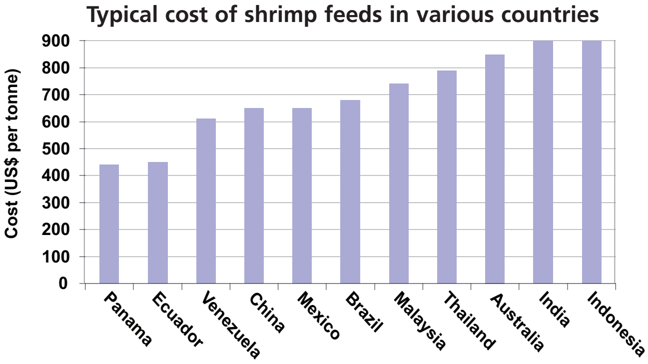
although some preliminary investigations reveal that most water-soluble vitamins and minerals are lost. It is estimated that top-coating typically increases the cost of feed by Rs 1 500 (US$33.33) per tonne.

The increase in global supply of farmed shrimp against a relatively stable demand in recent years has caused a gradual and possibly irreversible fall in the price of shrimp. As shrimp is a global commodity, producer countries need to be highly competitive. This competitiveness is even more important for countries such as India in which domestic consumption of shrimp is insignificant and which relies almost exclusively on exports. While India is competitive in terms of labour costs, it is highly uncompetitive with respect to feed and energy costs. Figure 10 shows that feed price is the highest among the major shrimp producing countries. This is in spite of the fact that India enjoys a competitive position with respect to the price of soybean meal and wheat in comparison with other major shrimp producers in Southeast Asia (Table 20). However, India is at a considerable disadvantage with respect to the price of fishmeal, all of which is imported, and for the tariffs imposed on imported additives. One should bear in mind, however, that *L. vannamei* is the predominant species in all major shrimp producing countries except Viet Nam, India and Bangladesh where *P. monodon* is still the dominant species. *L. vannamei* feeds are lower in nutrient density and quality when compared to *P. monodon* feeds and therefore cheaper.

FIGURE 9
Shrimp pellet mill with triple-pass conditioning

Steam pelleting technology combined with post-pellet conditioning is used to manufacture prawn and shrimp feed in India

FIGURE 10
Typical cost of shrimp feeds in various countries



Source: data collected by the author in 2004.

TABLE 17
Specifications commonly used for freshwater prawn feeds manufactured in India

Feed class	Target prawn size (g)	Feed type	Feed size (mm)	Crude protein (%)	Crude lipid (%)	Price/tonne*	
						Indian Rs	US$
Starter	0.5–5	Crumble	1.0–1.5	32–40	4–8	36 000–48 000	800–1 067
Grower	5–25	Pellet	2.0–2.3	24–30	3–4	24 000–36 000	533–800
Finisher	>25	Pellet	2.3	18–28	3–4	20 000–28 000	444–622

* Price range reflects protein content.

TABLE 18
Specifications commonly used for marine shrimp feeds manufactured in india

Feed class	Target prawn size (g)	Feed type	Feed size (mm)	Crude protein (%)	Crude lipid (%)	Price/tonne*	
						Indian Rs	US$
Starter	0.5–5	Crumble, short-cut pellets	0.5–1.8	40–44	6–8	44 000–48 000	978–1 067
Grower	5–20	Pellet	1.8–2.3	38–42	4–8	41 000–43 000	911–956
Finisher	>20	Pellet	2.3	36–38	4–8	38 000–41 000	844–911

* Range in price reflects range in protein level.

TABLE 19
Quality norms prescribed by the Marine Products Export Development Authority for shrimp feeds sold in India (percent dry matter basis except otherwise indicated)

	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 (kcal/kg of feed)	**3 200–3 600**	**3 200–3 600**	**3 200–3 600**
Essential fatty acid			
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**	**0.4**	**0.4**
Cholesterol	**0.5**	**0.2**	**0.2**
Astaxanthin (ppm)	**–**	**–**	**200**
Essential amino acid			
Arginine	2.03–2.32	1.74–2.03	1.74–2.03
Isoleucine	1.23–1.40	1.05–1.23	1.05–1.23
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	1.40–1.60	1.20–1.40	1.20–1.40
Tryptophan	0.28–0.32	0.24–0.28	0.24–0.28
Histidine	0.74–0.84	0.63–0.74	0.63–0.74
Lysine	1.86–2.12	1.59–1.86	1.59–1.86
Threonine	1.26–1.44	1.08–1.26	1.08–1.26
Valine	1.40–1.60	1.20–1.40	1.20–1.40

TABLE 20
Cost of feed ingredients (US$/tonne) in various Asian countries

Country	India	Thailand	Viet Nam	Malaysia	Indonesia	Philippines
Soybean meal (Hi-Pro)	297	348	348	324	300	357
Fishmeal (imported, S. American, prime)	733	740	736	661	675	622
Fishmeal (local)	467	666	536	500	545	505
Wheat flour	233	331	324	346	342	342
Import tariff on additives (%)	31.62	10.0	10.0	0	15.0	3.0

Source: data collected by author in 2004.

One of the highly significant factors influencing the price of shrimp feed in almost all of Asia is the cost of distribution. Unlike in Latin America, shrimp farming is largely in the hands of small- and medium-size producers. Farms that have 5–10 ponds each of 0.8–1.0 ha are typical of semi-intensive shrimp farms in India, whereas a typical South American farm is ten times larger in size. To cater to the small and medium farmers who are distributed widely and have no access to bank credit, feed companies in Asia rely on a distribution network. The feed distributors buy feed from the feed company on secured credit and store and sell it to the farmers on unsecured credit. Since the distributor is local, they have the ability to monitor the farmers' activities and know when and how to collect their dues. For this service, the feed company pays the distributor a commission of 12–15 percent on the retail price.

6. PROBLEMS AND CONSTRAINTS IN THE USE OF COMMERCIALLY MANUFACTURED FEEDS FOR SMALL- AND MEDIUM-SCALE AQUACULTURE

As discussed above, commercially manufactured feeds are widely used in freshwater prawn and marine shrimp farming in India. Farm-made feeds are used only in the traditional, extensive farming systems in Kerala and West Bengal. These systems are stocked at extremely low densities as the size and nature of the ponds (large, flood- or tidal-fed ponds) do not facilitate control of management protocols. Unless these systems are converted into manageable units, it is simply not viable to use commercial feeds.

For the small- and medium-scale farmers, who comprise the majority of the prawn and shrimp farmers in India, the major constraint in the use of commercially manufactured feed is the cost of production. The relatively constant feed price compared with falling shrimp prices means that feed cost as a proportion of total production cost continues rising to unprofitable levels. It is possible to reduce feed costs by by-passing the distribution network and buying directly from the feed manufacturer on a cash basis. For the small- and medium-scale farmers, such a bypass is not a realistic option as they lack the economy of scale and access to adequate credit. In such a situation, one of the following may occur:

1. The shrimp production and processing sector will start to integrate vertically to achieve higher efficiencies. A number of shrimp feed manufacturers in India already own hatcheries, farms and processing factories. A number of large shrimp producers already own or consider owning a feed manufacturing business. In this scenario, small- and medium-scale farmers will either sell their operations to the larger players or become contract producers.
2. Small- and medium-scale farmers will achieve better economies of scale through a cooperative form of collective bargaining and/or higher efficiency of feed use so that the proportion of feed cost to total feed cost is held in check.
3. The feed manufacturers will reduce their profit margins or improve their production and distribution efficiencies to pass on the margin differential to the farmers.

Scenarios (1) and (3) will depend on market forces, while scenario (2) will depend on deliberate policy intervention by government and other institutions (see recommendations).

Contrary to the prawn and shrimp farming sectors, fish farmers still rely mainly on farm-made feeds. The primary reason why manufactured feeds are not used in fish farming in India is the farmers' reluctance to use them based of the perception that they would not be cost-effective. This reluctance has in turn retarded the interest of feed manufacturers to develop and launch feeds for the fish farming sector. Preliminary information emerging from trials carried out by some of the large feed manufacturers and others (e.g. Godrej Agrovet and ASA) in India show that the perception of the farmers may not be correct. Under intensive farming conditions using current farm-made feeds at a cost of Rs 4–4.5/kg (US$0.08–0.10) the average FCRs range from 3 to 4:1. The cost of feed to produce one kg of fish is around Rs 14.00–15.75 (US$0.31–0.35). This means that an extruded feed with a FCR of 1:1 at a cost of Rs 13–14/kg (US$0.28–0.31) should theoretically be acceptable to the farmers. The recent drop in the price of extrusion plants made in China makes the prospect of affordable extruded feeds a real possibility. It is predicted that at least 30 percent of intensive carp, catfish and snakehead farmers are likely to use extruded feeds before 2010. This would equate to a production of about 250 000 tonnes of feeds, resulting in a doubling of the current level of aquafeed production.

The use of manufactured feeds would also lead to a reduction in water and pond substratum pollution, thereby reducing the costs associated with managing water quality and stress/disease, and this would facilitate higher stocking densities and yields. In addition, labour costs could be substantially reduced.

However, there are two major constraints to the use and manufacture of compounded feeds for fish farming in India. First, farmers are constrained by the low price of fish in certain markets and during certain times of the year such that they cannot afford manufactured feeds. Second, feed manufacturers are equally constrained by the buying power of the farmers, which reduces their flexibility with respect to the use of ingredients to produce cost-effective feeds. Remedial suggestions are provided in section 7.

7. RECOMMENDATIONS FOR IMPROVED UTILIZATION OF INDUSTRIALLY MANUFACTURED AQUAFEEDS

It is clear from the above synthesis that industrially manufactured feeds confer several microeconomic benefits. The lower FCRs achieved by the use of manufactured feeds leads to the improved utilization of national feed ingredient resources. Moreover, farming operations are simplified and streamlined leading to improved operational efficiency, higher yields per unit volume/area of water and higher profitability. Other benefits include improved fish quality, farm biosecurity and sanitation, etc. To improve the utilization of industrially manufactured feed, the following recommendations are made.

7.1 Freshwater fish culture sector

The primary and immediate need is to help farmers to understand the value of manufactured feeds. There have been some "on-farm" trials to demonstrate the performance of industrially manufactured extruted pellets in intensive culture of carps (see sections 5.1 and 6 for results of some of the trials conducted). Although some of these trials use a relatively expensive feed formulation, it is anticipated that a less expensive formulation could result in an equivalent economic performance. Trials with alternative, lower cost formulations will provide useful information for farmers and feed manufacturers alike. Research institutions working on freshwater fish nutrition need to place greater emphasis on understanding the nutrient composition of local, commercially available ingredients, such as de-oiled rice bran, rice polish, wheat bran, maize, sorghum, millets, broken rice, groundnut cake, cotton oilseed cake, soybean meal, sunflower meal, copra meal, maize gluten meal, local fishmeal, shrimp meal, blood meal, meat meal and feather meal. This would require closer collaboration between research institutions and the industry.

The long-term goal for improved utilization of feeds in freshwater fish farming is to improve the market price for fish. This goal is only possible through a systematic and sustained campaign to promote fish as food and ensuring that fish of a high quality are available to the consumer. The success of such an initiative requires all stakeholders (feed manufacturers, farmers, suppliers of other inputs to the farmers, and those in fish supply business) to unite and pool their resources. Broiler and egg producers in India have been successful in running and benefiting from such generic campaigns. Lessons can also be learned from generic promotion campaigns for soybeans, milk, cotton and catfish.

7.2 For the freshwater prawn and marine shrimp culture sector

The primary and immediate objective is to address those factors that have an impact on the price of feed. Among others these include:

1. The import tariff on additives is excessively high in comparison with other major shrimp producers in Asia and needs to be reduced.
2. The import permitting system for feed ingredients needs to be standardized and harmonized such that the importation process is free from unnecessary bureaucratic control.
3. It is possible that some of the available formulated feeds are overformulated for certain nutrients and ingredients. Facilities need to be established to conduct field trials. Creative solutions, such as the establishment of pubic / private entities, need to be found.
4. The nutritive value of locally available ingredients such as soybean meal, fishmeal, fish oil and shrimp meal may be improved by improving the processes used to produce these commodities. Policy-level initiatives such as technological assistance and incentives for processors would help.
5. The nutritive value of locally available ingredients such as coarse grains, grain by-products and oilseed residues for freshwater prawn and marine shrimp need to be established through research.

6. While scientists in research institutions such as the Central Institute of Brackishwater Aquaculture and the Central Institute of Freshwater Aquaculture have developed low-cost feed formulation options for shrimp and freshwater prawns, respectively, reliable feed performance data under field conditions prevent widespread use of such formulations. Closer collaboration between public institutions and the industry is required to achieve this goal.
7. Feed application research is necessary to improve the efficiency of feed utilization to reduce the cost of feed per unit of production. A study by Hari *et al*. (2004) is a case in point. They found that *P. monodon* raised on 25 percent protein feeds grew as fast as, or slightly better than, those raised on 40 percent protein feeds as long as the culture systems are provided with a source of carbohydrate (tapioca flour) to promote heterotrophic bacterial growth. A 35 percent reduction in feed cost and a 54 percent increase in revenue were recorded for the low protein feed plus carbohydrate treatment when compared to the high protein feeds alone.
8. A significant handicap for the small- and medium-scale farmers in managing the cost of feed is their lack of economies of scale and cheaper credit. Efforts should be made by the central and state government agencies promoting aquaculture to nurture the development of farmer cooperatives that would provide collective bargaining power for the purchasing of feeds, credit and other inputs.
9. Disease problems such as loose shell disease severely affect feed utilization. More resources should be employed on a timely basis to address such problems so that farmers can be educated on ways to prevent such outbreaks.

The long-term aim should include working towards and improvement in the market price for shrimp. While new export markets and opportunities need to be identified and opened, the biggest opportunity most likely remains at home. As the Indian economy improves and disposable income of the growing middle class increases, efforts to increase domestic consumption of shrimp and freshwater prawns are likely to be effective in increasing local demand. The generic campaign ideas discussed above for freshwater fish are also applicable to the shrimp and freshwater prawn sectors.

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REFERENCES

Ayyappan, S. & Ahamad Ali, S.A. 2007. Analysis of feeds and fertilizers for sustainable aquaculture development in India (this volume).

Ayyappan, S. & Diwan, A.D. 2004. Road map to increase fish production and productivity in India. *Fishing Chimes,* 24 (4): 24–26.

CLFMA (Compound Livestock Feed Manufacturers Association). 2005. *Summary report on feed in the 2005 Annual Meeting in Goa*. Mumbai, India.

FAO. 2006. FAO Fisheries Department, Fishery Information, Data and Statistics Unit. Fishstat Plus: Universal software for fishery statistical time series. Aquaculture production: quantities 1950-2004, Aquaculture production: values 1984-2004; Capture production: 1950-2004; Commodities production and trade: 1950-2004; Total production: 1970-2004, Vers. 2.30 (available at www.fao.org/fi/statist/FISOFT/FISHPLUS.asp)

Directorate of Economics and Statistics, Ministry of Agriculture. 2003. *Livestock census 2003*. Provisional report. New Delhi.

FAO. 2005. Fishstat Plus: Universal software for fishery statistical time series. Aquaculture production: quantities 1950–2003, Aquaculture production: values 1984–2003; Capture production: 1950-2003; Commodities production and trade: 1950–2004; Total production: 1970–2003. Vers. 2.30. FAO Fisheries Department, Fishery Information, Data and Statistics Unit, Rome (available at www.fao.org/fi/statist/FISOFT/FISHPLUS.asp).

Hari, B., Kurup, B.M., Varghese, J.T., Schram, J.W. & Verdegem, M.C.J. 2004. Effects of carbohydrate addition on production in extensive shrimp culture systems. *Aquaculture*, 241:179–194.

Hindu Survey of Indian Agriculture. 2004. Hindu Newspaper Group, Chennai, India.

Nath, D. & Das, A.K. 2004. Present status and opportunities for the development of Indian riverine, reservoir and beel fisheries. *Fishing Chimes*, 24 (1): 61–67.

Veerina, S.S., Nandeesha, M.C., Rao, K.G. & De Silva, S.S. 1993. *Status and Technology of Indian major carp farming in Andhra Pradesh, India*. Special Publication No. 9, Asian Fisheries Society, Indian Branch, Mangalore, India. 76 pp.

Veerina, S.S., Nandeesha, M.C., De Silva, S.S. & Ahmed, M. 1999. An analysis of production factors in carp farming in Andhra Pradesh, India. *Aquaculture Research*, 30: 805–814.

APPENDIX
Quality norms and standards of livestock feeds in India

A.1. Quality norms (% maximum) prescribed by CLFMA for dairy feeds

Characteristic	Dairy special feed	Type I feed	Type II feed	Type III feed
Moisture	12.0	12.0	12.0	12.0
Crude protein (dry matter basis)	22.0	20.0	18.0	16.0
Undegraded protein	8.0	-	-	-
Crude lipid	3.0	2.5	2.5	2.0
Crude fibre	7.0	7.0	12.0	14.0
Acid-insoluble ash	3.5	4.0	4.5	5.0

A.2. Quality norms (% maximum except otherwise indicated) prescribed by CLFMA for poultry feeds

Characteristic	Chick feed	Grower feed	Layer feed I	Layer feed II	Broiler starter feed	Broiler finisher feed	Breeder chick feed	Breeder grower feed	Broiler breeder feed	Layer breeder feed	Broiler male breeder feed
Moisture	12	12	12	12	12	12	12	12	12	12	12
Crude protein	18	14	16	14	20	18	18	14	16	16	14
Crude lipid	2	2	2	2	3	3	3	3	3	3	3
Crude fibre	7	8	8	10	6	5	5	7	7	7	7
Acid-insoluble ash	4	4	4	4	4	4	4	4	4	4	4
Metabolizable energy *(minimum cal/kg)*	2 600	2 300	2 500	2 300	2 600	2 700	2 600	2 400	2 500	2 500	2 400

A.3. Quality standards (% maximum) set by the Bureau of Indian Standards for poultry feeds

Characteristic	Broiler starter feed	Broiler finisher feed	Chick feed	Growing chicken feed	Laying chicken feed	Breeder layer feed
Moisture	11	11	11	11	11	11
Crude protein (N x 6.25)	23	20	20	16	18	18
Crude fibre	6	6	7	8	8	8
Acid-insoluble ash	3.0	3.0	4.0	4.0	4.0	4.0
Salt (as NaCl)	0.6	0.6	0.6	0.6	0.6	0.6

A.4. Quality standards set by the Bureau of Indian Standards for vitamins, minerals, amino acids and fatty acids in poultry feeds

Characteristic	Broiler starter feed	Broiler finisher feed	Chick feed	Growing chicken feed	Laying chicken feed	Breeder layer feed
Manganese *(mg/kg)*	90	90	90	50	55	90
Iodine *(mg/kg)*	1	1	1	1	1	1
Iron *(mg/kg)*	120	120	120	90	75	90
Zinc *(mg/kg)*	60	60	60	50	75	100
Copper *(mg/kg)*	12	12	12	9	9	12
Vitamin A *(IU/kg)*	6 000	6 000	6 000	6 000	8 000	8 000
Vitamin D_3 *(IU/kg)*	600	600	600	600	1 200	1 200
Thiamine *(mg/kg)*	5	5	5	3	3	3
Riboflavin *(mg/kg)*	6	6	6	5	5	8
Pantothenic acid *(mg/kg)*	15	15	15	15	15	15
Nicotinic acid *(mg/kg)*	40	40	40	15	15	15
Biotin *(mg/kg)*	0.2	0.2	0.02	0.15	0.15	0.20
Vitamin B_{12} *(mg/kg)*	0.015	0.015	0.015	0.01	0.010	0.01
Folic acid *(mg/kg)*	1.0	1.0	1.0	0.5	0.5	0.5
Choline *(mg/kg)*	1 400	1 000	1 300	900	800	800
Vitamin E *(mg/kg)*	15	15	15	10	10	15
Vitamin K *(mg/kg)*	1.0	1.0	1.0	1.0	1.0	1.0
Pyridoxine *(mg/kg)*	5	5	5	5	5	8
Linoleic acid *(mg/kg)*	1	1	1	1	1	1
Methionine + cystine *(g/100 g)*	0.9	0.7	0.6	0.5	0.55	0.55