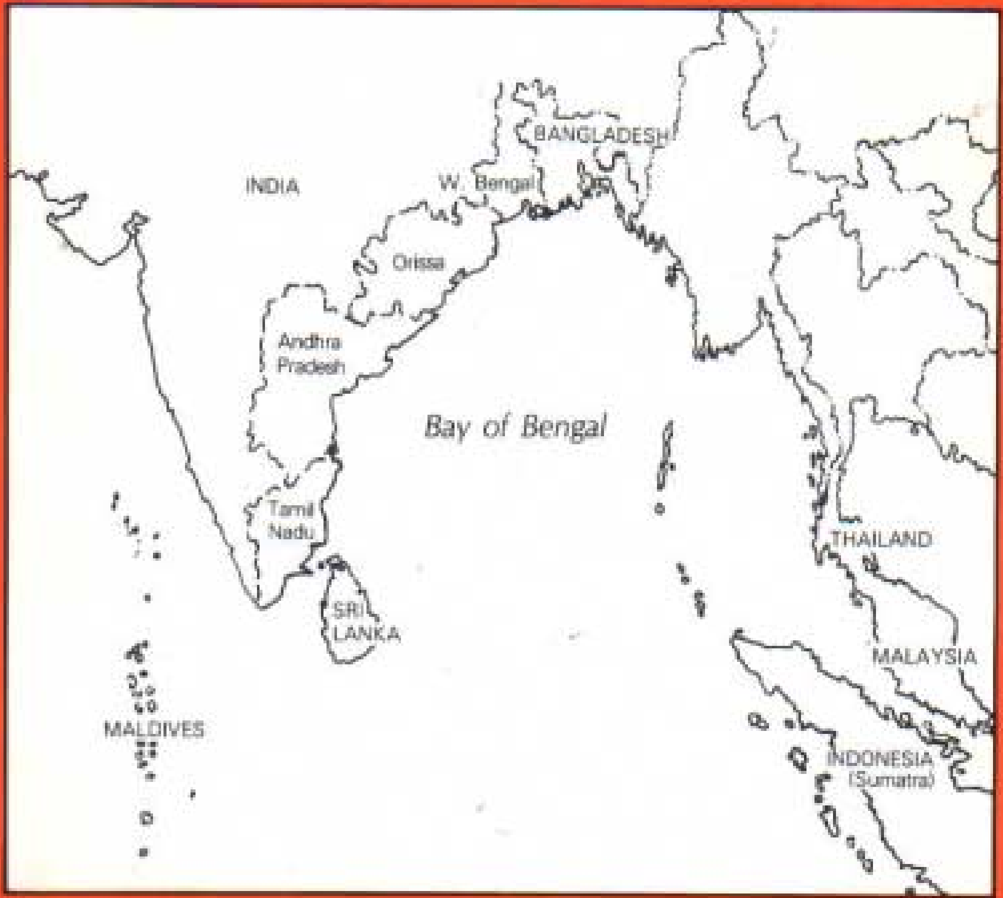
BOBP/REP/52

Feeds for artisanal shrimp culture in India — Their development and evaluation



BOBP For Fisheries Development
BAY OF BENGAL PROGRAMME

Feeds for artisanal shrimp culture in India — Their development and evaluation

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BAY OF BENGAL PROGRAMME
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In 1989, the Indian Council for Agricultural Research (ICAR) approached the UK Government-funded Post-Harvest Fisheries Project of the FAO's Bay of Bengal Programme (BOBP), based in Madras, for assistance in the formulation, manufacture and feeding trial evaluation of feeds for the artisanal culture of shrimp in India.

This report presents the findings of a collaborative programme conducted during 1989-91. It has been prepared in the hope that it will further stimulate the development of local shrimp feed manufacture and the artisanal shrimp culture industry in India. The case study is not, therefore, a reference text on the subject of shrimp feed production and evaluation, but a distillation of field experiences and results upon which new research and farm studies can be based.

The report describes the Indian shrimp culture industry, the principles and practices used within the project for the formulation of shrimp feeds, the principles and practices of pond environment assessment, feed manufacture and feed evaluation by feeding trial, a financial appraisal of the feeding trials and recommendations for further studies.

The Bay of Bengal Programme (BOBP) is a multi-agency regional fisheries programme which covers seven countries around the Bay of Bengal — Bangladesh, India, Indonesia, Malaysia, Maldives, Sri Lanka, Thailand. The Programme plays a catalytic and consultative role : it develops, demonstrates and promotes new techniques, technologies or ideas to help improve the conditions of small-scale fisherfolk communities in member-countries. The BOBP is sponsored by the governments of Denmark, Sweden and the United Kingdom, by member-governments in the Bay of Bengal region, and also by AGFUND (Arab Gulf Fund for United Nations Development Organizations) and UNDP (United Nations Development Programme). The main executing agency is the FAO (Food and Agriculture Organization of the United Nations).

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Abbreviations

ICAR : Indian Council for Agricultural Research, Delhi.

CIBA : Central Institute for Brackishwater Aquaculture, Madras.

MPEDA : Marine Products Export Development Authority, Cochin.

IAS : Institute of Aquaculture, University of Stirling, FK9 4LA, Scotland.

NRI : Natural Resources Institute, Chatham Maritime, Kent ME4 4TB, England.

CIFT : Central Institute of Fisheries Technology, Kochi.

1. INTRODUCTION

With the Government of India seeking to expand shrimp culture as a means of providing new labour opportunities in rural coastal regions, the culture of shrimp in brackishwater ponds in India is steadily increasing. To encourage shrimp culture, the Indian and state Governments have commenced a programme of opening up saline coastal lands for low-cost leasing for artisanal shrimp culture. But yields/ha, in the farms of India, are relatively low. Typical yields are 400-600 kg/ha/annum from a single harvest, compared with up to 12,000 kg/ha/harvest from intensive culture in Taiwan.

Storage of juvenile shrimp for growing out to market size is one of the factors limiting shrimp culture development. Some progress is now being made to meet the increasing demand for juveniles through the establishment of private and Government funded shrimp hatcheries. There is, however, an urgent need to develop shrimp feed processing technology and formulations which are appropriate to India's needs and culture practices.

The study reported on here was directed towards the development of feeds for artisanal shrimp culture. This sector is attempting the transition from minimal input, extensive shrimp culture to that of low input, semi-intensive culture. However, since shrimp feeding is only one component of shrimp culture management, it was considered necessary to also examine the way in which the pond environment and its management had an impact on feed utilization by shrimp.

The initial hypothesis put forward in establishing these trials was that the provision of improved quality feeds, with a minimum change in pond management practices, should enable shrimp yields of 1000-1500 kg/ha to be obtained from a single harvest. The extent to which this hypothesis was confirmed is examined in this case study.

Details of the specific project objectives are presented in Appendix I.

To whom is this case study directed?

- **To policy makers** concerned with the development of artisanal shrimp culture in India – to assess the impact on feed resources, and the opportunities and problems of shrimp culture expansion.
- **To the feed industry** – by outlining problems of feed formulation and manufacture, and to present a clearer picture of the farming systems in which any manufactured feed must compete.
- **To researchers** – to add to the present literature on artisanal shrimp studies and to suggest possible new areas of study.
- **To extension workers and shrimp farmers** – to assist them in identifying the most limiting factors to making a profitable family business through artisanal shrimp culture in India.

1.1 Summary of findings

The consensus among many Indian researchers and shrimp farmers interested in the development of shrimp feeds for indigenous shrimp culture is that artisanal feeds prepared from trash fish, rice bran and oilcakes are poor sources of nutrients for shrimp, and that what farmers need is a feed of higher nutrient specification. Typical yields from artisanal culture after a 120-140 day growing season are 400-600 kg/ha/harvest, there being only one harvest each year. Typical stocking density is five animals/sq m. *(P monodon)*.

An initial, small pond (18 ponds x O.O27ha/pond) feeding trial in West Bengal using experimentally pelleted feed of 35 per cent protein, and a stocking density of ten animals/sq m yielded the equivalent of 710 kg/ha in 80 days at a feed conversion ratio (FCR) of 2.9. The same feed formulation presented in a powder-based doughball form yielded the equivalent of only 440 kg/ha at an FCR of 3.3. This trial indicated that the experimental doughball was performing similarly to artisanal feeds and the pelleted feed, when fed over a full growing season with shrimps stocked at twice the normal stocking density, had the potential to more than double shrimp yields from the pond. (Results are means from at least two ponds; FCRs were calculated on a dry feed basis.)

A second stage, large pond (0.75ha/pond) feeding trial in Andhra Pradesh was designed to evaluate the performance of the pelleted feed and powder-based doughball under management procedures adopted by local shrimp farmers. The performance of shrimp fed the experimental feeds was also compared with shrimp fed a trash fish and rice bran based feed, prepared and fed according to practices adopted by local farmers. Stocking density was ten animals/sq m.

A harvest of 1345 kg/ha equivalent was obtained within a 143-day growing period from shrimp fed the experimental pelleted feed. This compared well with the extrapolated yield from the small pond trial and was two to three times the average yield from ponds using supplementary feeding. The harvest from the powder-based, doughball was 950 kg/ha equivalent, again comparable to an extrapolated small pond trial result. FCRs were, however, poorer at 4.4 and 7.0 for the pellets and powder-based, doughball respectively.

The unexpected result from this trial was the yield of 1410 kg/ha equivalent from ponds fed the local, moist feed. This yield also surprised our collaborating scientists, since yields of this level had not previously been noted. The feeding regime for this local feed was similar to that of pellets and powder-based, doughballs. Since the composition of the local feed varied from day to day according to the availability of raw materials, an assessment of its typical composition could only be made at the end of the trial. The feed had an average crude protein content of 26 per cent, and the apparent FCR on a dry feed basis was 5.6.

Pond pollution in the large pond trial (as evidenced by the degree of blackness of the pond bottom mud) was most prominent in ponds using the powder-based, doughball and the local, moist feeds. The water-stable pellet appeared to produce little blackening of the mud, and thus, from a pollution prevention aspect, pelleting would appear to be highly desirable.

A financial analysis of the feeding trial results indicated that for the pelleted feed to be cost effective, its price would need to be reduced from 15 Rs/kg to 5.5 Rs/kg.

On the assumption that the nutrient requirements for shrimp can be provided in a feed of dry form, but of comparable composition to the local, moist feed, feed manufacturers may then be able to prepare feeds at a price which is competitive with the use of moist feeds. This requires experimental confirmation. Appropriate feeding strategies have been suggested.

The environmental factor which appeared to limit shrimp growth during the latter stages of both the small pond and large pond trials was low dissolved oxygen (DO) levels in pond waters. This was due in part to low DO in the pond's incoming supply water, to oxygen demand for the decomposition of unconsumed feed, and to the higher-than-usual stocking density for shrimp. Occasional water aeration by pumping was necessary for the high yielding ponds during the final 2-3 weeks prior to harvest, when pond DO levels were below 3ppm.

The trials reported in this case study indicate that high nutrient-density diets, as used for intensive shrimp culture, appear to be inappropriate for artisanal shrimp culture in India. The use of lower nutrient specification diets could result in substantial reductions in the cost of production of pelleted shrimp feeds. Their development would improve the availability and distribution of feed raw materials to an expanding shrimp-farming market, enable shrimp farmers to feed a product of constant quality, considerably reduce the time required for feed preparation and reduce the risk of pond pollution.

2. A GENERAL OVERVIEW OF SHRIMP CULTURE

2.1 Worldwide shrimp culture

Shrimp has proved to be one of the great aquaculture cash crops of the 1980s and a source of prosperity in a number of developing countries. This has happened because supplies of wild, caught shrimp have stagnated, with catches around the world approaching, or even surpassing, their maximum sustainable yields. Since 1977, world landings have stabilized in the region of 1.6 million t/yr. (See Table 1 for production by the major shrimp suppliers to the world market.)

Table 1 : Shrimp production of major world suppliers

Country	Typical producrion 1985[2] (t/ha)	Aguaculture production 1986[2] (1000 t)	Marine landings 1986[3] (1000 t)
India'	0.4	17	201
Taiwan	7.7	65	55e
Thailand	0.4	16	117
China	0.7	70	230e
Indonesia	0.2	48	112
Ecuador	0.6	36	—
Philippines	0.2	9	76
Japan	6.0	1	59e

Ref. [1] Csavas (1988); [2] Liao (1988); [3] MPEDA (1987); e = estimate

However, demand is income-elastic and shrimp consumption has continued to grow, spurred on by the generally increasing prosperity in the major industrialized markets. During the 1970s and 1980s, countries able to develop a shrimp culture industry found a seller's market as they plugged the gap between wild, caught supply and demand. World aquaculture production has soared, growing from 25,000 t in 1975 to 340,000 tin 1987, accounting for 16 per cent of the total harvest in the latter year. However, the early 1990s have seen alevellingin demand for shrimp and a fall in prices in the world market. This development may, therefore, limit the extent to which shrimp production in India through aquaculture can expand.

2.2 General classification of shrimp culture systems

Shrimp culture operations can, in general, be broadly classified into three categories: extensive, semi-intensive and intensive. The characteristics of the three systems are indicated in Table 2.

Table 2 : General classification of shrimp culture systems

	Extensive	Semi-intensive	Intensive
Stocking density (shrimp/sq m)	0.3-2	2.5-8	>10
Water management	Tidal + Pump	Pump	Pump t treatment
Aeration	No	Some	Yes
Fry source	Wild or hatchery	Wild or hatchery	Hatchery
Feed	Natural feed through fertilization	Fertilization with supplementary feed (fresh/formulated)	Formulated
Crops/year	1-3	2	2-2.5
Production t/ha/yr	0.3-0.8	1-3	8-12

(Kungvankij P and Kongeo H, 1988)

Intensive production is characterized by a high level of investment and technical expertise and takes place mainly in Taiwan and Japan. In the Philippines, Thailand, Indonesia, and Malaysia, there are increasing moves towards intensification. By way of contrast, many farms in Latin America and China have adopted semi-intensive methods.

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Liao I-C, (1988) History, present status and prospects of prawn culture in Taiwan, p. 195 in Shrimp '88 *(ibid.)*

Kungvankij P and Kongeo H. (1988) Culture system selection, p. 123 in *Shrimp '88, (ibid.)*

MPEDA : Personal communication — data for 1987.

3. THE SHRIMP CULTURE INDUSTRY IN INDIA

3.1 Shrimp production

India is one of the world's larger shrimp exporters with an estimated annual production, in 1987/88, of 245,000 t. Approximately 215,000 t of this was sea-caught shrimp, the remaining 30,000 t coming from brackishwater culture in West Bengal, Andhra Pradesh, Kerala and Goa (Chong Kee-Chai 1991). But the sea-caught harvest, by far the primary source of foreign exchange for the shrimp industry, has remained constant over the last 5-10 years. Much interest is, therefore, being directed towards expanding shrimp production by culture, both in terms of the area of water under culture, and the yield/ha.

India's production of cultured shrimp has expanded rapidly during the last 13 years, with output rising from about 4,000 t in 1975 to 17,000 t in 1985 and at least 24,000 t in 1988. Notwithstanding this remarkable achievement, India's rate of growth in shrimp production has been slower than in a number of Asian countries which have moved faster to fill market requirements.

In 1975, India was Asia's (indeed the world's) second highest producer of cultured shrimp, but by 1985 her position had fallen to sixth in Asia and seventh in the world due, in part, to Ecuador's rapid expansion in prawn productivity (see Table 1).

Shrimp yields from pond culture in India are, however, low, averaging 500kg/ha/crop, although this is comparable with yields from extensive culture in other countries such as Indonesia or the Philippines.

However, for five months of the year, the monsoon rains lower pond and estuarine water salinity to levels below which shrimp culture is practically not viable. India's shrimp farmers are, therefore, limited to only one major growing season a year. Despite this difficulty, an increasing number of shrimp farmers, in Andhra Pradesh In particular, are attempting to culture a second, low-input crop when the water salinity is low but the price of shrimp juveniles is also low.

3.2 Traditional shrimp culture practices

3.2.1 EXTENSIVE SHRIMP CULTURE IN WEST BENGAL

The culture of shrimp in West Bengal has, traditionally been associated with rice production, whereby rice was intercropped with naturally stocked fish and shrimp seed which had been washed over the ricefield perimeter bunds during high tides. This type of culture is termed bheri culture, after the local name for the large, flooded ricefields. Impoundments or bheris may range in size from 1 to 200 ha of water without subdivision, although IO ha could be considered to be a 'typical' farm size.

In traditional bheri culture, no feed supplementation is practised. Shrimp and fish growth are dependent upon natural pond fauna and flora as the sole feed sources. Some enterprising shrimp farmers in West Bengal are also supplementarily stocking their tidal ponds with wild or hatchery-reared shrimp post-larvae at a stocking density of 55,000/ha (56/sq m).

3.3 Recent developments in shrimp culture

3.3.1 FEEDING PRACTICES

The most rapid developments in shrimp culture have occurred in Andhra Pradesh. Here there has been no history of rice-cum-fish/shrimp culture and the otherwise unproductive saline coastal lands have been converted to brackishwater ponds.

Farmers adopting supplementary feeding practices use mixtures of oil cakes, rice bran, locally available snail, clam or mussel meat, and buffalo meat. Some examples of feed mixtures are presented in Table 3. Mollusc and buffalo meats are often pre-cooked and minced to a paste. A blend of these raw materials may then be mixed with cooked tapioca (cassava) as an adhesive binder. Moulded paste balls are placed in pottery bowls at marked feeding sites (approximately 30/ha), and feed consumption is examined at 2-3 hourly intervals.

Table 3 : Typical shrimp feed mixes

	Mix 1	Mix 2	Mix 3
Groundnut meal	10%		
Cooked buffalo meat		40%	
Rice bran	60%	60%	50%
Soyabean meal	20%		
Groundnut cake			20%
Tapioca (cooked)	10%		
Dried shrimp head waste			20%
Clam meat			10%

Towards the end of the shrimp growing period, a low percentage of locally available dried trash fish may be added in the feed mixtures in an attempt to boost shrimp growth.

Feed conversion ratios using these feeds are very variable even on the same shrimp farm. Some farmers indicated that feed conversion ratios of 10 kg moist feed/kg shrimp growth were commonplace, especially during periods of low water salinity.

3.3.2 RAW MATERIAL SHORTAGES

A particular problem with formulations based on molluscs is that they are not sustainable in the long term. They depend on scarce proteinaceous ingredients whose availability cannot sustain a major increase in demand.

Obtaining raw materials of animal and marine origin for shrimp feed preparation is becoming increasingly difficult as the number of operational shrimp ponds rises. Often there is considerable competition for the limited quantities of trash fish available, particularly when fishing boats are unable to go to sea because of bad weather. At these times, shrimp farmers may use sundried fish as an alternative to fresh trash fish. There would appear to be no long-term opportunities for large increases in fishmeal production within India. (The problem of competition for fishmeal by the poultry sector is discussed in section 3.7.)

Supplies of beef from buffalo or cattle are also erratic, as beef availability is dependent upon the variability in the demand for skins by the leather industry.

The method of feed preparation is very time-consuming. Common experience shows that approximately six man-hours daily are needed for the preparation of sufficient feed for a 1 ha pond. A further three man-hours may be required for the daily collection of trash fish and beef.

3.4 Problems of environmental concern

Although the artisanal and landowner shrimp farmers have demonstrated to their own satisfaction the short-term profitability of using moist feed mixtures, many farmers are concerned at the increasing problems of deterioration in pond water and sediment quality arising from feed disintegration and decomposition.

Of equal concern is the practice of discharging pond effluent into the channels which also serve as the source of incoming ‘clean’ water.

Since the tidal amplitude of many of the supply creeks is low, and sedimentation rates are high (due to both natural processes and anthropogenic effects), the potential for adequate water exchange is steadily decreasing. Without improved pond planning, this problem will be compounded as the number of shrimp farmers attempting to culture shrimp increases. This practice also becomes of major importance should shrimp disease outbreaks occur in a locality.

The problem is re-examined in paragraph 7.3 in the light of the results from the feeding trials.

3.5 Manufactured shrimp feed and its potential demand

In addition to the provision of land and seed, the Government of India has identified the need to provide feed for shrimp culture. This requirement has been recognized for some years, but, to date (1991), there is no established shrimp feed manufacturing industry in India.

There is a general conception by Indian shrimp farmers that local moist feeds do not produce the shrimp yields that they anticipate, and that manufactured feeds in pellet form of high nutrient quality and water stability would give improved yields comparable to those in other shrimp-producing areas of the world. Shrimp farmers are, however, unwilling to pay the price for imported feeds which meet this criteria, and locally manufactured pelleted feeds are considered to be of low water-stability, poor nutritional quality, untested and too expensive. There is, therefore, a need to determine the extent to which the Indian shrimp industry can benefit through the use of high-quality feeds. Since the Government of India foresees an important role for the artisanal shrimp farmer in shrimp culture expansion, it is important that the farmer is provided with appropriate technology for controlling pond inputs, including the possible preparation of feeds from local raw materials.

The desire to develop water stable feeds of proven, consistent quality, but at the right price, remains, therefore, a prime objective of the Government of India.

3.5.1 POTENTIAL FUTURE DEMAND FOR SHRIMP FEED IN INDIA

Forecasting the demand for shrimp feed is difficult, but if Indian manufacturers were to supply a feed of proven quality and at a reasonable price, it might, at the present rate of shrimp farm development, be adopted by 1993 for regular use in 8000 ha. This area is about 15 per cent of the total area currently under culture, or about half the area belonging to farmers registered with MPEDA in 1990. The potential feed demand can be estimated if a number of assumptions are made. For example, assuming that

- the annual yields/ha were to commence at 800 kg, and rise at five per cent/annum throughout the 1990's;
- the apparent feed conversion ratio was 2.5 : 1;
- the total area under culture was increasing by five per cent/annum, and
- the proportion of farmers using supplementary feed was rising by 10 per cent/annum (i.e. there is a 20 per cent compound annual growth in demand and the area using supplementary feed would be increased to 28,000 ha in ten years),

THEN, the annual feed demand would rise to about 82,500 t over that period.

Given the number of imponderables, there is a considerable margin of error in such estimates. However, it should be noted that even if demand for shrimp feed were to increase to 80,000 t it would still be only 2.5 per cent of the 1990 demand for poultry feed.

The implication of these findings is that shrimp culture is unlikely to greatly affect supply and demand for many of the feed ingredients which are used in large quantities for poultry and other livestock feeds. However, an expanding poultry feed market faced with raw material shortages could well deprive a developing shrimp feed industry of some of its key raw materials.

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3.6 Current proposals and developments

Experience in other Asian countries suggests that India will progressively move from extensive to semi-intensive culture using supplementary feeds, and that the Taiwanese model of intensive culture will be adopted by only a few farms with sufficient capital and expertise. Moreover, under the conditions of depressed prices which are likely to pertain in the 1990s due to over-supply in the shrimp market, there may be sound economic reasons for preferring extensive/semi-intensive as opposed to intensive production systems.

Although some Indian shrimp culturists have looked enviously at the high yields of shrimp obtained by intensive culture in countries such as Taiwan (at up to 12 t ha/harvest and 2-3 harvests/year), the Government of India has taken a more realistic approach in seeking to find appropriate means of increasing yields from a typical 500 kg/ha, to 1000 to 1500 kg/ha on a low input, sustainable basis. Simultaneously, the Government of India is opening up new lands for the construction of shrimp ponds for use primarily by financially weaker groups. Under the Government of India guidelines, new lands must be apportioned in the following way :

- 60 per cent to financially weaker groups, including fisherfolk, scheduled caste groups and those of any caste with an income of less than Rs 6000/annum;
- 20 per cent self-employed technocrats; and
- 20 per cent larger entrepreneurs.

Expansion of shrimp culture has occurred most rapidly in Andhra Pradesh. By 1990, approximately 6,000 ha of land were under shrimp culture, although 23,000 ha have been identified for potential pond development. Expansion is planned for, and being implemented, in other coastal states.

In seeking to establish new ponds, the Government of India is taking precautions against the destruction of the coastal mangroves, which are the natural breeding grounds of marine shrimp, by siting new ponds away from such areas.

Shortages of shrimp seed are being addressed through the construction of shrimp hatcheries in both the private and Government sectors, e.g. MPEDA hatcheries at Gopalpur, Orissa, and Mangamaripet, Andhra Pradesh, which use French and American hatchery technology respectively.

3.7 Shrimp feed ingredients

The nutritional requirements of aquatic organisms vary greatly from those of terrestrial animals, interms of both the balance and structure of macro- and micro-nutrients.

However, some of the major ingredients which have been recommended in the technical literature for the manufacture of shrimp and fish feeds are the same as for farm animals, particularly poultry. However, because of certain specific nutrient requirements of shrimp – for example, to enable good exoskeleton moulting and regeneration – and the desirability to make feeds attractive to the slow-feeding shrimp, some less common materials have also been recommended for inclusion in feeds.

Since it is generally accepted that shrimp feeds fed under intensive or semi-intensive shrimp culture should be water stable for a minimum of two hours, raw materials and manufacturing processes must also be selected in terms of their ability to induce water stability.

In terms of raw material requirements for shrimp grown under semi-intensive/intensive culture, the most critical are the marine proteins and oils, the major sources in India being fish meal, shrimp heads, small non-penaeid shrimp, meat from bivalve molluscs and snails, squid processing waste and squilla (stomatopods). Unfortunately these materials are available only in limited quantities. This is particularly the case with fish meal, because it is an essential source of protein in alternative animal feeds. In contrast, oilseed meals and cereals are in abundant supply, though there will be competition between the poultry and the expanding shrimp industry for those materials of high protein quality which are least available (i.e. soya and sesame meals as plant sources of lysine and methionine/cystine, respectively).

Ingredients for low inclusion level, but which are essential for most diets — such as fish oils, phospholipids and sterols for good skeletal moulting, vitamin and mineral mixtures and polymer binders — may need to be imported.

However, in presenting this list of recommended ingredients, it must be emphasized that the nutrient requirements of shrimp grown under differing culture systems is not fully known. (This aspect is considered in more detail in sections 4.1 and 4.2 concerning feed formulation. Recommended nutrient levels for intensive shrimp culture are listed in Table 9.)

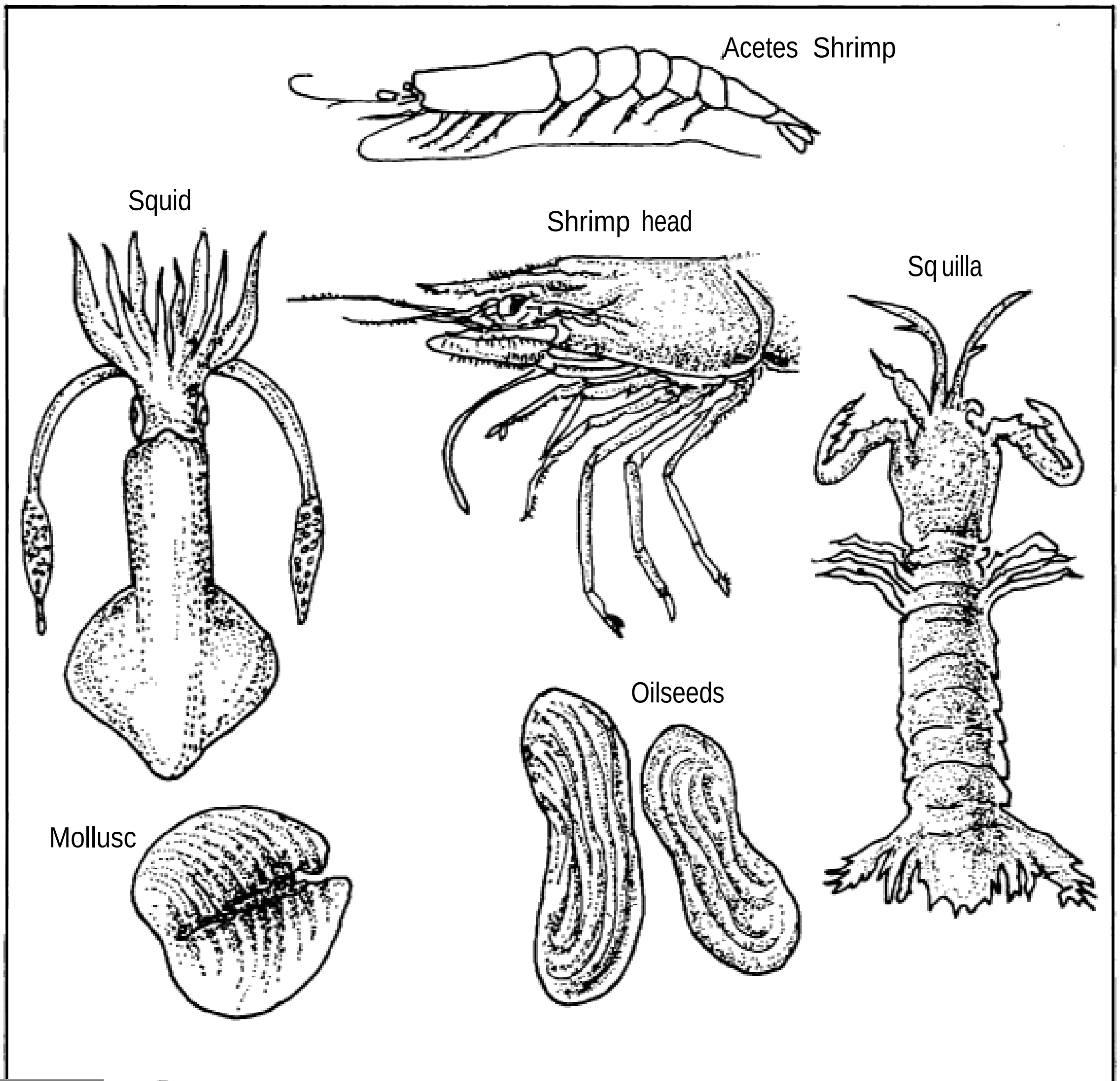
Potential sources of shrimp nutrients within India are given in Table 4 and Fig 1. Raw material availability and competitive users are quantified in Table 5. (See facing page.)

3.7.1 FISHMEAL

Composition of fishmeal

Fishmeal is made almost exclusively from small demersal fish and shellfish brought in as by-catch — and not used for direct human consumption — as well as with some processing waste and some

Fig. 1 **Possible raw materials for the manufacture of shrimp feed** in India



'functional' properties of the protein to form an omelette will have been lost. The same is true for proteinaceous raw materials for feed preparation by extrusion cooking which have received heat treatment prior to extrusion.)

Much has been written about the cooker extrusion of foods rather than feeds, but detailed discussions of the thermodynamics and engineering aspects of the process are not appropriate in this publication. Readers interested in cooker extrusion should refer to the bibliography.

Extrusion processing is a potentially versatile process for shrimp feed manufacture. Capital equipment is expensive and may need to be imported if process trials in India are to be fully conducted. Brief preliminary processing trials in India using a snack food extruder were unsuccessful and are not described in this case study.

Moist feed-doughballs

The process of moist feed preparation as practised in India has been outlined in Section 3.3. Details of this method of preparing feeds for a feeding trial are described in Section 6.2.

4.4 Practical feed manufacture

The stages of processing for the preparation of the experimental pelleted feed were:

1. Raw material pre-blending and grinding
2. Pulverization
3. Mixing
4. Pelleting
5. Cooling
6. Crumbling
7. Packing

The experimental feeds were prepared in a commercial cattle feed mill to the formulation given in Table 10, and to mantifacturing specifications set by the authors as described below.

4.4.1 PELLET BINDER SYSTEM

For manufacturing purposes, wheat flour was selected because of the binding effect of wheat gluten, althought the primary binding system was through the conversion of a viscous solution of sodium alginate (a seaweed extract) into an insoluble gel of calcium alginate. In this process, Plaster of Paris (calcium sulphate) was the slow-release calcium source to bring about the alginate-setting reaction. It also has an independent binding role, similar to its use as a building plaster.

[Although the inclusion of Plaster of Paris into a shrimp feed increased the total calcium level to beyond that which was nutritionally desirable, much of the calcium was considered to be nutritionally unavailable because of its low solubility. (The high calcium levels may have also complexed with phosphorus, but these aspects require confirmation by further experimentation.)]

To permit the alginate reaction to work correctly for the manufacture of ring die pellets it was important to prepare the raw materials in two main blends, 'A' and 'B' for grinding and pulverization.

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The grinding blends were :

Blend ‘A’ — Wheat flour, soya meal, broken rice.

Blend ‘B’ — Fishmeal, shrimp head meal, squid meal.

Blend ‘B’ was high in calcium, albeit of low solubility as calcium carbonate and calcium phosphate in shrimp head and fishmeal respectively, and was kept separate from ‘A’ until the appropriate point in the mixing cycle (Figure 2).

4.4.2 PRE-BLENDING AND GRINDING: PROBLEMS AND SOLUTIONS

The grinding of feed raw materials to a fine particle size is essential if shrimp are to receive a true mix of nutrients from compounded feed. Ideally, particle size should be less than 300 microns, but to achieve this degree of fineness, raw materials may require a two-stage size reduction, particularly if materials are initially of widely varying size and texture/grinding characteristics. In the processing trials the following procedures were adopted:

Marine proteins:

The fibrous nature (fish muscle fibres) and high proportion of scales in sun-dried Indian fishmeals, and the leather-like texture and large piece-size of dried squid (cuttlefish) preclude them from fine grinding unless milled as a blend with more easily ground materials. The dietary proportions of fishmeal, shrimp head meal and dried squid were therefore blended in a horizontal mixer (17 rpm) for three minutes and ground through a hammer mill fitted with an 8mm screen, to a flowabte, coarse meal.

Plant materials :

Wheat *atta* (multipurpose flour of appoximately 80 per cent extraction), soyabean meal and broken rice were similarly pre-blended. Grinding the mixture through an 8mm screen was not necessary prior to pulverization.

4.4.3 PULVERIZATION

Test Runs : Samples of mixed plant materials (Mix A) and coarse ground marine materials (Mix B) were ground first through a hammer mill fitted with a 2 mm screen, then through a plate mill, to determine if the fineness of grind was sufficient for shrimp feed manufacture. The products were, however, too coarse, particularly for feeding to post-larvae. The blends were, therefore, pulverized in a hammer mill/pulverizer fitted with broad faced hammers and adjustable breaker plate (Singhasini Ltd, Vishnapuram, Kanpur). (See Table 11)

Table 11 : Sieve profiles of ground and pulverized feed mixtures (% retained on sieve)

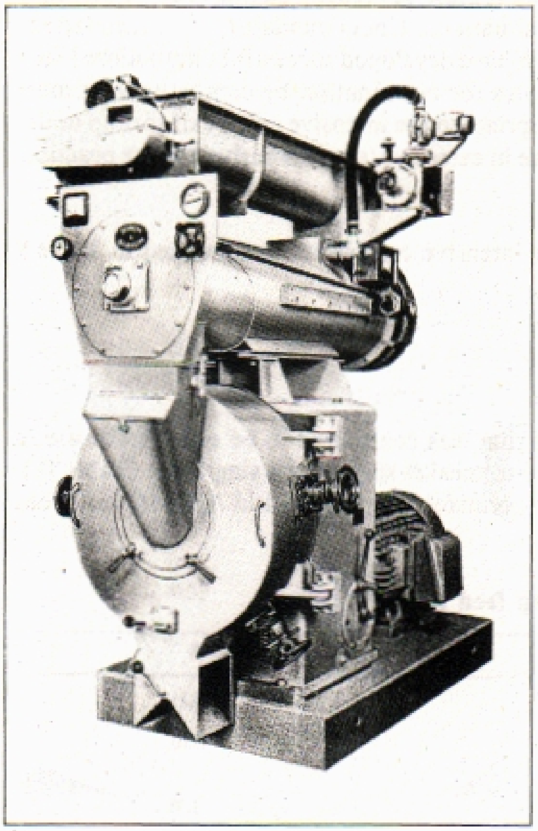
Sieve aperture	2mm screen Plant Mix A %	Marine **Mix** B %	Pulverizer	Product A t B %
355 mllcron	36.2	21.4		1.4
230	16.2	28.2		1.5
180	14.6	13.8		7.2
125	12.8	12.8		6.0
85	9.6	8.8	< 125u	83.9
55	11.2	8.4		
35	0.4	0.4		
Thro's	nil	nil		

Pulverizer throughput rate: ApproximateI) 125kg/hour for the 75HP machine when the motor was drawing 60 amps.

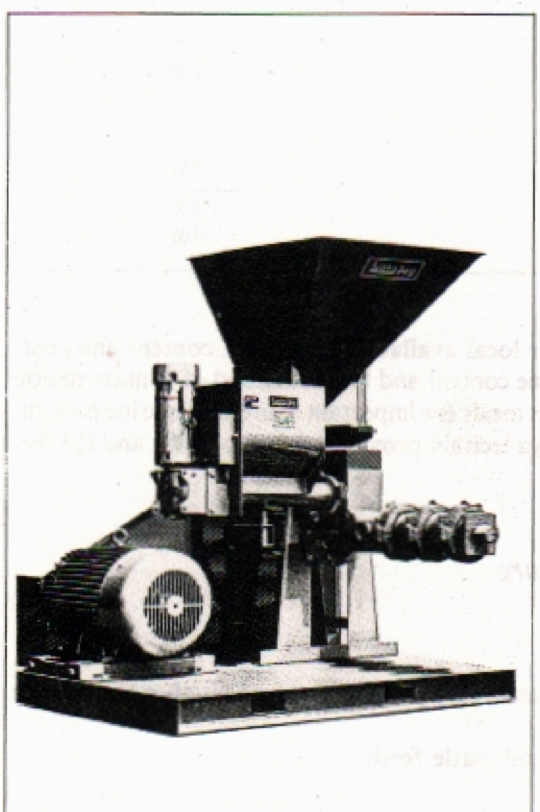
SAFETY NOTE : Mixtures of finely ground dry feed ingredients, when suspended in air, can form explosive mixtures. It is essential, therefore, that pulverizing plants are fitted with explosion relief vents, are correctly earthed against the build up and discharge of static electricity, and are fitted with permanent magnets for the removal of spark-producing tramp ferrous metal.

4.4.4 MIXING : PROBLEMS AND SOLUTIONS

The horizontal, paddle-type batch mixer used in the trial manufacture of feeds was of 500 kg max. capacity. However, with a shaft speed of only 17 rpm, liquid materials (fish oil, lecithin and sodium



Typical commercial feed pelleter



Friction type feed extruder

Ring die pellets

The quality of ring die pelleted feed is primarily dependent upon the careful use of steam, to precondition raw materials to a desired plasticity, and the inclusion of binders, to bring about particle adhesion during high compression and compaction on passing through the pelleter die (see alongside). Many substances have been evaluated as pellet binders for shrimp feeds, including plant-and seaweed-based gums, celluloses, synthetic polymers, modified starches and wheat gluten, and there are many companies advertising these products in the international feed trade press. Successful feed manufacturers have, however, spent considerable sums in perfecting their binder and manufacturing processes. These, of course, remain trade secrets.

Extrusion cooking

The principle of cooker extrusion for inducing water stability is dependent upon the transformation of water insoluble starches into viscous starch gels and the simultaneous conversion of soluble proteins into an insoluble fibrous network due to the effects of shear and heat in the extruder barrel (see alongside). Binders should not be needed in this system if the correct choice of raw materials has been made. It is important that the protein materials do not receive heat treatment prior to extrusion since the heat may have denatured the protein and thus make it resistant to plasticization and development as the binder.

The extent of binding is a function of raw materials, their inclusion levels, moisture content, temperature and the mechanical configuration of the extruder barrel and shaft in which the materials are processed. When the hot mixture is extruded, it may expand or puff to form a perous texture, giving the product the ability to float. This is a desirable characteristic for feeds to be fed to rapidly-feeding, top feeding fish such as salmon and trout, but the process must be carefully controlled if the extruded pellet is to have a sufficiently high density to sink, as is required for shrimp feed.

(Analogy: A simple analogy relating to the effects of the heat treatment of raw material proteins on the product of extrusion cooking is the inability to make an omelette from a hard boiled egg. Although the boiling process will have had only limited effect on tHe nutritional quality of the egg, the physico/chemical or

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Table 4 : Sources of major nutrients for prawn feeds in India

Type	Typical inclusion level (%)	Sources	Major Nutrients Supplied: Protein	Corbohydrafe	Essential fatty acids	Phospho-lipids	Sterols	Attractant properties	Waler stability properties
Marine Proteins	30-50	Fishmeal	X		X	X	X	X	
		Shrimp meal	X		X	X	X	X	
		Shrimp head meal	X		X	X	X	X	
		Squid meal	X		X	X	X	X	
		Clam meat	X		X	X	X	X	
		Mussel meat	X		X	X	X	X	
		Snail meat	X		X	X	X	X	
		Squilla meal	X		X				
Non-marine Animal Proteins	1-5	Meat meal	X						
		Blood meal	X						
Vegetable Proteins	15-30	Groundnut cake	X		X				
		Soyabean cake	X		X				
		Sesameseed cake	X		X				
		Copra cake	X						
		Dried yeast	X						
Cereals	15-30	Wheat flour	X	X	X				
		Wheat gluten	X	X					X
		Wheat bran	X	X					X
		Rice bran	X	X					
Starches	1-20	Tapioca (precooked)		X					X
Phospholipids	0.5-2	Lecithin			X	X			
oiis	I-5	Fish Oil			X				
Polymer binders	0.5-4	Guar/gum							X
		Celluloses							X
		Alginates							X
		Synthetics							X

Table 5 : Availability of major raw materials for prawn feeds in India

R o w materials	Estimated potential availability per annum (tonnes)	Estimated off take by other users (tonnes)	Of her users
Fishmeal	110,000	110,000	Poultry feed
Shrimp head mea)	2,200	100	Export, resource IO be developed
Acetes shrimp	15,000	15,000	Human food — export
Squilla meal	10,000	10,000	Poultry feed/fishmeal, fertilizer
Clam meal	500+	500	Export — Taiwan
Mussel meat	N.A.	N.A.	Used wet in local prawn feeds, Human food
Rice bran'	2.2 million	N.A.	Poultry and cattle feed
Groundnut cake[2]	I .4 million	300,000	Export-animal feed
Sesame cake'	270,000	1.1. million	Animal feed
Soyabean cake'	560,000	560,004	Animal feed
Tapioca	5.6 million	N.A.	Human food, Starch, Aanimal feed

Notes : I 55.5 million t. paddy per annum x 4% rice bran fraction.

2 6.7 million t. shell on nuts per annum x 50% crushed x 43% cake.

I 0.5 million I. seed per annum x 90% crushed x 60% as cake.

4 0.7 million t. seed per annum x 80% as cake.

N.A = not applicable

small pelagic fish caught in periods of glut. The small demersal fish and shellfish used are almost entirely shrimp trawler by-catch or, rather, that part of the catch which remains after the larger and more valuable species have been separated out for human consumption.

Annual production

Sources within the Indian fishmeal industry estimate the annual national production to be around 110,000 t. This figure agrees with estimates of by-catch from shrimp landings, and is probably the best estimate of fishmeal production levels. Expansion of fishmeal production, at least in the short term, does not seem feasible since unpublished data from the Government fisheries institutes indicate that overall fish landings have fallen greatly in 1987-88, and it is feared that this is the beginning of a long-term trend resulting from over-fishing and/or ecological phenomena. In 1988, the fall in landings due to reduced catch size resulted in an estimated 45 per cent decrease in fishmeal production from the normal (110,000 t) to about 60,000 t. It should be added that shortage of marine fish is a problem affecting many parts of the world, but the Indian subcontinent in particular.

Production technology

Most of the fishmeal plants using reduction technology (rather than sun drying and grinding) were established in India during the 1960s and 1970s. Many are now out of business, though plants in Karnataka operate during the peak anchovy/sardine season. At the same time, the proportion of sea-caught shrimp by-catch which is landed and is available for conversion to fishmeal is slowly decreasing, as more and more of it is marketed fresh, or dried, for human consumption. Feed compounders seem unwilling to pay the price for trash fish which is now used for human food, for conversion to fishmeal.

Most Indian fishmeal is made by sun-drying on the beach and grinding. The fishmeal is of low quality because of poor handling and processing. Material with a protein content of 45 per cent or more is now considered the best quality, compared with 65 per cent or more in the international markets. Most Indian fishmeals also have high microbiological counts and contain rancid oils and considerable impurities, including salt and sand. These are major headaches for feed manufacturers, affecting the quality of their formulations, feed palatability and the useful life of their processing equipment.

Possible sources of material

However, since large quantities of shrimp by-catch are discarded at sea, there is the possibility of increasing fishmeal production if the collection of by-catch and its conversion to fishmeal can be made economically viable. Up to 690,000 t of by-catch are estimated as being discarded at sea per annum from shrimp trawling operations. This is equivalent to approximately 172,000 t of fishmeal. However, the economic viability of returning such material to shore remains doubtful.

Fishmeal consumers

The primary consumer of fishmeal is the poultry industry. An average inclusion rate of 5-7 per cent in poultry feed, as typically recommended, equates to an annual requirement by the poultry industry of about 210,000 t. This is twice the estimated availability of fishmeal in normal years and almost four times the availability in 1988. As a result of this scarcity, the price of fishmeal during 1988 increased by about 60 per cent over the previous level.

With the poultry feed industry growing by 10-12 per cent/annum, and fishmeal supplies probably declining in the long term, there is a prospect of increasing scarcity and rising real prices. If shrimp feed manufacturers are obliged to buy domestically produced fishmeal, which is of poor quality and in chronically short supply, then the rate of development of shrimp culture in India may be severely hampered. There is, therefore, a case for permitting the import of quality fishmeal into India at non-prohibitive rates of duty for the manufacture of shrimp feeds.

3.7.2 SQUID WASTE

Where not discarded overboard, most squid waste is dried for use as fishmeal. For this reason, it cannot be regarded as a separate resource in addition to those already discussed. Small quantities of squid waste are dried for export to Taiwan. However, logistical problems of waste collection and the export of squid in whole form prevent larger quantities from being collected.

3.7.3 SHRIMP HEADS

Present availability

The main unutilised source of marine protein and oils is the heads of shrimp from the shrimp packing and processing industry. Heads are usually removed in peeling sheds near the landings or at packing plants. Shrimp landed by the large trawlers operating from Vishakhapatnam are, however, deheaded at sea.

India's total annual availability of heads, based on the quantity of shrimp exported, is estimated to be 30,000 t (where average export of tails is 55,000 t/annum and the weight ratio of heads:tails is 35 : 65). However, since this figure does not include catches of metapenaeid shrimp which increase the estimated total marine landings of shrimp to 210,000 t, a more realistic estimate of the quantity of shrimp head waste available for upgrading is 73,000 t *(i.e. 35* per cent of 210,000 t). Most of this quantity is currently discarded as waste, but small amounts are hot air dried for export to Taiwan, where it is believed to be used in the manufacture of shrimp feed. Since shrimp are deheaded at many small landing sites, there are logistical difficulties in collecting much of this material.

If shrimp head meal of high quality is to be obtained, the wet heads must be dried quickly after deheading in order to avoid deterioration due to enzyme activity. Hot water blanching, to denature enzymes before sun-drying, or rapid hot air drying are recommended methods of treatment.

Head meat extraction

A further possible development which merits investigation is the extraction of head meat by use of a meat bone separator before drying. The protein content of the whole shrimp head meal produced by hot air drying is believed to be about 30 per cent, but by extracting the head meat, an ingredient with a higher nutrient density and upwards of 60 per cent protein can be made. It might also be possible to produce chitin and chitosan as useful by-products of the process. However, in many of the small landing sites, the quantity of product available on a daily basis would not justify the investment in machinery for shrimp head processing.

The potential for shrimp heads extraction to yield a quality protein product also raises the question of the use of the extracted head meat for human consumption. Although such an alternative use is recognized, in the short term the development of technology for upgrading shrimp heads as a feed ingredient would enable a more rapid utilization of this waste product to be made.

3.7.4 ACETES SHRIMP

Landings of acetes shrimp *(Acetes indicus),* caught mainly in Maharashtra, averaged in excess of 70,000 t (approximately 15,000 t dried product) in 1985 and 1986. The potential of this small shrimp in animal feeds is limited, since it is mainly used for human consumption in India as well as being exported to Japan (for human consumption). Small quantities are also exported to Spain and Portugal as bird feed. In view of this trend, acetes should not be relied upon as a source of protein for shrimp feeding.

3.7.5 BIVALVE MOLLUSCS AND SNAILS

Meat from cooked mussels and snails is being used for shrimp feeding in localities where these animals can be easily collected. However, the supply based on known and accessible resources is limited, and will not sustain a major increase in offtake. For example, in Andhra Pradesh,the cost of clam meat to the farmer is 4.50 Rs/kg. On a dry weight basis, this is three to four times the wholesale price for fishmeal, and prices were reported to have doubled in the preceding two years. Similar constraints were reported with the use of snails in the Chilika Lake area of Orissa.

One company produced dried grey clam *(Vilforita cyprinoides)* and mussel meat for export to Taiwan, where they are presumably used as attractants in the manufacture of shrimp feeds. At a price of around 1500 and 2000 US $/t respectively, they cannot be considered as major sources of marine protein for Indian shrimp feeds, though they may find similar uses in India to those in Taiwan.

3.7.6 SQUILLA

Landings of stomatopods, consisting mainly of squilla *(Ovallosquilla nepa)* were estimated to be 40,000 t in 1985 and 1986. Landings are largely concentrated on the Karnataka coast. This resource is dried for use as a fertilizer and low-grade fishmeal. The main point of interest is that squilla could possibly be processed by the meat-bone separator as suggested for shrimp heads. The techno-economic feasibility of this proposition should be included in any studies on upgrading of shrimp heads by meat extraction.

3.7.7 OILSEED MEALS

India is a major producer of oilseed meals which could be utilized in shrimp feeds. Soya, sesame and groundnut are the most important oilseed cakes, though the latter should be screened for aflatoxin contamination.

3.7.8 CEREALS AND BY-PRODUCTS

There is a plentiful supply of cereals and their brans within the feed market for use in shrimp feeds. However, the development of water stability in shrimp feeds may require inputs of food grade wheat flour, so it is desirable to keep such inputs to a minimum.

3.7.9 MISCELLANEOUS INGREDIENTS

Minor essential ingredients

As indicated earlier, many of the minor but essential ingredients may need to be imported, the cost of which, including any duty, must inevitably be passed on to the feed purchaser. A list of possible ingredients is given in Table 6. An increased demand for these materials may encourage the emergence of local manufacturers, but in the short term, import would appear to be necessary.

Table 6 : Minor raw matehals for use in shrimp feeds

Ingredient	*Function*
Cholesterol Lecithin	Carapace development, moulting, and nutrient metabolism
Ethoxyquin Butylated hydroxy toluene Butylated hydroxy anisole	Oil anti-oxidants
Carboxy methyl cellulose Sodium alginate Guar gum Synthetic polymers	Polymer binders

3.7.10 SUMMARY OF RAW MATERIAL AVAILABILITY

From the above examination of raw material availability within India, it is clear that there is a major deficiency in marine protein and oils for shrimp feed manufacture. This problem will, of course, increase in relation to the rate of expansion of semi-intensive shrimp culture. Since deficiencies in marine proteins will limit feed production, the establishment of mechanisms to improve the supply of quality fishmeal to the industry requires attention.

References:

Chong, Kee-Chai, (1991). Structure, conduct and performance of the Asian shrimp culture industry. p. 191 in *Technical and Economic Aspects of Shrimp Farming,* Eds: New M, de Saram H, and Singh T. Proceedings of the Aquatech '90 Conference, Kuala Lumpur, Malaysia, June 1990 (INFOFISH, Kuala Lumpur, Malaysia).

4. *PRINCIPLES AND PRACTICES OF SHRIMP FEED FORMULATION, MANUFACTURE AND EVALUATION*

4.1 *Principles of shrimp feed formulation*

The formulation of shrimp feeds for industrial manufacture or pond side preparation should follow the principles of feed formulation for farm animals.

Formulations may be calculated manually or, more cost effectively, using computer formulation programmes. In both cases, the formulator is comparing the known nutrient requirements of the animal under a given farming system, against the nutrient content and price of the available raw materials, in order to produce a practical feed of the desired physical and nutritional quality at lowest cost.

However, several additional factors must be taken into account when formulating shrimp feeds, which are not required, say, for poultry feeds.

They are:

- The nutrient requirement for shrimp of different species, age, culture conditions have not been fully identified.
- Shrimp feeds should be water - stable (i.e. resistant to breakdown in pond water) for a minimum of 1 1/2-2 hours.

The latter requirement places constraints on feed formulation and manufacturing stages since raw materials must be selected for both water stability and nutritional quality. These two factors are not always complementary.

Examples of typical shrimp feed formulations are given in Tables 7 and 8.

Table 7 : Generalized shrimp feed formulation

Row material	*Inclusion (%)*
Marine proteins	30
Marine attractants	6
Vegetable proteins	27
Cereals/starches	26
Oils/phospholipids	4
Binders	3
Vitamins	1.5
Minerals	2.5

Table 8 : Comparison of marine and vegetable protein sources in typical shrimp diets

Ingredient	*Soyameal diet* (%)	*Fishmeal* dief (%)
Soyabean meal	34	12
Cottonseed meal	5	—
Fishmeal	18	40
Meat and bone meal	3	—
Fish solubles	3	—
Shrimp meal	10	6
Squid meal	5	4
Rice bran	5	—
Wheat middlings	10	4
Wheat gluten	—	3
Wheat flour	—	*21*
Brewers yeast	2	—
Fish oil	2	1
Vitamin/mineral premix	3	3
% Protein	40.7	40.7
Ingredient cost per tonne (US $)	498	607
Rs/Kg tat IUS $ = I Rs 16 approx.)	8.0	9.7

Formulations are for extrusion processing
(Ref : Dominy, W G; Huber, G R and Castaldo, D J. *Wet extrusion: "texturised" proteins for aquafeeds.* Feed International Feb. 1991 p. 33)

Table 9 : Recommended dietary nutrient levels for omnivorous shrimp species under intensive culture'

			Shrimp size class[2]			
Nutrient level %	*Larval*	*PLl-2s*	*PL25.lg*	*Juvenile*	*Grower*	*Brood stock*
Crude lipid	14	13	12	11	10	10
Marine: plant lipid'	5:1	5:l	5:1	5:1	5:1	5:1
Cholesterol	2	15	15	1.0	1.0	1.0
Crude protein (% min),	55	50	45	40	35	45
Amino acids (% min)						
Arginine	2.98	2.71	2.44	2.17	1.90	2.44
Histidine	0.85	0.77	0.69	0.62	0.54	0.69
Isoleucine	1.31	1.19	1.07	0.95	0.83	1.07
Leucine	2.69	2.45	2.20	1.96	1.71	2.20
Lysine	2.83	2.57	2.31	2.06	1.80	2.31
Methionine	1.04	0.95	0.85	0.76	0.66	0.85
Cystine	0.52	0.47	0.42	0.38	0.33	0.42
Penylalanine	1.48	1.35	1.21	1.08	0.94	1.21
Tyrosine	1.50	1.37	1.23	1.09	0.96	1.23
Threonine	1.85	1.68	1.51	1.34	1.18	1.51
Tryptophan	0.52	0.47	0.42	0.38	0.33	0.42
Wine	1.64	1.49	I.34	1.19	1.0-l	1.34
Carbohydrate (max)	15	20	25	30	35	25
Crude fibre (max)	1	15	2	2	3	2
Major minerals Calcium (max)	3	3	2.5	2.5	2	2.5
Available P (min)	18	1.6	1.4	1.2	1.2	1.4
Potassium (min)	11	1.0	0.9	0.8	0.7	0.9
Magnesium (min)	0.18	0.15	0.13	0.10	0.08	0.13
Added dietary supplements (Trace minerals mg/kg min)						
Iron	100	90	80	70	60	100
Zinc	120	110	100	90	80	120
Manganese	60	55	50	45	40	64
Copper	12	11	10	9	8	I1
Cobalt	1.2	11	1.0	0.9	0.8	1.2
Iodine	6	5.5	5	4.5	4	6
Chromium	1.0	0.9	0.8	0.7	0.6	1.0
Selenium	0.25	0.23	0.21	0.19	0.17	0.25
(Vitamins IU/kg min)'						
Vitamin A	12000	11000	10000	9000	8000	12000
Vitamin D3	4000	3600	3700	2800	2400	4000
Vitamins mg/kg min						
Vitamin E	*400*	360	320	280	240	400
Vitamin K	14	13	12	11	10	14
Thiamine	90	84	78	72	66	90
Riboflavin	90	84	78	72	66	90
Pyridoxine	90	84	78	72	66	93
Pantothenic acid	300	280	260	240	220	300
Nicotinic acid	450	420	390	360	330	450
Biotin	0.75	0.69	0.63	0.57	0.54	0.75
Folic acid	18	16.5	15	13.5	12	18
Vitamin B12	0.12	0.11	0.10	0.09	0.08	0.12
Vitamin C	2500	2250	2000	1750	1500	2500
Choline	3200	3000	3800	2600	2400	3200
Inositol	2100	1950	1800	1650	1500	2100

Notes :

I. Dietary nutrient levels recommended for clear water 'intensive' aquaculture systems i.e. tanks, cages and raceways

2. Shrimp size class :
Larval ' protozoea substage 1 to post-larval substage 1 (PL1); PL1 to PL25 (25 days from PL1); PL25 to lg; juvenile — lg to 10g; grower — 10g to harvest; broodstock — 10g t

3. Marine lipid includes shrimp head oil, marine body oil, marine fish liver oil or marine invertebrate oils. So as to satisfy a possible dietary phospholipid requirement, a concentrated source of phospholipid should be added in the form of soya bean oil or a soy-lecithin preparation,

4. Cholesterol can be added either in purified form or by using a dietary lipid source naturally rich in cholesterol, such as shrimp head oil.

5. Amino acid requirements based on the carcass essential amino acid pattern of the short necked clam.

6. Maximum limit refers only to crude fibre of plant origin, and excludes crude fihre derived from shrimp meal i.e. chitin.

7. Suggested vitamin levels required to prevent deficiency signs. Values presented have taken into account processing, storage and leaching losses, the latter being 2 to 5 times greater than the recommended dietary requirements due to the extremely slow and extended feeding habits of marine shrimp, and to compensate for the considerable losses of vitamins which occur through leaching. However, the actual level should be adjusted according to the water stability of the diet and the feeding response of the shrimp to the diet and the time period the feed remains in the water before total consumption.

Reference :

Tacon A.G.J. *(1987). The nutrition andfeeding of farmed fish and shrimp, a training manual, I. The Essential Nutrients,* **FAO Report GCP/RLA/075/ITA** Field Document 2/E, FAO Brazilia, Brazil, June 1987, 117 p.

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In presenting these examples of 'typical formulations', it must be recognized that there is no single formulation that is applicable to all shrimp culture situations. Understandably, the formulations and manufacturing practices of large companies which have developed successful international feed enterprises are not divulged in their technical literature for examination by competitors. It must also be recognized that formulations which are appropriate to the intensive culture of shrimp under high stocking densities may not be appropriate for use in extensive/semi-intensive culture practices in rural artisanal shrimp ponds.

The known nutrient requirements for shrimp under intensive culture are summarized in Table 9 (see facing page).

4.2 Practical shrimp feed formulation

Shrimp feeds were formulated to a nutrient content that was considered to be suitable for use in the semi-intensive culture of shrimp from post-larvae to market size using a single diet (Table 10). The nutrient compositions of the raw materials and premixes are presented in Appendix II. Feed costs are derived in Appendix III.

Table 10 : Pelleted shrimp feed formulation

	Raw materials	%
	Wheat flour	19.25
Blend A	Soyabean meal (44% cp)	39.00
	Soya flakes (52% cp)	
	Broken rice(polished)	5.00
	Fishmeal (sun-dried)	10.00
Blend B	Shrimp head meal	10.00
	Squid/cuttlefish meal	5.00
	Fish oil	3.00
	Soya lecithin	2.00
Others	Mineral premix	2.00
	Vitamin premix	1.00
	Choline chloride (50% concentration)	0.25
	Plaster of Paris (calciumsulphate)	2.00
	Sodium alginate	1.50
		100.00
Water (for alginate gel preparation)		15.00

cp = crude protein

Raw materials were selected to meet the criteria for local availability, nutrient content and cost. **Soya** products were chosen because of their high lysine content and low likelihood of contamination with aflatoxin. Shrimp head meal and squid/cuttlefish meals are important sources of marine protein, oils, cholesterol, and undefined feed attractants. Soya lecithin provides phospholipids, and the fish oil, essential fatty acids.

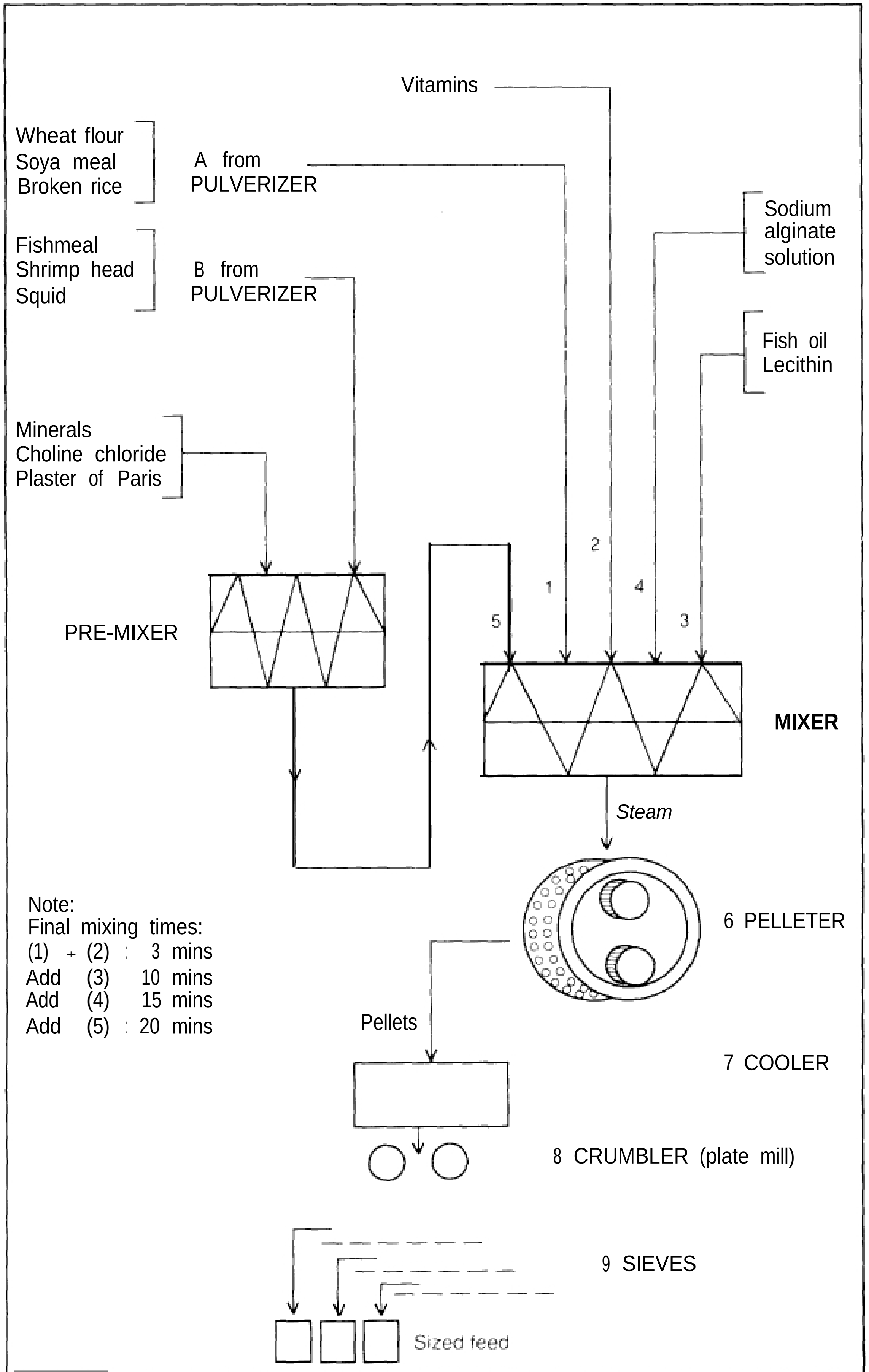
4.3. Principles of shrimp feed manufacture

4.3.1 PROCESSING OPTIONS

The technology of shrimp feed manufacture encompasses feed pelletization by a number of different methods.

- Ring die pelletization as used for poultry and cattle feed;
- Cooker extrusion; and
- Simple moist feed production in doughball or noodle form.

Fig 2. Ring die pellets: operating sequence



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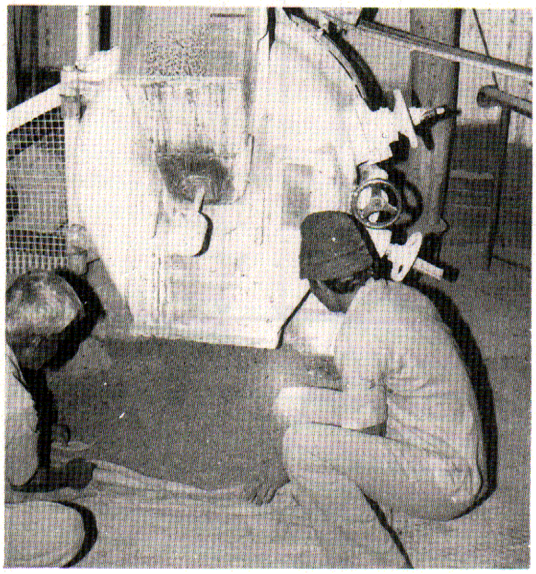
alginate solutions) tended to form balls of liquid coated with dry feed particles, rather than feed particles coated with liquid. Extensive mixing for more than one hour did not bring about the phase change to the degree ideally desired.

A shaft speed of 30rpm should be considered to be the minium for mixing the finely ground materials: Alternatively, passing the 'balled' mix through a high-speed molasses mixer may give the desired product. The sequence of addition of raw materials into the mixer for each feed product is given in the diagrammatic operation sequence, Figure 2.

Mixing of sodium alginate solution

Sodium alginate is a very finely divided powder which is easily wetted, forming a viscous gel. To obtain the maximum gel-forming characteristics, sodium alginate was added with rapid stirring, using an electric stirrer, to softened boiler water (from the feed mill steam boiler) (low in calcium) in the ratio one part alginate to ten parts water. The alginate gel was allowed to stand overnight, then well-stirred before use



Collecring pelleted feed from pellern

The blending of alginate solution into Mix A is required before pelleting through a ring die. The product, after mixing, should be a moist crumb, indicating that the dry feed particles have been coated with alginate. Although the moisture content of the mixture should be approximately 28 per cent, the moisture is not free but bound within the alginate. Hence, the mixture does not form a paste within the mixer.

On addition of the 'B' materials, minerals, oil etc, the moisture content of the diet is reduced to 22 per cent. At this stage it should be a free flowing crumb. (Pilot plant studies in the UK had showed that the power demand per unit output when pelleting the alginate mixture was lower than when alginate is absent, thus indicating the lubricating action of the alginate gel.)

However, in these trials, the unavoidable lengthy delays between mixing and remixing, power cuts and the need to manually transfer large quantities of feed mixes from the ground floor of the feedmill to the third floor for feeding into processing bins etc. resulted in the apparent partial setting of the alginate and premature drying of the mixtures prior to pelleting.

Grading of crumbled feed pellets to the desired size

4.4.5 PELLETING

Steam conditioned feed was pelleted through a 4mm die used for poultry feed manufacture. A die of 2-2.5mm was preferable, but dies of this size were not available in India. To avoid contamination of shrimp pellets with other pelleted feeds produced in the mill, the pellets were cooled on the floor. Cold pellets were crumbled in a plate mill and screened to obtain products of the desired size. (See picture alongside).

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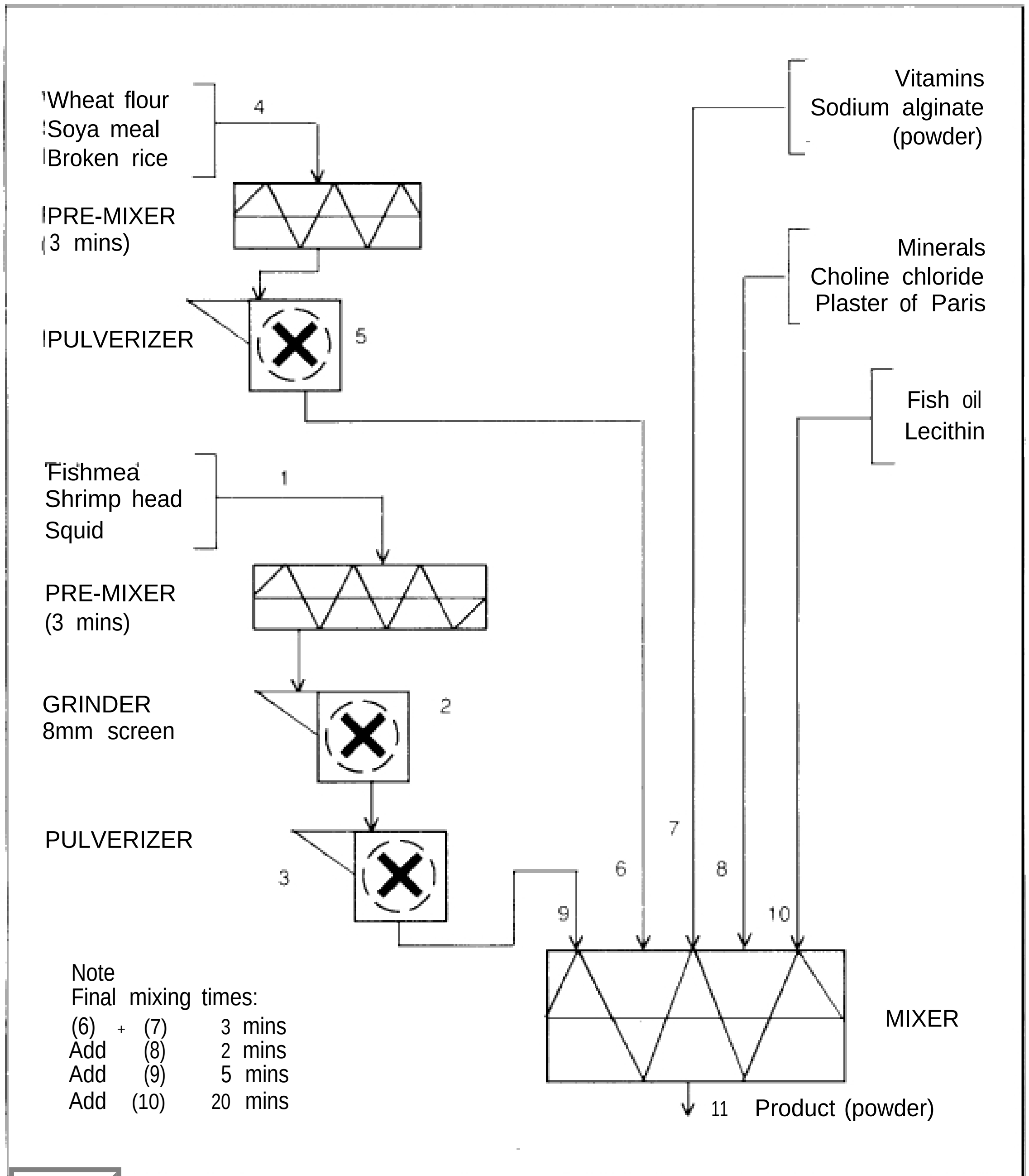
4.5 Practical manufacturing technique used for the preparation of experimental doughball feed.

As described earlier, 'doughballs are the form in which many artisanal shrimp farmers are attempting to supplement feed their shrimp. This is a simple procedure, although it is very time-consuming for the farmer. There appeared, therefore, to be an opportunity to evaluate shrimp performance when shrimp were fed a nutritionally balanced diet in doughball form, but pre-prepared as a dry powder mix which only required reconstituting with water, kneading and forming into doughballs at the pond side.

In the research study, doughballs were prepared to the same formulation as pelleted feeds (see Table 10). Sodium alginate was added as a dry powder and not as a hydrated gel (Figure 3). A measure of water stability resulted from the hydration and kneading of the wheat proteins (gluten), hydration of sodium alginate and the partial setting of the alginate gel by calcium ions which were slowly released from the Plaster of Paris included in the formulation, and from the setting of the Plaster of Paris itself.

Doughballs prepared from the powder base had a water stability of about 30 minutes before disintegration.

Fig. 3 Doughball mixture Operating sequence



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5. PRINCIPLES AND PRACTICES OF POND ENVIRONMENTAL ASSESSMENT.

5.1 Principles of pond quality assessment

An assessment of the water quality in pond aquaculture is vital in order that conditions deleterious to the animal cultured (in this case *Penaeus monodon)* are foreseen and avoided. Furthermore, in a study such as this, which compares the effective utilization of a variety of nutrient inputs such as feed and fertilizer, it is valuable to assess the trophic status of the pond, and to elucidate how the inputs have been translated into water nutrients, production of aquatic plant life, and growth and survival of the target animal, the shrimp. With these aims in mind, a monitoring programme, inclusive of the most appropriate water parameters, was designed.

The normal, optimal and critical values of the various parameters are presented in Table 12.

Table 12 : Working guidelines for water quality parameters for shrimp culture

Parameter	*Normai*	*Optimal*	Critical
Dissolved oxygen (mp 1)	3-13	4-7	> 2.5 < 15.0
Secchi (cm)	25-60	25-40	> 20 <60
Chlorophyll A (ug 1)	20-225	90-140	> 20 < 225
pH	6.0-Y 0	7585	>6 <10
Salinity (ppt)	I0-34	15-20	>8 <- 30
Temperature (C)	17-33	28-33	< 14 > 35
Hydrogen sulphide (ug l l	0. 1 0	0	>2
NH4 (mg 1)	< 0.01	NA	> 0.15
NO2 (mg, l)	< 0.01	NA	> 1.5
NO3 (mg l/	< 003	NA	NA
Total organic nitrogen (mg 1)	0.5-3 0	NA	NA
Dissolved react phosphorus (ug 1	8-10	NA	NA
Total phosphorus (ug, 1)	60-120	N A	N.4

NA = Not applicable. Preswnt research has not yet recognized optimal or critical levels

DISSOLVED OXYGEN

The oxygen contenr of the water, known as the dissolved oxygen (DO), must remain above a critical level in order to provide sufficient oxygen to the shrimp. Low levels of DO will result in stress, which will be expressed, initially, though unusual behaviour, and a curtailment of growth, but eventually as death through suffocation Oxygen requirements show some species specificity, and *P. monodon* has been defined to be optimally cultured at 4-7ppm, and critically stressed at and below 2.5ppm DO.

TEMPERATURE AND SALINITY

Like any aquatic organisms, shrimp exhibit preferences for water temperature and salinity. Extreme values will result in stress and its manifestations. Water temperature can only be partially controlled as it is dependent on the depth of the culture ponds. However, with an approximate depth of Im maintained under local climatic conditions, water temperature should be suitable. Similarly, salinity can be controlled only in a limited fashion by pond flushing or water pumping, as the tides allow. The monitoring of temperature and salinity, although necessary, was not expected to be critical over the months studied.

pH

pH, as a measure of the acidity of the water is critical in the culture of shrimp. The pH will reflect the balance between photosynthesis and respiration, thus reflecting the productivity and stability of the system. The pH will influence the toxicity of certain compounds, such as ammonia, by altering the degree of ionisation.

NITROGEN COMPOUNDS

Assessment of the total organic nitrogen (TON) is an indication of that nitrogen which is tied up in organic matter and not immediately available for incorporation by phytoplankton. The inorganic nitrogen compounds are the mineralized forms of nitrogen, of which nitrate (NO_3) is the most available nutrient. Nitrate is the least toxic inorganic nitrogen compound, unlike ammonia, a proportion of which (depending on temperature and pH) will be in the toxic unionized form (NH_3). Ammonia is the product of nitrogen catabolism in shrimp and will reflect the shrimp biomass and feeding regime. It also acts as a plant nutrient. The intermediate compound in the nitrification of ammonia to nitrate is nitrite (NO_2), which is also toxic to aquatic animals.

PHOSPHORUS COMPOUNDS

Total phosphorus (TP) is an indication of the phosphorus in all forms within the system, and is often well correlated to the primary productivity of freshwater. The inorganic fraction, dissolved reactive phosphorus (DRP), is that portion of the phosphorus which is available as a plant nutrient.

CHLOROPHYLL

Chlorophyll (CHL), as a measure of the photosynthetic pigment chlorophyll-A, is an indication of the influence of the nutrients on the plant community. Although phytoplankton have variable levels of photosynthetic pigments, the variation is not too great, and CHL is generally used as a measure of phytoplankton biomass.

TURBIDITY

The parameter of turbidity, assessed with a Secchi disk, gives a rough indication of the level of total solids in the water, both as organic material, including plankton and zooplankton, and as inorganic material, such as clay particles. It defines the level at which light may penetrate, thereby influencing primary productivity, temperature, and, most importantly, chlorophyll and DO distribution.

SULPHUR COMPOUNDS

The most common form of sulphur in water is sulphate, but depending on pH, it may be present in the toxic form, as hydrogen sulphide (H_2S). Saline waters are more prone to problems with H_2S because of the higher concentration of sulphate in saline water.

PRIMARY PRODUCTIVITY

Primary productivity is a measure of the aquatic plant productivity, or the rapidity of chlorophyll turnover. It reflects the nutrient status of the environment, and, typically, may be linked to fish, and perhaps shrimp, production.

The rise and fall in certain parameters including DO, temperature and pH can be expected in freshwater bodies and should be assessed to indicate the ranges of these parameters to which the shrimp are exposed. Extreme ranges are known to be stressful to all aquatic animals, and are best minimized. The ranges in DO and pH will also be indicative of the productivity of the system, and how well the biotic communities are balanced.

REDOX POTENTIAL

The sediment parameter of redox potential is a valuable indicator of the potential for deoxygenation at the sediment -water surface which accommodates the shrimp.

Climatic weather conditions, including sunlight, cloud cover, wind and rain, will influence the chemistry of the entire system through physical, chemical and biological mechanisms. The interactions are complex, but avoidance of low DO and high toxic compound concentrations are vital.

5.2 Frequency of assessment sampling

The frequency and timing of sampling for the various parameters is dependent upon several factors, including :

- The rapidity with which they might be expected to change in the ponds;
- The potential severity of their effect on the shrimp population;
- The development of adverse climatic conditions;
- The time of day at which each compound is at its most critical stage (e.g. low DO); and
- The limitations in the practical aspect of sampling and analysis under present laboratory conditions, in terms of staffing, availability of equipment and reagents.

5.3 Procedures and techniques of sampling and analysis

The following paragraphs outline the practices of water quality assessment conducted during the trials reported in this case study. Details of water chemistry are not presented, but readers requiring more information should consult the Bibliography. Complex analytical methodology was in part avoided by the use of a commercial water testing kit (Hach Company — see Bibliography). The general programme of water sampling is given in Table 13.

Table 13 : Water quality sampling method

Parameter	*Sampling method*	*Units*
Frequent sampling		
Dissolved oxygen	DO meter	mg/1l
Temperature	DO meter	C
Redox	BOD bottle/pH meter redox probe	mv
Total depth	Depth marker	cm
Turbidity	Secchi disc	cm
Weekly sampling		
Salinity	Refractometer	ppt
Total solids	Tube sampler	mg/1
Fortnightly sampling		
Total phosphorus	Tube sampler	mg/ 1
Total organic nitrogen	Tube sampler	mg 1
Ammonia	Tube sampler	mg/1
Nitrate	Tube sampler	rng/ 1
Nitrite	Tube sampler	mg/ 1
Dissolved reactive Phosphorous	Tube sampler	mg/ l
Chlorophyll A	Tube sampler	ug 1
Phaeopigments	Tube sampler	ug/ l
Hydrogen sulphide	Tube sampler	mg: l

Parameters recommended for sampling every three days were DO, temperature, redox, pH, total depth and turbidity. It was recognized that daily sampling might be necessary as the shrimp biomass increased and conditions indicated potential stress to the animals. Such conditions were defined as DO levels of either less than 3mg/I or more than 15 mg/i.

Sampling : All samples should be taken at a fixed time of the day. Early morning (7.00 hrs) was the preferred time.

Salinity : By salinity refractometer.

Dissolved oxygen and temperature : Measurements were most easily made using an electronic portable DO meter.

pH and redox potential : By pH/ redox meter.

Biological oxygen demand (BOD) : BOD probe on DO meter

Ammonia NH_3 NH_4+ Nitrate NO_3- Nitrite NO_2- Dissolved reactive phosphorus (DRP) Hydrogen sulphide (H_2S) Total phosphorus	Hach spectrophotometer
Chlorophyll-A (CHL) Phaeopigments (PHA) Total organic nitrogen (TON)	See Stirling *(1985)*

Turbidity : By Secchi disc

Depth : By depth marker fixed into pond bottom

Total solids: APHA method 1980

SAMPLING TECHNIQUES

For measuring redox, pH and BOD we used equipment as in Figure 4(a) (See facing page). Use a 125ml sampling bottle to minimize interference with oxygen. The rod-mounted bottles permitted access to the pond bottom and the aperture tubes allowed the air to be displaced by pond water. The sampler was slowly lowered into the water, and, on surfacing, the tubed bung was replaced with a ground glass stopper. Instrument probes were placed in the sampling jar and readings recorded after 60 seconds.

Water sampling was made with the sampler illustrated in Figure 4(b). The tube was 4cm dia x 1.5m approximate length. A column of water was entrapped in the tube by the bung and chord running through the tube. The sample was transferred to a bottle for analysis.

Samples for NH,, NH., t ' NO,, NO, and DRP were filtered through 0.45µ m glass fibre filters under suction. (Samples may be frozen but should be analyzed within one week.)

For CHL and PHA, 100-500ml of pond water were filtered through a 0.45µ m filter, washed with distilled water and assayed by the method used in Stirling (1985).

(Note : The sampling tube must not be used for water which is to be analyzed for H_2S content. To minimize volatalization, samples must be collected with minimal disturbance using the BOD bottle system. Analysis should be completed immediately.)

PRIMARY PRODUCTIVITY

Primary productivity measurements were taken once a month using the sampling frame illustrated in Figure 4(c). The frame had one light and one dark incubation bottle which were filled in the same manner as described for redox sampling. An initial bottle and the incubation bottles were analyzed immediately after filling by the Winkler titration (APHA 1980) method. The time of incubation is dependent upon the amount of sunlight and the chlorophyll status of the ponds, but a period of 2-3 hours between 11.30-14.30 hrs was recommended. (The DO meter may be used in place of the Winkler titration method but the interpretation and reliability of the data may be limited.)

Diel (24-hour) sampling

Diel sampling was conducted once a month. DO, temperature, and pH were measured at four hour intervals, ***i.e.*** at 7.00, 11.00, 15.00, 19.00, 23.00 and 3.00 hrs.

Pond mud sampling and analysis

Samples were taken fortnightly at 7.00 hrs using a plastic tube corer approximately 30cm long (Figure 4(d)). The rod was lowered and a shallow core sample taken before the rod was raised, the bung removed and the piston inserted into the lower apperture. The mud sample was pushed to the upper end of the tube so that the mud/water surface was exposed. The redox probe was inserted about lcm into the mud and the reading recorded after 60 seconds. Mud pH was measured according to Black (1965).

Daily *weather* ***readings***

At midday, measurements were taken of wind direction, wind speed, rainfall, maximum and minimum temperatures and solar energy.

References

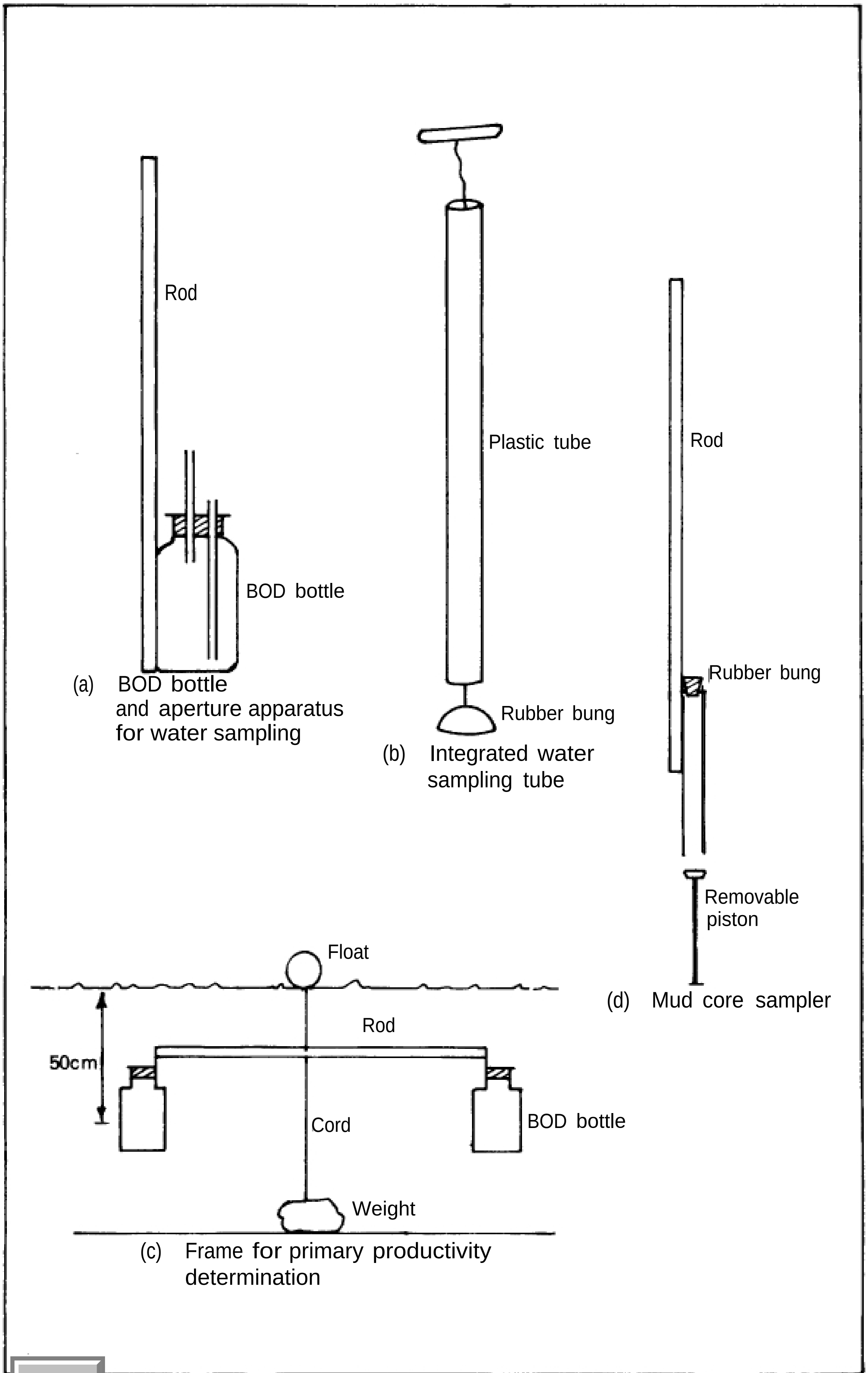
APHA (1980) Standard method.7 /or the examination of public and waste water. 15th edition. American Public Health Association, Washington DC, 1134 p.

Black, C. A. (I 965) Methods of soil analysis. Part 2. Chemical and microbiologicalproperties. I st edition. American Society of Agronomy, Madison, Wisconsin, 1572 p.

Stirling, H. P. (1985) Chemical and biological methods of water analysis for aquaculturists. 1st Edition. Institute of Aquaculture, University of Stirling, Scotland, 119 p.

Water Test Kit Supplier: Hach Company, P 0 Box 389, Loveland, Colorado, USA.

Fig. 4 Equipment used for sampling



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5.4 Practical pond quality assessment

Section 4.3 described the range of water quality parameters proposed for pond water examination during the feeding trials described in this case study. Delays in the supply of certain items of equipment meant that all methods could not be applied to both small and large pond trials.

During small pond trials in West Bengal the following parameters were measured: DO, temperature, pH, Secchi, turbidity, salinity, total phosphorus, dissolved reactive phosphorus, H_2S and mud redox.

During large pond trials in Andhra Pradesh, measurements of DO, temperature, pH, Secchi, turbidity, salinity, NO,, dissolved reactive phosphorus, total phosphorus, H_2S and primary production were made.

At both sites, climatic records of wind speed and direction, rainfall and solar radiation were also kept. However, measurements of solar radiation were often greater than the instrument limit of 50,000 lux and, hence, could not be accurately measured.

5.5 Methodology for bacteriological analysis

To obtain a preliminary picture of the bacteriological status of shrimp cultured in experimental ponds, samples of shrimp, mud and feed were examined for the presence of *Vibrio cholerae* and *Salmonella.* All samples were obtained at shrimp harvest.

The methods used to isolate the *Salmonella* and *Vibrio cholerae* were those recommended by the International Commission for Microbiological Specifications for Foods (ICMSF 1978). Final identification was by means of API 20E diagnostic strips (API). In addition, a new rapid technique for detecting *Salmonella,* using a semi-solid agar medium and based on a method described by de Smedt and Bolderdijk (1987), was employed. The technique uses a modified semi-solid Rappaport-Vassiliadis medium (MSRV). To avoid sampling errors, the rapid technique was initiated from the buffered peptone water enrichment, which formed the first stage of the ICMSF technique.

Three samples of shrimp and one sample of mud/water from each pond were examined together with one sample of dried poultry manure (fertilizer).

The shrimp samples were drawn from a number of hauls taken from each pond with a castnet, 250g being drawn from the pooled catch and transported fresh to the laboratory. All shrimp samples were stored at 8°C for three days prior to analysis.

The mud samples were taken at the mud/water interface, as the ponds were drained at harvest – one sample from each corner and one from the pond centre. The samples were pooled in a bucket, stirred and then 125ml of mixture were poured into a sterile plastic container. The samples were analyzed on the day of collection.

25g subsamples were prepared by aseptically chopping the shrimps (at least ten of them) with a pair of scissors, into the appropriate enrichment broths (see below for details). The sliced tissues were deemed to be thin enough that homogenization was not required.

Mud/water samples were shaken to re-suspend the mud in the water and 25g were poured into the enrichment broths.

The semi-solid agar method used the medium as described by de Smedt and Bolderdijk, but SRTEM (Unipath) elective broth (without novobiocin) was used at the enrichment stage. The SRTEM was inoculated with lml of buffered peptone water from the ICMSF method. The broth was then incubated overnight at 35°C.

The semi-solid plates were inoculated with four, well-spaced 300µ l drops from a sterile micropipette and allowed to air-dry. The plates were incubated overnight in a brass cylinder submerged in a precision water bath running at 42°C. Plates were examined for drops which showed migration away from the original site of inoculation. Drops which exhibited migration were tested using a latex antibody specific for *Salmonella* spp (Unipath).

References

de Smedt J.M, and Bolderdijk R.F., (1987). Journal of Food *Protection. Vol 50.* pp.658.661

ICMSF (1978) *Micro-organisms* in food 1. University of Toronto Press.

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6. EXPERIMENTAL PROCEDURES

6.1 Guidelines for conducting feeding trials

The performance of a shrimp feed is not determined by its nutrient content, method of manufacture or water stability, but by its acceptance and consumption by shrimp, and its ability to increase shrimp growth, survival and production. Feed performance can only be properly evaluated by practical feeding trials under pond management practices comparable to those in which the feed is to be used by farmers.

Shrimp ponds are complex environments, where feed input is only one of the factors associated with increased shrimp yield. The generation of pond foods for shrimp through natural pond productivity (which has been stimulated by the addition of manures or inorganic fertilizers) will be of greater importance at low stocking densities, as found in extensive and semi-intensive culture, than where stocking density is high. Under intensive culture, most, or all, of the nutrients for shrimp growth must be provided in the prepared feed.

In order to conduct an investigation into the contribution to shrimp production made by a particular feed or feeding method, it is essential to monitor various factors, e.g.

- Shrimp production – yield, mortality, growth rate, food conversion ratio.
- The water quality parameters that can influence general pond productivity.

Interpretation of results of feeding trials may be difficult, but should provide a better indication of how shrimp are utilizing a feed and give a guide to what extent the feed and/or pond environment is responsible for any differences in the results obtained.

In the feeding trials conducted within this project the following experimental restrictions applied :

- Equal stocking densities of shrimp post larvae per unit area;
- A common water supply and water exchange programme to each pond;
- Ponds of equal dimensions and design;
- Each feed treatment applied in a minimum of two ponds; and
- Feeds fed, if possible, for a full growing season.

Feeding trials were conducted at two sites at two different seasons.

- Small pond trials at the CIBA Research station, Kakdwip, West Bengal, using ponds of 0.027 ha.
- Large pond (farm) trials at the Directorate of Fisheries/BOBP site at Kakinada, Andhra Pradesh.

6.2 Practical feeding trial methodology

The feeding trials were designed to determine the nutritional and economic performance of feeds for potential use under low capital, semi-intensive culture in India.

All ponds were stocked with *P* monodon at ten animals/square metre. This is approximately double the stocking level adopted by most artisanal shrimp farmers. The purpose of this increase was to observe the effect of the higher stocking density on the potential for increasing the yield per pond from a national average of 400-600kg/ha to 1.0-1.5 tonnes/ha from a single harvest.

Prior to stocking, all ponds had been drained and sun-dried for several months and treated with lime. Chicken manure was also used as a preliminary pond fertilizer in all feeding treatments (Table 14). Sampling procedures for estimating stock density are given in Table 15.

Table 14 : Pond preparation and stocking

Example from pond trials :

Pond size : 6 ponds of 120m x 60m (*i.e.* 0.72ha water surface area per pond) /
18 ponds of 27m x 10m (i.e., 0.027ha water surface area per pond)

Sequence of pond preparation activities :

(i) Ponds sun-dried for 100-120 days

(ii) Pond bottoms dug over, sediment partially removed for pond bottom levelling

(iii) Day I : Pond liming. Slaked lime applied at 700kg/ha by scattering over pond bottom.

Day 2 : Application of sun dried poultry manure at 250kg/ha. No pesticide was applied

Day 3 : Water pumped into pond to depth of 10-15cm and left to stand for 6 days

Day 10 : Pond filled to 1m depth.

Day 13 : Fry stocked into *happas*

Day 20 : Fry transferred to ponds and *happas* removed.

Table 15 : Sampling procedures and indices of shrimp growth and survival

(i) Growth :

Shrimp were sampled at fortnightly intervals at 2% of stocking number (i.e. 54 animals per pond) for the small pond trial and 1 IO animals per pond from the large pond trial.

Weight and length were recorded.

Length Rostrum tip to extended telson tip

Weight for small shrimp: mean of 3 groups of I8 animals.
Weight for larger shrimp; mean of 6 groups of 9 ammals.

(ii) Survival

The estimation of survival is a difficult procedure. However, to obtain a 'best estimate' for a calculation of feeding rates, the following method was used :

For small ponds :

I. Make 3 casts per pond, 2 from the bundjdqke, one from the platform

2. Example of calculation :

Cast net area = IO sqm. Pond area = 270 sqm.

Assume a throwing efficiency and water factor to reduce effective net area by 25% to a harvest area of 7.5 sqm.

If mean number of ammals per net harvest = 50,
then : number of animals in the pond =

(pond area x 50)/ 7.5 = (270 x 50)/7.5 = 1800 animals

% survival = (initial stock x 100)/current stock

= (2700 x 100)/ 1800

= 66.7 per cent

<<

The feeds and feeding regimes (treatments) under test were:

Small pond trial

1. No feed, tidal estuarine water only (control)
2. Control + additional chicken manure fertilizer
3. Manufactured doughball feed presented on a tray*
4. Doughball on tray* + chicken manure fertilizer
5. Pellets broadscattered
6. Pellets broadscattered + fertilizer
7. Pellets fed on tray
8. Pellets fed on tray + fertilizer

* feeding tray prepared from split bamboo and five mesh woven nylon was approximate 0.8 m x 0.8 m in area with a rim height of 6 cm.

See Figures 5 and 6 for pond stocking method and pond layout.

Fig. 5 Individual pond layout – Small pond trial

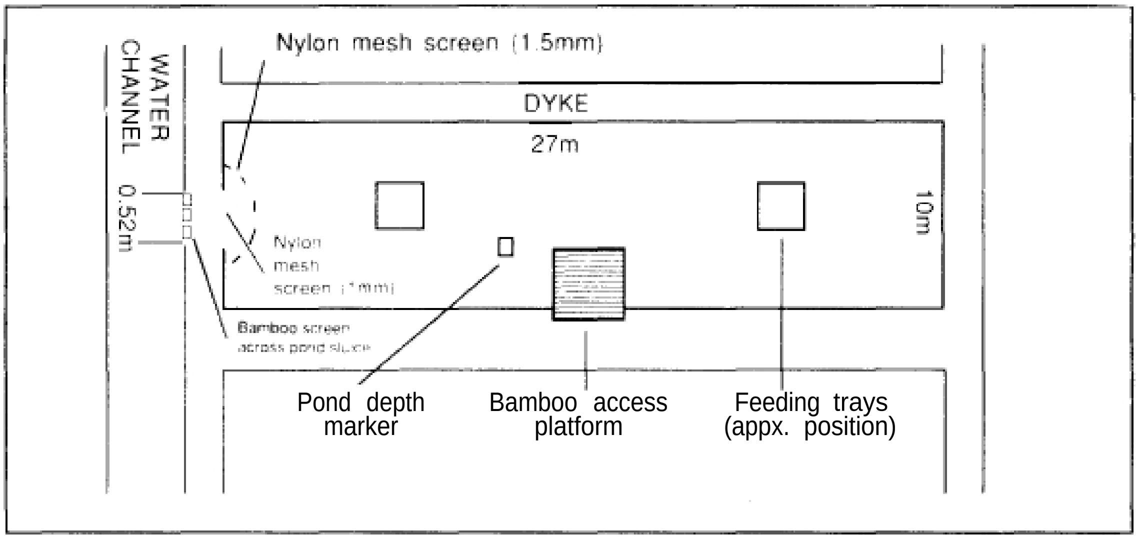
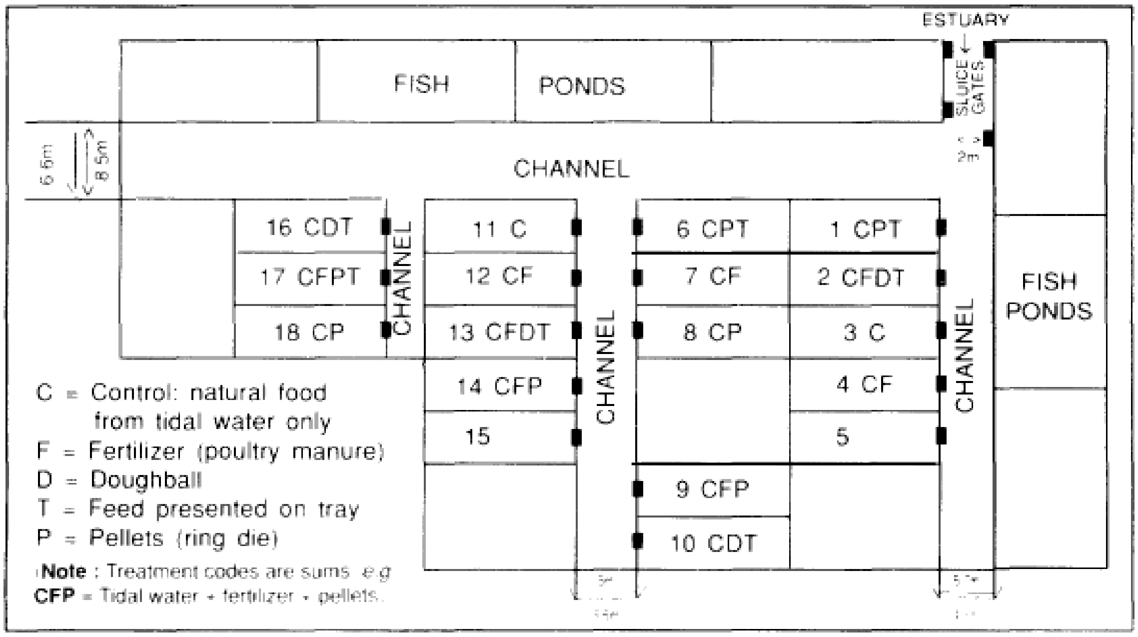


Fig. 6 Pond layout – Small pond trial



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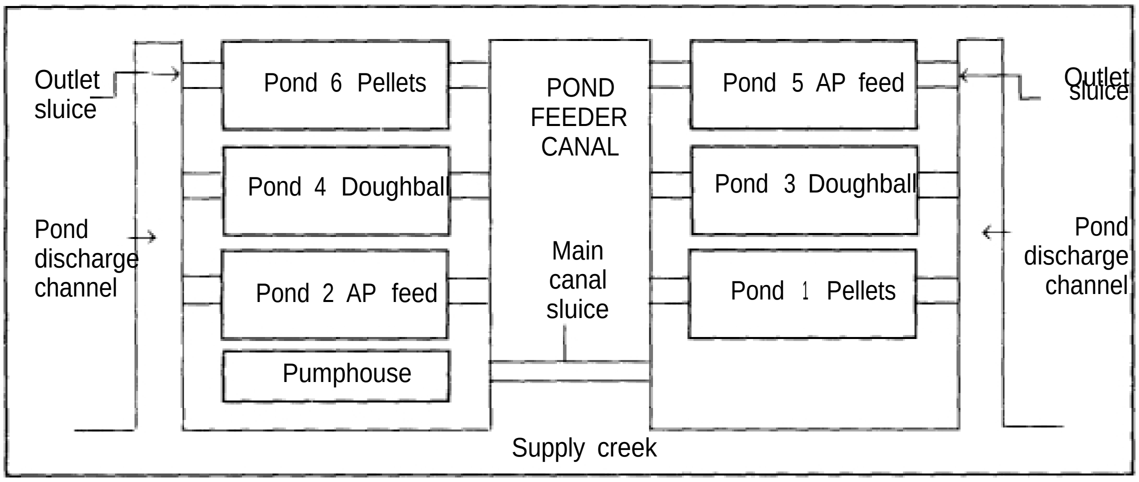
Large pond trial

1. Manufactured doughball presented in clay bowls.
2. Pellets broadscattered.
3. Andhra Pradesh moist feed presented in clay bowls.

See Figure 7 for pond layout

Fig. 7 Pond layout – Large pond trial

(Each pond was fed from a common pump-fed canal and drained from an exit sluice on the opposite bank. The layout is given be/ow)



These treatments were chosen to observe:

- **In the small pond trial,** the productivity of shrimp ponds in the presence and absence of feed, the effect of continuous manuring of ponds, and the effect of feed form (pellet or doughball) and method (tray *vs* scattered) on pond productivity.
- **In the large pond** trial, to compare shrimp performance and profitability when feeding shrimp dry, pelleted feed or doughball feed, or the local moist feed with which shrimp farmers were somewhat dissatisfied.

6.3 *Feed formulations*

6.3.1 SMALL POND TRIALS

The manufactured doughball and pelleted feeds had a protein content of approximately 35 per cent and were prepared to the formulation and by the processes described in Sections 4.2 to 4.5.

Pellets were water-stable for approximately two hours and were considered to contain the desired nutrients for optimum shrimp growth. The manufactured doughball base was a dry powder mix of the same formulation as the pelleted feed. This was prepared into a water-stable doughball by mixing with water at the pond side (Section 4.3).

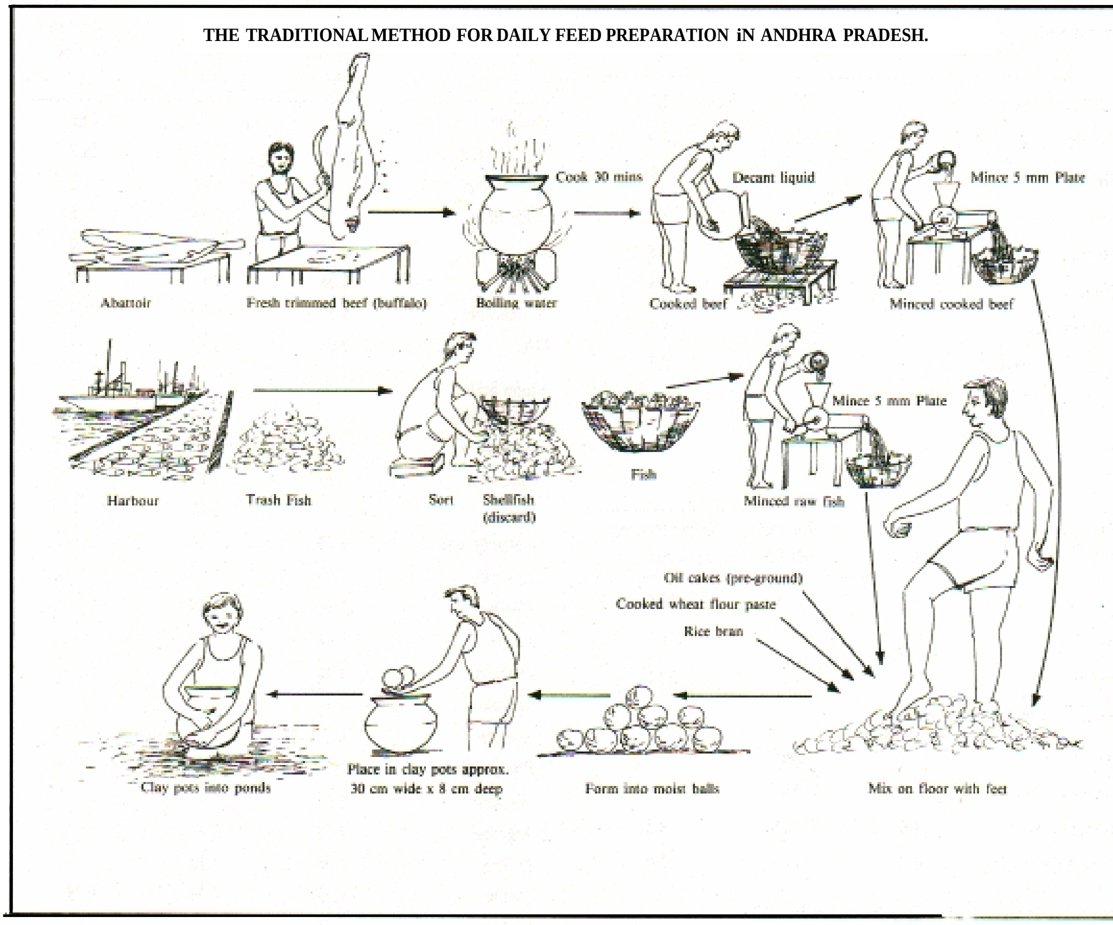
6.3.2 LARGE POND TRIALS

Pelleted feed and manufactured doughball feeds were of the same formulation as in the small pond trials.

6.3.3 ANDHRA PRADESH MOIST FEED

The local feed (AP) was prepared from trash fish, beef, rice bran and soya meal. (See pictures below and Figure 8 below) The feed was not of constant composition, varying almost daily with the'

Fig. 8 The traditional method for daily feed preparation in Andhra Pradesh and as used in large pond feeding trials.



The ingredients that go into the making of a better quality Andhra Pradesh shrimp feed formulation,

Making the 'dough ball' at a shrimp farm in Andhra Pradesh.

availability of the ingredients. The AP feed contained approximately 26 per cent protein (on a 10% moisture basis) (See Tables 16 and 17). No fertilizer was added to the ponds except for pond conditioning prior to stocking with post larvae

Table 16 : Formulation and cost of local AP shrimp feed

Raw materials	*As fed (wet)* %	*A t 10% moisture* %
Fresh beef (cooked)	7.2	27
Trash fish (raw)	27.0	10 0
Dried fish	9.3	11.8
De-oiled rice bran	21.7	29.0
Rice bran	28.3	37.8
Groundnut cake	2.4	3.2
Soyabean meal	3.6	4.8
Whear flour *(maida)*	*0.5*	*0.7*

LOCAL **AP FEED** COST :

Raw materials	*As fed* %	*R M cost* *Rs 'kg*	*Rs per inclusion* *Rs.*
Fresh beef (cooked)	-.2	4.25	30.6
Trash fish	27.0	21	56.7
Dried fish	9.3	4.2	39. I
De-oiled rice bran	21.7	I.1	23.9
Rice bran	28.3	3.0	84.9
Groundnut cake	2.4	4.0	9.6
Soyabean meal	3.6	4.25	15.3
Whear flour *(maida)*	*0.5*	*4.0*	*2.0*
Cost/100kg of moustfeed at 67% dry matter Rs 262,1			
Cost/kg of moist feed at 67% dry matter Rs. 2.62			
Cost/kg of moist feed at 90% dry matter Rs. 3.5			

Table 17 : Chemical analysis of shrimp feeds

	By analysis		*By colculation*
	Doughball %	*Pellets* %	*AP feed* %
Moisture	3.85	6.21	10.0
Crude protein	35.48	33.79	26.2
Ether extract	6.85	6.01	7.2
Crude fibre	3.18	2.45	7.8
Ash	15.75	14.54	12.9
Calcium	2 68	2 6:	1.7
Phosphorus	0.9:	0.99	1.5
TIA	2.00	2.29	—
Ammo acids : (as 4 of diet)			
Aspartic acid	3.75	3.52	
Threonine	I 39	1.20	
Serine	1.77	I 52	
Glutamic acid	6.71	5.98	
Gylcine	1.69	1.56	
Alanine	1.66	1.56	
Valine	1.63	1.59	
Isoleucine	I 50	1.50	
Leucine	2.37	2.23	
Tyrosine	I 17	I 25	
Phenylalanine	1.59	1.64	
Histidine	1.57	1.47	
Arginine	2.53	2.43	
Proline	1.64	1.88	
Cystine	0.63	0.59	0.28
Methionine	0.65	0 59	0.58
Total ly sine	2.09	2.01	1.71
Available lysine	1.97	I.89	1.50

6.4 Conduct of the feeding trial

Two ponds were allocated per feed treatment according to the pond layouts in Figures 10 and 11. Ponds were sampled at foitnightly intervals for the measurement of shrimp survival and size, thus enabling calculation of feeding levels. During these samplings, predators and non-P. *monodon* shrimp were removed from the ponds. Sample weighings occurred at the pond side and all *P. monodon* were returned alive to the ponds.

6.4.1 FEEDING RATE

Shrimp were fed according to a predetermined feeding scale which indicated a potential feed conversion ratio of 2.5 on a 90 per cent dry matter basis. The feeding scale for the large pond trial is given in Appendix IV.

6.5 Harvesting

At harvest, all ponds were partially drained overnight during the period of low tide, and then harvested by castnet. Final pond drainage was by pump. Ponds were hand picked for shrimp to ensure maximum shrimp recovery.

All shrimp were mixed with crushed ice within 20 minutes of harvest. Harvested shrimp (see picture below) were transported to the freezing plant within eight hours of harvest.

Size sorting the shrimp, after 80 days' growth (small pond trial)

7. RESULTS OF TRIALS

7.1 Results of feeding trials

The small pond trial was terminated after 80 days of growth because of transport difficulties with feed supply, whereas the large pond trial was terminated after 130 days of growth.

Treatments were assessed through an examination of the following parameters.

- Shrimp survival.
- Yield per hectare (or equivalent).
- Growth rate.
- Feed conversion ratio (kg feed per kg shrimp liveweight gain).
- Changes in water quality.

SMALL POND TRIALS

Using experimental pelleted feed of 35 per cent protein content and a stocking density of 10 animals/sq.m. a yield equivalent of 710 kg/ha of P. monodon was obtained in 80 days at an apparent FCR of 2.9 (See'Table 18, overleaf).

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The same formulation presented in a powder-based doughball form yielded the equivalent of only 440 kg/ha at an apparent FCR of 3.3. Feed conversion ratios were, however, difficult to calculate because of the level of non-monodon species which were competing for the feed targetted at *P. monodon* (See Table 18).

Table 18 : Shrimp performance data from feeding trial, March-June 1990 (Small pond trial)
*(Data presented as equivalent from 1 ha ponds) (mean **of** two ponds)*

Treatment	*% survivai*	*Pond yields calculated as kg/ha*		*% Crop P. monodon*	*Apparent jeed* conversion *ratios (kg feed/kg live wt gain)*		
		Total biomass *kg/ha*	*P. monodon kg/ha*		*A*	*B*	*c*
Control	17.5	153	53	34.5	–	–	–
Control t Fert.	38.0	302	125	41.4	–	–	–
Doughball (T)	47.0	600	3%	66.0	5.9	3.9	3.9
Doughball (T x F)	60.0	784	494	63.0	4.3	2.8	2.7
Pellets (Scat.)	68.0	939	746	81.4	3.7	3.0	3.0
Pellets (Scat. x F)	77.0	1106	841	76.0	3.6	2.8	2.8
Pellets (T)	55.0	1012	597	59.0	4.5	2.7	2.4
Pellets (T x F)	58.0	883	688	17.9	5.2	3.6	3.3

Notes : T = feed presented on tray F = fertilizer added to pond

FCR data A = Assuming all feed was consumed by *P. monodon* B = Assuming feed consumption by total biomass

C = Assuming feed consumed by *P.* monodon was in proportion to the % of *monodon* in the harvest.

Taking into account the higher stocking density used in this trial and the shorter growing season, this trial indicated that the experimental doughball was performing similarly to requested results from farmers for artisanal feeds, and the pelleted feed had the potential to double shrimp yields if fed over a full growing season.

Yields of *P. monodon* were greater in ponds fed scattered pellets than with pellets on trays or manufactured doughballs. (A local moist feed was not tested in this trial.)

The use of chicken manure as pond fertilizer appeared to boost the survival and yields for almost all feed treatments. In the case of the unfed control, fertilizer addition more than doubled the yield and survival; for pelleted feed the increase due to fertilizer was approximately 13 per cent.

The yield of *P. monodon* as a percentage of total biomass in the ponds was lower than anticipated. In hindsight, the mesh size of the pond inlet screens (16 mesh/sq in) was sufficiently large to permit the auto-entry of other shrimp and fish fry during pond water exchange. These competed with *P. monodon* for the feed provided and thus made the calculation of FCR rather complex.

The overall performance of the pelleted feed from the 80 day trial was particularly encouraging. The result indicated that the use of pelleted feed over a full growing season in ponds stocked at twice the normal stocking density had the potential to more than double shrimp yield/ha.

Low dissolved oxygen in the ponds appeared to be the most limiting environmental factor to increasing shrimp yields.

LARGE POND TRIAL

Three feeds were tested in duplicate on a six-pond site.

A harvest of 1345 kg/ha equivalent was obtained within a 140-day growing period from shrimp fed the experimental pelleted feed. This compared well with the extrapolated yield from the small pond trial and is two to three times the average yield from artisanal ponds using supplementary feeding. (Table 19).

Table 19 : Shrimp performance data from feeding trial in large pond (September 1990 — February 1991)

Pond size : 0.75 ha

Stocking density : 100,000 animals/ha

Two replicate ponds per treatment.

	Days growing *period*	Survival %	Yields *P. monodon* *(kg/ha)*	Daily lwg * *(g)*	% crop *P. monodon*	*Apparent FCR* **
AP feed	147	79.0	1806	0.16:	97.1	4.8
	126	38.0	1014	0.220	98.6	6.4
Means	137	58.5	1410	0.193	97.9	5.6
Pellets	147	65.1	1596	0.167	99.0	3.9
	140	34.5	1094	0.222	96.9	4.9
Means	143	49.8	1345	0.196	98.0	4.4
Doughball	140	74.2	992	0.099	97.5	6.5
	126	47.1	906	0.149	89.6	7.6
Means	133	60.9	949	0.124	93.5	7.0

* Daily live weight gain calculated from sample data at harvest.

* FCRs calculated at 10 per cent moisture.

The harvest from the powder-based doughball feed was 950 kg/ha equivalent, which was again comparable to an extrapolated small pond trial result.

FCRs were, however, poorer, at 4.4 and 7.0, for the pellets and powder-based doughball feed respectively.

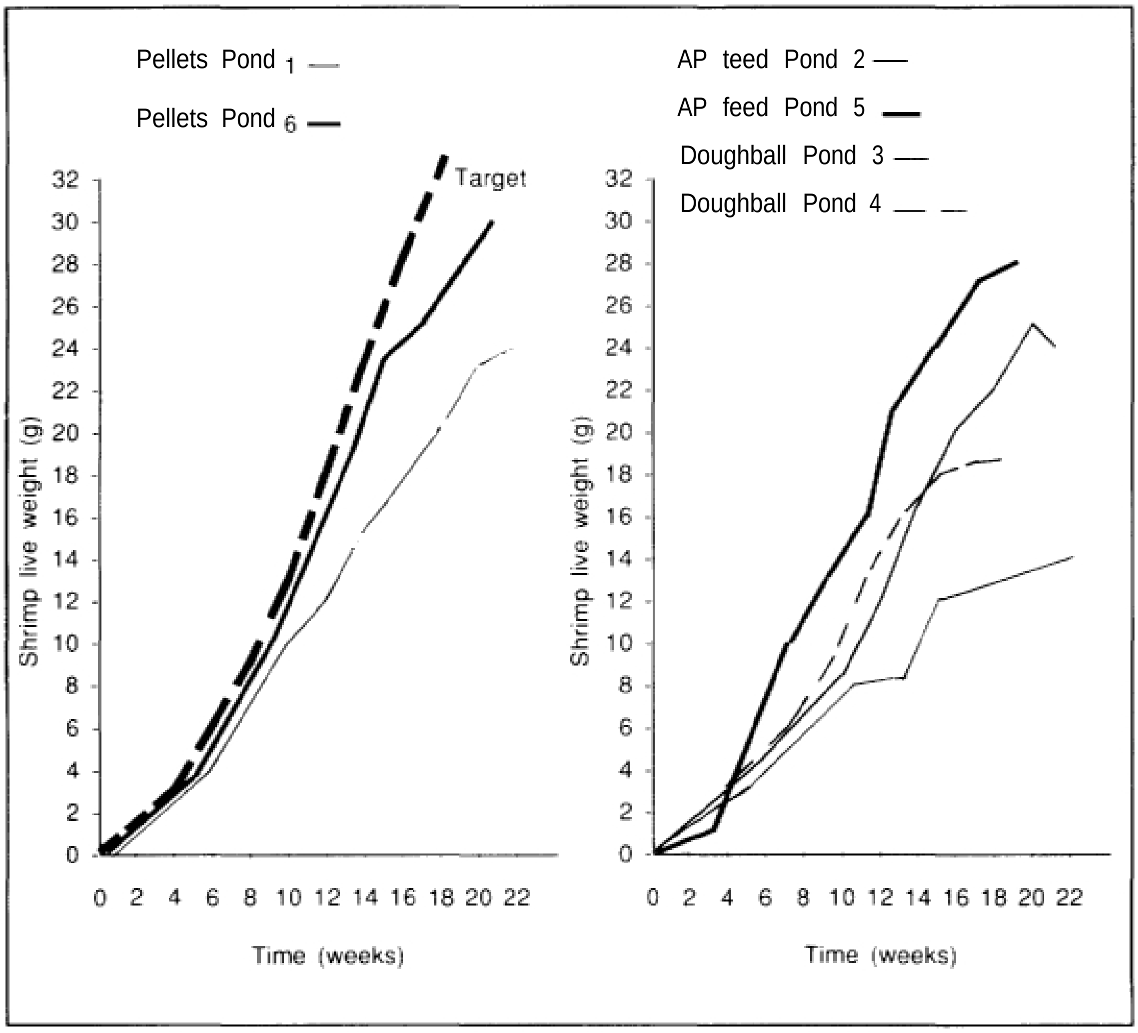
The unexpected result from this trial was the yield of 1410 kg/ha equivalent from ponds fed the local moist feed. This result also surprised our collaborating scientists, since yields of this level had not previously been noted. This feed, with an average crude protein content of 26 per cent, returned an apparent FCR on a dry feed basis of 5.6.

The conversion of feed into shrimp growth was more efficient for shrimp that were fed pellets rather than the local moist feed or the manufactured doughball mix. In relation to the small pond trials; the results suggest a measure of overfeeding due to difficulties in assessing actual survival and stocking levels of shrimp throughout the growing period.

The mean growth rate of shrimp fed the pelleted feed diet and the local Andhra Pradesh moist feed diet quite closely followed the desired target growth curve for the first 16 weeks of the trial, but the growth rate decreased during the final six weeks prior to harvest (Figures **9(a)** and (b) and 10). This was no doubt due to limitations in dissolved oxygen rather than nutritional deficiencies within the feed.

Fig. 9 Shrimp growth rates – large pond trial

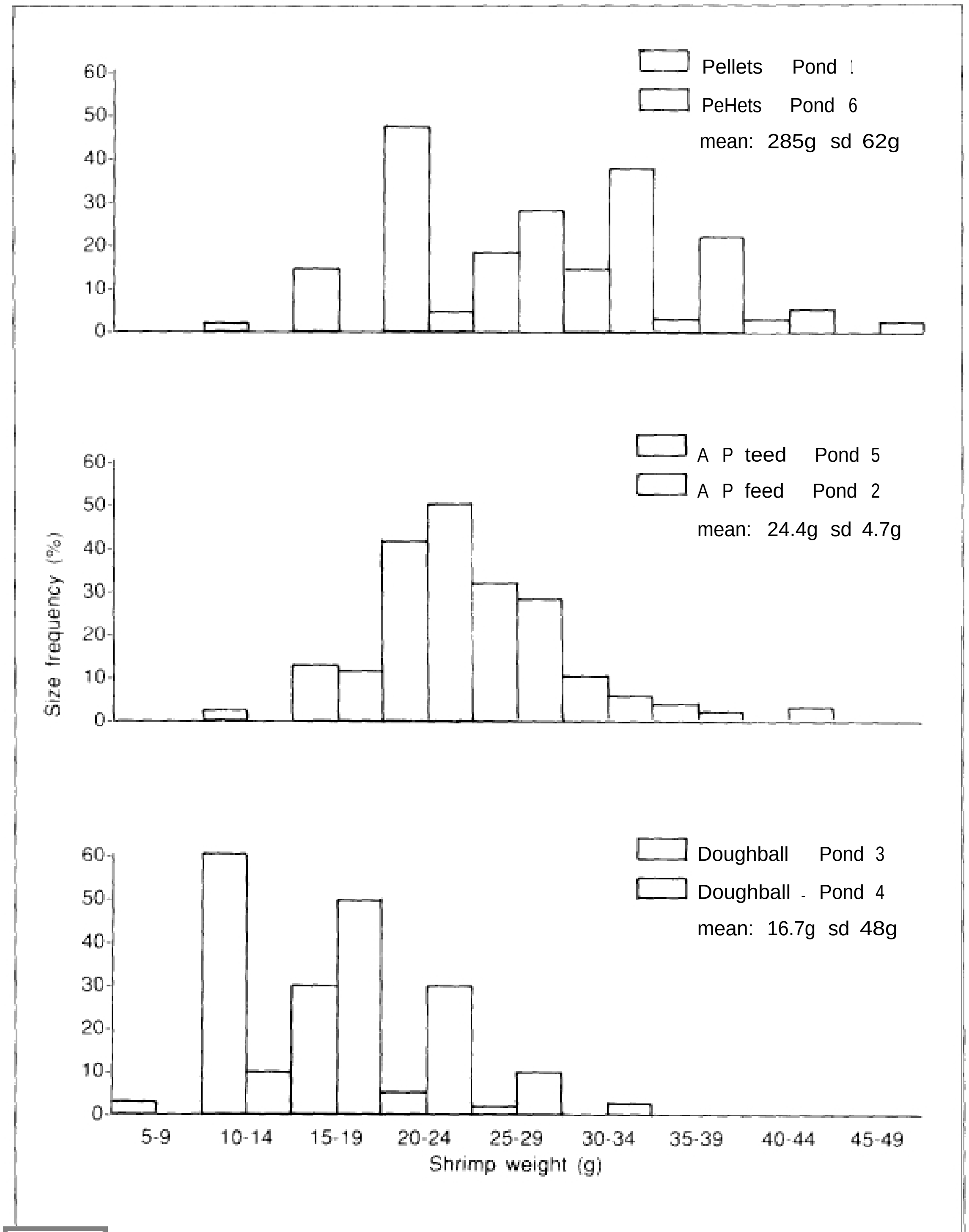
(a) Shrimp fed pelleted feed **(b) Shrimp fed doughball feed**



There was a high percentage of *P. monodon* in the harvested crop (89-99 per cent depending on pond and treatment). These findings indicate the considerable benefit of using pond sluice screens of 40 mesh/sq cm rather than 16 mesh/sq cm as used in West Bengal as a means of minimizing auto-entry of fish and shrimp fry from the supply canal. In addition, the mechanical action of the pump used to raise the water from the creek to the pond may have also killed potential pond competitors (and, presumably, added a small quantity of feed to the ponds in the form of mascerated competitors).

Large differences in yields and survival occurred between paired ponds receiving the same treatment; in particular, for ponds supplied with the local AP feed or pelleted feed. The differences appeared to he related to pond siting effects, since the ponds giving the highest yields within each treatment were nearest to the pump end of the water canal and thus with the lowest yields were furthest from the pump. (The fact that the two ponds which were sited furthest from the pump were also furthest from the research centre building and, thus, more easily harvested by night time poachers, was also a probable explanation.) Ponds supplied with the manufactured doughball mix were adjacent to each other and yields and survival were similar. It was interesting to note that, within paired ponds, the pond with the lowest yield contained the larger shrimp (Figure 10).

Fig. 10 Size distribution of shrimp at harvest
(Data from Random Sampling)



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7.2 *Changes in pond environment during the feeding trials*

SMALL POND TRIALS

Throughout the feeding trial, pond water salinity remained constant at approximately 13 ppt. Of the other parameters measured, dissolved oxygen was most critical. During the last month of the trial, the pond DO levels were less than the critical level of 3ppm. The number of times that this occurred appeared to be roughly proportional to the eventual yield in the pond. When DO levels reached 3ppm, intermittent pumping was commenced to raise the DO above this critical level. Pumping was done as necesssary during the final weeks of the trial.

The chemical parameters showed generally synchronous trends, implying that the treatments had less effect on the water chemistry than the supply water itself. It is probable that the flushing allowed considerable mixing between treatments and any differences that might have been expected due to feed and fertilizer application were lost.

LARGE POND TRIALS

At the Andhra Pradesh trial, dissolved oxygen and salinity levels varied to the greatest extent and therefore had the greatest effect on shrimp performance. Figures 11, 12 and 13 (below and facing page) illustrate the water DO, salinity and pH levels found in the ponds and supply creek throughout most of the culture period. At the commencement of the feeding period, DO levels were within the optimum range in both the creek and pond, but the salinity was very low due to the heavier-than-usual monsoon rains.

While water salinity increased as the trial progressed, the DO levels steadily decreased, due in part to the increasing oxygen demand of the growing shrimp. DO was not being replaced through photosynthesis of the pond flora and the daily replacement of 10-15 per cent of pond water with creek water. However, since, for much of the trial, the DO level in the supply creek was only *4-5mg/I,* it was not surprising that the DO levels in the ponds were below 3mg/I. Aeration of water by pumping was commenced when DO levels were below 3mg/I.

Fig. 11. Creek and pond salinity (Large pond trial)

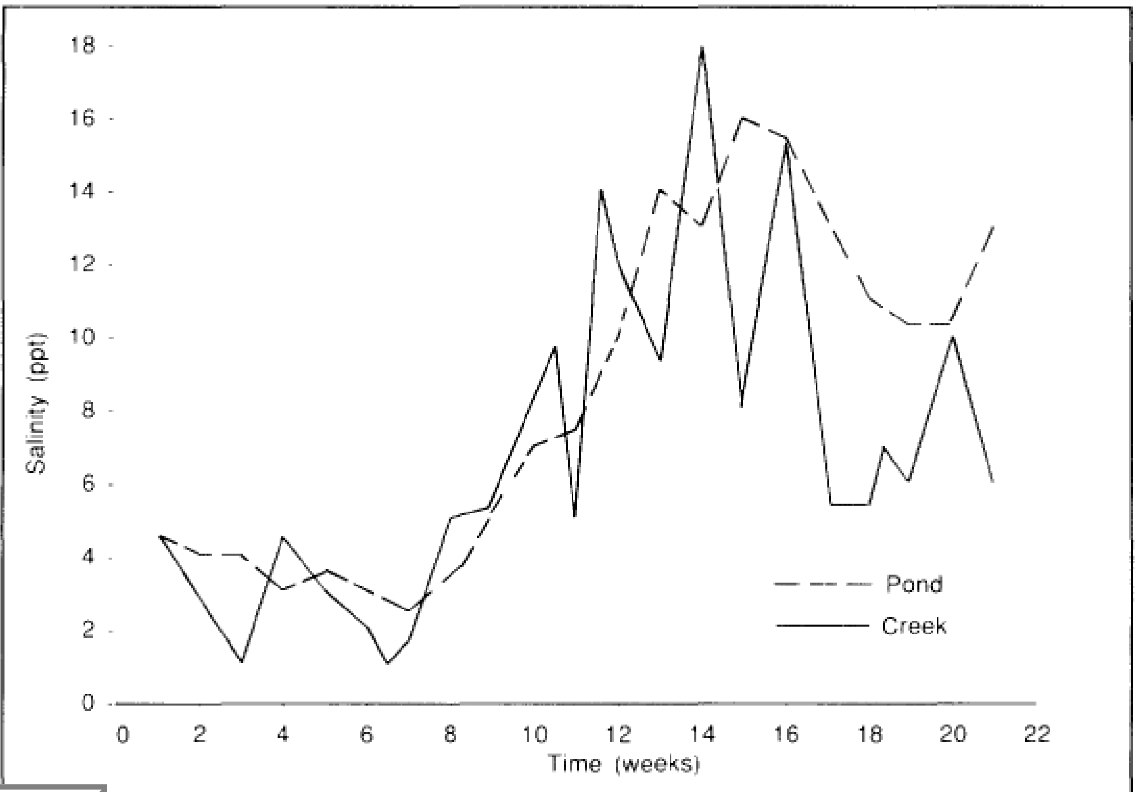

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Fig 12. Changes in pond bottom water dissolved oxygen at dawn during growing season (large pond trial)

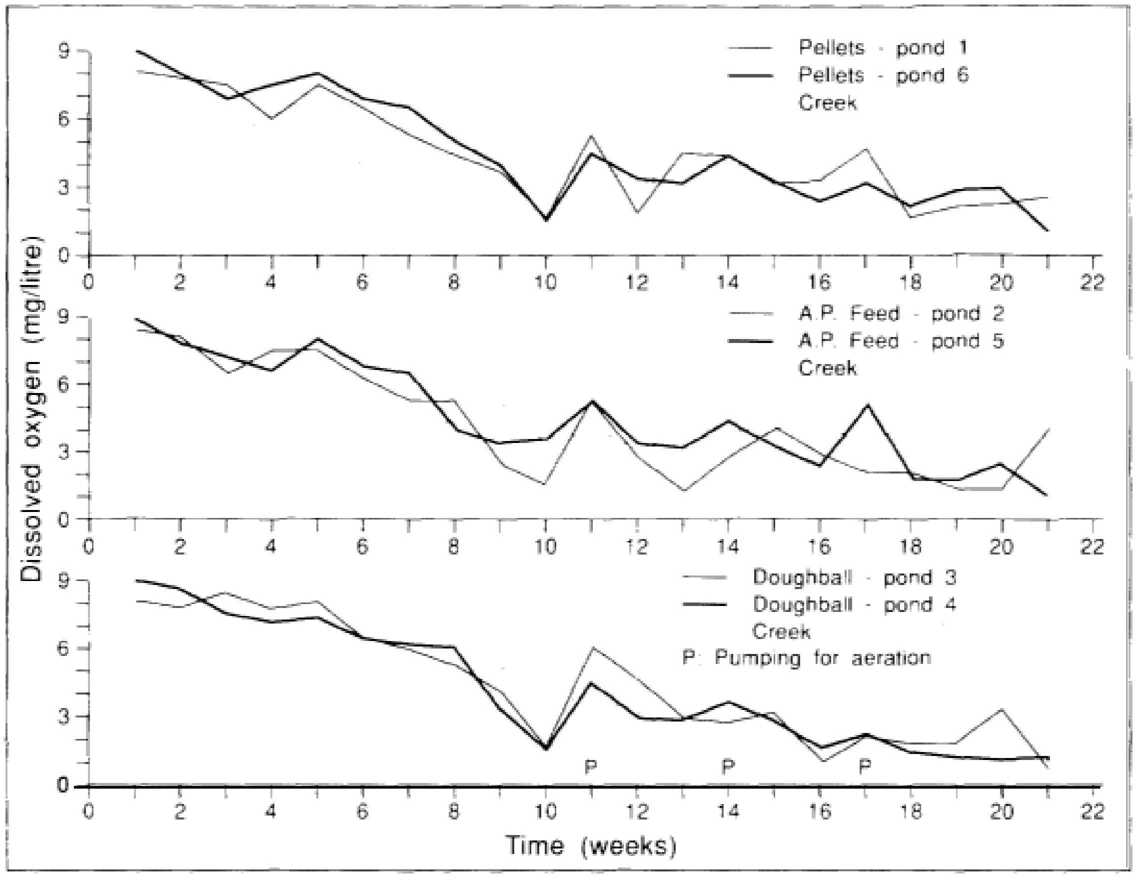
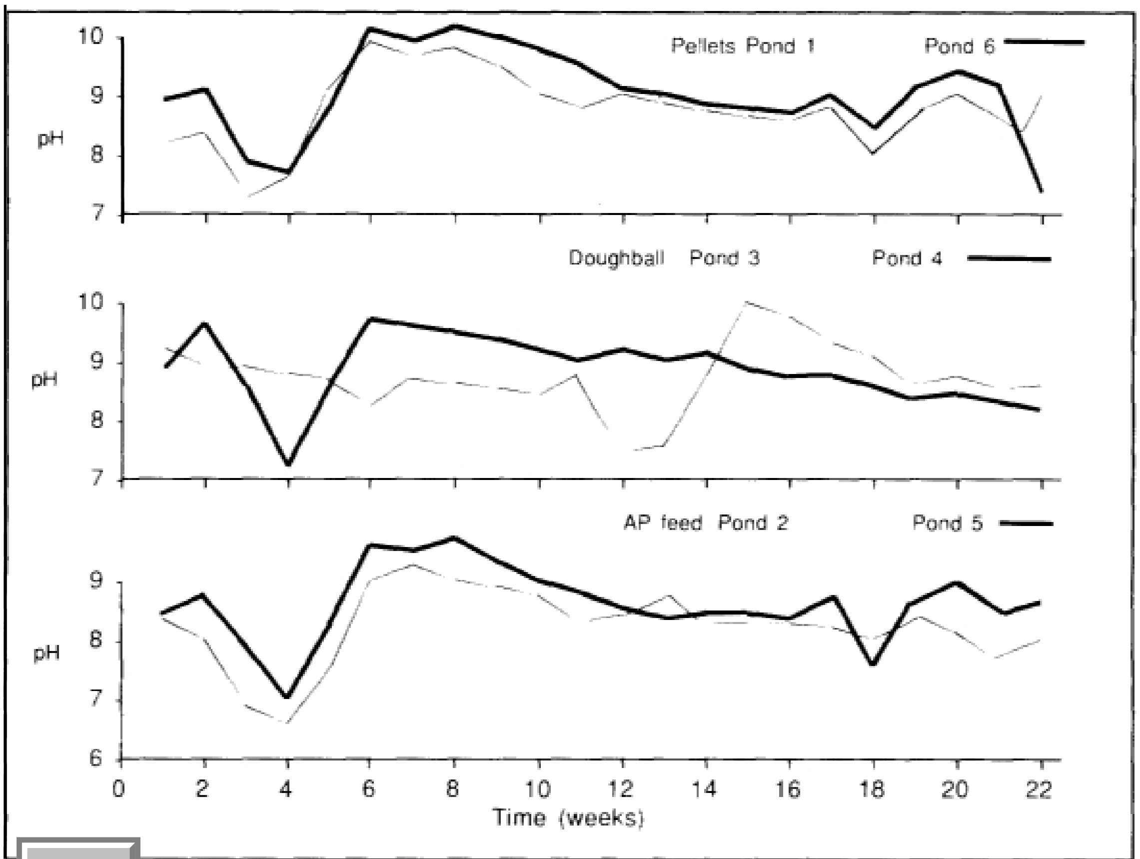


Fig 13. Changes in pond bottom water pH at dawn during shrimp growing season (large pond trial)



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Dissolved oxygen levels at the mud bottom of ponds were approximately 0.2 mg/l less than surface levels for all ponds.

NOTES

1. The pond water analysis indicated that the trial conditions were not sufficiently extreme to cause difficulties apart from those associated with low dissolved oxygen levels.

2. Problems associated with high salinity may be partially overcome by mixing saline water with fresh groundwater (if available). There is no similar option for overcoming the problem of water of low salinity if the primary supply source is a tidal estuary and the ponds are a considerable distance from the sea.

7.3 Potential implications of pond environmental assessment

Insufficient data was obtained to present a clear picture of the ways in which the water quality of shrimp ponds was being affected by shrimp stocking density or feeding system. However, if the measured DO levels in creek waters were representative of typical values throughout the year, then there may be little opportunity for increasing pond yields through higher stocking density without supplementary water oxygenation through the use of electro-mechanical aerators.

Low DO in the latter stages of both small and large pond trials was probably the most limiting factor to shrimp growth. This suggests that a stocking level of ten animals/sq m is too high for non-areated artisanal ponds.

It would be valuable to test varying shrimp stocking densities under local conditions to determine a maximal level of stock possible before oxygen stress is induced. It is expected that this density would be between 6-9 animals/sq m. A lower stocking density is likely to result in lower yield, although, given the right conditions, they could grow to a larger size at a faster rate. In this context the cost effectiveness of aeration as a pond management option requires examination from both an environmental and shrimp production perspective.

Monitoring of the creek waters in the vicinity of the Kakinada trial ponds over the last ten years has indicated that the DO levels in creek water have been steadily declining from a high of 9mg/l to the present level of 4-5 mg/l. This may be the result of the increase in the number of shrimp ponds becoming operational in this region of Andhra Pradesh, and which are drawing water from, and discharging pond water drainage into, the same supply creek. The increasing use of fertilizers and other agrochemicals on rice crops and the drainage of field water into the same creeks only add to the problem.

7.4 Results of the bacteriological analyses of shrimp and pond sediment

Samples of shrimp and mud/water mixtures from each pond were analyzed for the presence of *Salmonella* and *Vibrio cholerae.* The *Salmonella* samples were examined using the traditional method and a new semi-solid agar technique. Counts of aerobic mesophylic bacteria, *Enterobacteriaceae,* and faecal *Streptococci* were also made.

Water for the West Bengal ponds was drawn from the Hooghly river, some 70km downstream from Calcutta. Although the ponds are not in a densely populated area, the river is subject to sewage pollution.

Water for the Andhra Pradesh ponds was drawn from a small creek/tributary of the Godavari River, some 20km from the river mouth but within the tidal estuary. The river is not subject to gross sewage pollution

RESULTS

It was found in the small pond trials in West Bengal that *Salmonella* was present in one shrimp sample and two mud/water samples. From Andhra Pradesh, presumptive *V. cholerae* were isolated from one sample of mud from a pellet feed pond, in two shrimp from a local feed pond and in one shrimp from a doughball feed pond.

DISCUSSION

The results of the bacteriological examination were insufficient to draw firm conclusions as to the effect of the feeding regimes on the microbiological quality of the shrimp and their environment.

In Andhra Pradesh, the overall incidence was very low and the findings suggest that none of the feeding treatments resulted in an unusual microbiological flora in the shrimp ponds.

However, in West Bengal, all of the isolates from the samples were identified by serotyping to be *Salmonella virchow* phage type 2. Whereas most *Salmonella* serotypes give rise to the well-known gastroenteritis, S. *virchow* is one of the select band which is capable of initiating a systemic infection involving the blood and cerebrospinal fluid. There was insufficient data to enable the likely source of the organism to be identified, but it is known to be a particularly virulent pathogen.

All of the isolates of *V. cholerae* from Andhra Pradesh were found to be of the non-O: 1 serotype (serotype 0: 1 is the causative agent of epidemic cholera). Non-O: 1 *V. cholerae* have been isolated from freshwater and estuarine environments throughout the world as well as from birds, frogs and freshwater fish (Bashford *et al* (1979)).

The majority of the non-0:1 strains of *V. cholerae* isolated from the environment do not appear to be enteropathogenic and appear to be indigenous there.

The limited number of samples taken during this survey will have resulted in sampling variations for both shrimp and mud/water. Many more samples from different sites within each pond would need to be examined before these factors could be resolved.

Reference :

Bashford, D. J., Dononan, T. J., Furniss, A. L., and Lee J. V., (1979) Lancet I: pp. 436-437

8. FINANCIAL APPRAISAL OF TREATMENTS AND FEEDING TRIALS

As with any farming enterprise, it is difficult to obtain accurate comparative information on the financial profitability of different enterprises because of the diverse ways in which they are managed, the terms of farm occupancy, family structure, farm size etc. This is true for the shrimp culture industry in India as well. Thus, any financial breakdowns must, of necessity, be broad generalizations of what may be happening in reality.

Nevertheless it is important that potential new feeding systems are examined in relation to plans for the expansion of shrimp culture by artisanal shrimp farmers, and in relation to what may be known of the apparent profitability of existing practices.

In this section the potential income from a model *bheri* farm in West Bengal (extensive, no feed input) is used as a baseline against which the relative apparent profitability of the semi-intensive culture in Andhra Pradesh, and the results of the feeding trials can be assessed. There are many limitations in the use of cost models, but it is hoped that the models and examples put forward will enable some constructive conclusions to be drawn on future shrimp feed developments.

8.1 Traditional bheri *culture*

Table 20 presents a cost model based on the experiences of local fisheries researchers during field visits and consultations with farmers. It shows that the net profit from a 10ha *bheri* farm could be of the order 60,000 Rs/annum. This would be the sole source of income for the farmer.

The cost model does not give a picture of the incremental value to farmers of shrimp farming over alternative crops since, within West Bengal, farmers have realized the benefits of *bheri* culture over rice culture or other crops in the estuarine areas. In addition, the higher soil salinity arising from repeated flooding of the *bheri* lands and the organic loading from shrimp culture (faeces, carapaces etc.) will inhibit rice growth and development.

Table 20 : Cost model : Progressive shrimp farmer in West Bengal (Supplementary stocking but no feed inputs)

"Typical" farm size: *10* ha as a single *bheri*

Typical total biomass yield (mixed fish and shrimp) : 350.500kg/ha/annum, say 400kg/ha/annum.

Financial parameters	*IRs**
Operating costs	
Lease on land 10ha x 5000Rs /ha	*50,000*
Feed	nil
Shrimp seed 10ha x 55,000pcs/ha x 50 Rs/1000 2	**27,500**
Labour 1 owner	nil
2 skilled labour x 10 months x 450 Rs/ month 3	9000
3 night watchmen X 6 months X 700 Rs/month 4	**12,600**
Harvesting commission 1 5 Rs/kg crop harvested 5	**3600**
Pond weeding/dyke maintenance 10ha X 5000 Rs/ha 6	**5000**
Bamboo for traps and screens	**5000**
Depreciation on diesel pump/pipes Rs. 12,000 over 5 yrs	**2400**
Pump fuel	**1000**
	113,100
Revenue	
Total yield of 10ha X 400 kp/ha	
Composition of harvest :	
Fish 20% X 4000kg X 25 Rsikg	**20,000**
p. monodon 35% X 4000kg x 90 Rs/kg (7)	**126,000**
Other shrimp 45% x 4000kg x 20 Rs/kg	**3,600**
	182,000
Net Profit	**68,900**
i.e. appx. 6900 Rs/ha	

NOTES

1. Land lease 4000-7000 Rsiha depending on distance from the sea.
2. Shrimp seed prices range Rs. 20-200 depending upon season.

   Note : Wild seed is a mixture of appx. 85 per cent *P.* monodon and 15 per cent miscellaneous species, and is added to the pond as a mixed stock. Approximately 10per cent of seed is bought at the higher prices during February-March, the remainder being purchased at a low price during the low salinity monsoon season when mortality is likely to be high (May-July). Typical annual average of 50 Rs/1000 stock unsorted. (This should be compared with a typical average of *250* Rs/1000 for sorted *P. monodon* for monoculture. In Andhra Pradesh, sorted seed is appx. 70 Rs/1000.)
3. Skilled labourers for making split bamboo screens as filters at sluice gates, fish traps, harvesting. May receive a harvest bonus of Rs 200-500 if crop is a high yield. Pay: 400-500 Rs/month + food. Sleep on the pond sites in a small hut.
4. Night watchmen for six months (May-October) at appx. 700 Rs/month without food supplement
5. Harvesting commission is based on crop harvested by gillnet or castnet, i.e. appx. 60 per cent of crop. Remaining 40 per cent of crop caught in traps. Harvesting is intermittent throughout the growing period.
6. During May-June ponds may become choked with emerging reeds at up to 3-5kg biomassisq m. These must be periodically removed before harvesting.
7. Sales price of *P. monodon* ranges 40-120 Rs/kg. Estimated annual average is 90 Rs/kg.

* US $ 1 = I Rs 19 appx. in 1989-91

8.1.1 SHRIMP SURVIVAL

If it can be assumed that the data in Table 20 represents a fair picture of extensive shrimp culture, then it can be seen that the overall survival of the supplementary stocked shrimp may be very low.

If the initial stocking = *55,000 P. monodon/ha* + natural seed
and
if final *P. monodon* harvest = 140kg/ha (1400kg/10ha see Table 16) and average shrimp weight = 20g,
THEN,

The number of *P. monodon* in the harvest = 140,000/20 = 7000 animals. i.e., a survival of **7000/55,000 x 100 = 12.7** per cent.

If the mean *P. monodon* weight was 15g, THEN survival = 17 per cent.

These figures, therefore, raise the question as to what would be the optimum level of supplementary stocking of tidal water ponds, without feed supplementation, that would be cost-effective to the farmer.

8.1.2 PROPOSITION FOR COMPARING EXTENSIVE AND SEMI-INTENSIVE SHRIMP CULTURE

If it can be assumed that an income of 68,000 Rs/annum is an acceptable income from a 10 ha pond without feed supplementation, and is sufficient to provide an improved standard of living for the farmer and his family, it could be argued that feed supplementation should enable an artisanal farmer with a smaller pond area to earn a similar income because of improvements in shrimp yield per pond arising from feed use.

The conditions under which this scenario could occur are examined in the light of the findings from the large pond trial.

8.2 Profitability : pellets vs local moist feed

Contrary to expectations, the local Andhra Pradesh moist feed was considerably more cost-effective than the pelleted feed (Table 21). The powder-based doughball made a loss. It was initially assumed that the labour costs for the long preparation period for the local feed would, in part, compensate for the difference in feed costs. This was not the case in practise (see Appendix V).

Table 21 : Summary of financial inputs into shrimp production at Kakinada, Andhra Pradesh (values are means of two ponds)

OPERATING COSTS

Feed	*Pellets*	*Doughball*	*Local A.P. Feed*
I. Feed	66,819	73.019	20,727
2. Feed collection	–	–	7,700
3. Labour for daily feding	385	581	3,800
4. Seed	5,250	5,250	5,250
5. Lime	611	611	611
6. Land lease	100	100	100
7. Harvesting cost	1,180	1,180	I.180
8. Water pumping cost	2,000	2,000	2,000
SALES REVENUE	76,345	82,741	4 1,368
P. monodon	*87.207*	30,573	88,640
Net Profit	t 10,862	52,168	* 47,272

NOTES : Cost derivations

I. FEED : Pellets (dry) 4353 kg x Rs. 15.35, Doughball (dry) : 4940 kg x Rs. 14.78, Local feed (moist) : 7911 kg x Rs. 2.62.
2. RAW MATERIAL COLLECTION COST : 50 Rs/day for local raw materials = Rs. 50 x 155 days =7700 Rs/season
3. LABOUR FOR DAILY FEEDING : see Appendix V
4. SEED : 75000 P. monodon per pond x 70 Rs/1000 = 5250 Rs/pond
5. LIME : 815 kg per pond x 0.75 Rs/kg = 611 Rs/pond
6. LAND (POND) LEASE : At Government rate of 100 Rs/annum to financially disadvantaged farmers. (compared with 5000 Rs/ha in West Bengal (Table 20)
7. HARVESTING COST : Rs 7080 for 6 ponds = 1180 Rs/pond
8. WATER PUMPING COSTS : For filling ponds from creek and recirculation within ponds for aeration.
9. SALES REVENUE : Actual income from shrimp packing plant.

From a development perspective, the poor performance of the powder-based doughball was disappointing, since the technology of manufacture was simple and was applicable to rural communities. The need for fine grinding to produce a water-stable doughball from the dry powdered ingredients was, however, its weakness . When the doughball disintegrated, the feed particles were probably too small for easy ingestion by shrimp and were, thus, lost in the pond environment.

Pelleted feed performed quite well on a nutritional and environmental basis, but was not competitive on price when compared with the net profit from shrimp fed the local moist feed.

The degree to which profitability could be improved through more accurate feeding, for example, can only be determined through further feeding trials, but even with an FCR of 2.9 for pelleted feed, as was obtained in the small pond trials, the net profit would have been only Rs 33,500 compared with Rs 47,000 for the local feed.

The profit figure of 47,000 Rs/ha for local feed ponds from this trial would appear to be representative of the potential income from l ha ponds where stocking density is ten animals/sq m. Local artisanal shrimp farmers in AP using shallow ponds and stocking at five animals/sq m were obtaining profits of Rs 15,000-25,000 from a single harvest. Their feeds were also based on beef, trash fish, rice bran etc.

On this level of profitability, a 1.5 ha pond under a pellet feeding regime and stocking density of ten shrimp/ha would appear to be comparable with the profitability of a no-feed input, extensive ten ha pond with an initial stocking density of five shrimp/ha. However, comparisons of this nature can be misleading, since there are considerable differences in the cost of land leasing between the West Bengal model (5000 Rs/ha) and that of Andhra Pradesh (at 100 Rs/ha for new Government lands for artisanal shrimp farmers).

8.3 Feed factors affecting shrimp pond profitability

To examine the potential for profitable shrimp feeding it is important to investigate the relationship between FCR, feed prices and yield on profitability.

This relationship is summarized in Tables 22 and 23 for shrimp fed on dry pelleted feed or moist feed respectively.

Table 22 : Potential pond profitability from the use of dry shrimp feeds. (using production costs as per Table 21)

Assumed income from shrimp sales : 1300kg shrimp/ha x 85 Rs/kg = 110,500 Rs/ha

	Feed Cost (Rs/kg)						
FCR	4	6	8	10	12	14	16
2.0	87300	82100	16900	71700	66500	61300	56100
2.5	84700	58200	71700	65200	58700	52200	45700
3.0	82100	74300	66500	58700	50900	43100	35300
3.5	79500	70400	61300	52200	43100	34000	24900
4.0	76900	66500	56100	45700	35300	24900	14500
4.5	74300	62600	50900	39200	27490	15800	4100
5.0	71700	58700	45700	32700	19700	6700	– 6310

Table 23 : Potential pond profitability from the use of local moist feeds. (using production costs as per Table 21)

Assumed income from shrimp sales : 1300kg shrimp/ha x 85 Rs/kg = 110500Rs/ha

	Feed Cost (Rs/kg)				
FCR	I	2	3	4	5
5.0	77900	71400	64900	58400	51900
6.0	76600	68800	61000	53200	45400
7.0	75300	66200	57100	48000	38900
8.0	74000	63600	52200	42800	32400
10.0	71400	58400	45400	32400	19400
12.0	68800	53200	37600	22000	6400

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This position, therefore, raises the question concerning other possible dry feed options which could be as, or more, cost- effective to use than the local feed but which could also be more consistent in quality and more environmentally stable.

Some options are discussed in the following section.

During the period of these studies the sales price of shrimp remained steady at about 90 Rs/kg. The price of seed was very variable, depending upon supply source (wild or hatchery), time of year etc. However, the nutritional performance of feeds and the price of feed are clearly the most important factors in determining the potential profitability of shrimp production.

8.4 Future options

From a nutritional viewpoint, the trial indicated that shrimp grown under the prevailing conditions did not require a feed of as high a nutritional quality as formulated in the pelleted feed. But to enable a dry feed to financially compete with the apparent profitability of the local moist feed, it must be available at a lower price and lower FCR than the pelleted feed evaluated in this trial.

The derived formulation of the Andhra Pradesh moist feed is very simple. It contains no supplementary minerals, vitamins, attractants, sources of sterols or phospholipids all of which are usually considered desirable in feed for intensive culture. These nutrients are presumably being provided from the secondary food chains within the pond.

With this background, the following questions could be raised :

- If a feed of simple formulation, comparable to the local feed, were presented in pellet form, would it result in an improved yield, survival, growth response and reduce pond quality deterioration when compared with the local feed using similar materials in wet form?
- Would it be preferable to feed the high protein fishmeal/meat/oilcake fraction as a water-stable pellet for direct ingestion by shrimp but provide the rice bran as pond fertilizer, or feed it as a complete feed?

Other fertilizer materials such as poultry or cow manure, or inorganic fertilizers, could be considered as alternatives to, or mixed with, rice bran for pond fertilization.

8.4.1 FEED OPTIONS - COST?

Firstly, if such options were considered for trial, what would the feed cost be, and could feeds be prepared in artisanal communities?

A 'dry' formulation of comparable nutrient composition to the local feed would be : (%) Meat meal 2.7; Fishmeal 21.8; Soyameal 4.8; Groundnut cake 3.2; Wheat flour 0.7; Rice bran 37.8; De-oiled rice bran 29.0.

To be of practical use, the raw material mix must have a binding system if it is to have water stability. (Table 24).

Table 24 : Potential dry 'local feed' equivalent with binder system

	%	/ Rs/ kg	1 Rs/inclusion
Meat meal	*2.70*	*6.00*	*16.20*
Fishmeal	*21.80*	*4.60*	*100.28*
Soya meal	*4.80*	*4.25*	*20.40*
Groundnut meal	*3.20*	*4.0*	*12.80*
Wheat flour	*0.70*	*4.00*	*2.80*
Rice bran	*34.30*	*3.00*	*102.90*
De-oiled rice bran	*29.00*	*1.10*	*31.90*
Plaster of Paris	*2.00*	*3.00*	*6.00*
Sodium alginate	*1.50*	*90.00*	*135.00*
			428.28
HENCE **: Raw material cost/kg feed**			4.30
General manufacturing cost incl. pulveris'n			2.00
			6.30
Profit and transportation			1.50
Total feed Cost per kg finished feed			Rs. 7.80

This, however, is unlikely to be successful in terms of physical manufacture, given the high fibre content and high percentage of rice bran in the formula.

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Alternative

An alternative on this theme is the adoption of a two-component feeding system, but using the same ingredients as above.

For example : a feeding system where the high protein material and rice bran were added to the pond as separate pellet and fertilizer components respectively would reduce the cost of the overall feed from 7.80 Rs/kg to 5.10 Rs/kg (Table 23) *i.e.* to a price which is competetive with the moist local feed (at 5.50 Rs/kg) at a similar moisture content (10 per cent).

Table 25 : Feed costs for pellet and fertilizer component feeding system. (Feed system comprises 36.7% pellets + 63.3% fertilizer.)

Pellet component	% of feed	Component %	Rs/kg	Rs/inclusion
Meat meal	2.7	7.8	6.20	48.40
Fish meal	21.8	63.4	4.60	291.60
Groundnut cake	3.2	9.4	4.00	37.60
Soya meal	4.8	13.9	4.25	59.00
Wheat flour	0.7	2.0	4.00	8.00
Plaster of Paris	2.0	2.0	3.00	6.00
Sodium alginate	1.5	1.5	90.00	135.00
	36.7			
Raw material cost per 100kg pellets				Rs. 585.60
Raw material cost per kg pellets				Rs. 5.90
General manufacturing cost				Rs. 2.00
Profit and transportation				Rs. 1.50
Total cost per kg pellet component				Rs. 9.40

Fertilizer componet	% of feed	Component %	Rs/kg	Rs/inclusion
Rice bran	**34.3**	**54.2**	**3.00**	**162.90**
De-oiled rice bran	**29.0**	**45.8**	**1.00**	**45.80**
	63.3			
Raw Material cost per 100 kg fertilizer component				**Rs. 208.70**
Raw Material cost per kg fertilizer components				**Rs. 2.10**
Transportation cost per kg bran				**Rs. 0.50**
Total cost per kg fertilizer component				**Rs. 2.60**

Hence cost of feeding system :

(36.7 kg x 9.40 Rs/kg) + (63.3 kg x 2.60 Rs/kg) = 100kg x 5.10 Rs/kg
i.e. equivalent cost of feed = 5.10 Rs/kg

From a feed manufacturing aspect, the partitioning of the diet into two components is advantageous since feeds containing large quantities of rice bran are difficult to grind and pellet. It also minimizes the need to transport large quantities of material from one place to another thus helping to reduce transport costs. In addition, since the quantity of sodium alginate needed to bind the feed is in proportion to the pellet fraction only, then the cost of this expensive material within the overall feeding system would be reduced by approximately 65 per cent.

8.4.2 POTENTIAL ADVANTAGES FROM A TWO-COMPONENT FEED SYSTEM

Advantages

- A more efficient use of the limited supplies of raw materials available for shrimp feed manufacture on a local basis.
- The ability to provide farmers with a feed of constant quality throughout the growing seasons, and whose availability is independent of the weather or fishing season.
- A reduced time requirement for feed preparation by shrimp farmers, thus releasing more time for pond management, monitoring and repair.

Disadvantages

- Unconsumed materials are potential pond pollutants as well as pond fertilizers. This is of particular importance if 65 per cent of the feed materials are being added to the pond as secondary sources of nutrients. The best form of fertilizer addition requires investigation.
- The decreased input, or load of pellet, into the pond (since 65 per cent as rice bran to be added loosely) could affect the shrimp by two mechanisms :
  - Although shrimp do actively seek out food, the decreased number of pellets/sq. m. may result in decreased pellet encounter and, hence, lower nutrient gain per individual shrimp.
  - Increase the cannabalism in a species of known aggression, given that pellet encounter will be less frequent.

9. RECOMMENDATIONS FOR FURTHER STUDY

The studies reported here have identified important factors which we believe require further investigation in support of the establishment of a viable shrimp feed industry in India.

The recommendations for further action are as follows :

9.1 Feeding trials

To investigate the feeding response of shrimp (P. monodon) to

- Feeds of lower nutrient specification, and the form in which they are fed, e.g. feed components as a complete feed, or high protein materials as a water stable pellet, or high fibre materials as fertilizer.
- Poultry/animal manure or inorganic fertilizers as alternatives to crop by-products for pond fertilization and their potential as pond pollutants.
- Feeds fed as above, but replacing beef **and** marine proteins with increasing levels of vegetable proteins.

It is strongly recommended that a feed of constant composition be used as a control standard within all feeding trials. This control feed could be imported, or of local manufacture, but its use will enable differences in shrimp performance, in relation to feed development and environmental conditions, to be more realistically compared and evaluated.

The trials conducted in West Bengal and Andhra Pradesh have underlined the variability that can occur between two ponds on the same site given the same feed treatment. It is therefore recommended that future trials should utilize three ponds per treatment on any pond site, and that ponds be carefully designed and managed throughout the trials. Increasing the number of ponds will, almost certainly, limit the number of treatments that can be examined, but will allow for more accurate interpretation of the results.

9.2 Environmental monitoring

Increased monitoring of the quality of water in shrimp ponds, supply channels and discharge creeks is strongly recommended. Studies are needed to determine the potential environmental damage which could result from expanding shrimp culture, and to seek ways of reducing the risk of water contamination.

Particular emphasis should be placed on the effects of pond draining on BOD/COD levels in supply creeks, and the rates of change in water quality due to tidal effects. Since many shrimp farmers follow similar growing cycles, there is the potential for a massive outflow of organic material from the ponds into the creeks at the seasonal harvest periods.

In this respect, care must be taken at the pond design stage to provide separate supply and discharge creeks for pond waters. A study to identify differences in water oxygenation due to distance from water supply pumphouses is also recommended.

9.3 Forum for sharing experience

Throughout the conduct of the feeding trials reported here, representatives of central fisheries institutes, state fisheries and shrimp feed manufacturers expressed the desire for a forum at which all matters of mutual interest in the development of the shrimp industry could be discussed and experiences shared. The establishment of such a forum is considered essential if the shrimp culture industry at large is to maintain its image as a producer of a quality product, and problems facing it are to be effectively tackled.

9.4 Shrimp feed manufacturers

Investment in new technology always bears some risk, but it is here that feed manufacturers wishing to enter the shrimp feed business will need to make further commitments.

The introduction of small-diameter dies and controlled steam- conditioning will bring improvements in pellet quality and water stability which cannot be achieved though the use of large-diameter poultry or cattle feed pelleting dies. Pellets from large dies must be crumbled and extensively screened to obtain products of desired particle size. This is an energy-inefficient method of preparing feeds which will decrease the value of the binding agents.

There must also be a willingness on the part of research and industry to co-fund and monitor nutrition/feeding trials, since neither sector has the experience or facilities to operate research studies independently.

9.5 Aeration

Although these trials have shown the potential increases in yield that can occur through the doubling of shrimp stocking density, the decrease in dissolved oxygen through increased oxygen demand of the shrimp, together with oxygen loss through waste feed decomposition, may be the limiting factor to the successful survival of shrimp prior to harvest. It is recommended that studies be established to more closely determine the oxygen requirements for shrimp production, particularly during the latter stages of growth prior to harvest, and the most cost-effective method of water aeration of artisanal shrimp ponds.

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APPENDIX I

The specific objectives of the Project

The specific objectives for the collaborative research programme were as follows :

i. To develop shrimp feeds which maximized the use of indigenous raw materials, thus minimizing imports.

ii. To formulate shrimp feeds for the growth of tiger shrimp (*Penaeus monodon*) under farming systems used by artisanal culturists.

iii. To use feed manufacturing machinery, preferably of Indian origin.

iv. To evaluate the performance of feeds in pellet and doughball forms, with and without additional fertilizer pond supplementation.

v. To prepare financial evaluations of shrimp productivity under the different feed treatments.

To meet these objectives, a three-phase project was established as follows :

Phase 1. An evaluation of the availability of raw materials for shrimp feed production in India, and the potential availability of machinery of Indian origin to meet the manufacturing requirements for shrimp feed.

Phase 2. A feeding trial to be conducted with CIBA to determine, under small pond research conditions, the effect of feed form and fertilizer application on the growth rate, survival and yield of *P. monodon* under conditions of artisanal shrimp culture in West Bengal. In West Bengal, ponds are filled and emptied with water during changes in tidal amplitude.

Phase 3. A feeding trial to be conducted with the DoF, Andhra Pradesh, using farm scale ponds of 0.75 ha, to determine the effect of feed form as demonstrated from the West Bengal trial against the performance of the local Andhra Pradesh doughball feed in the pump-filled ponds used by artisanal shrimp culturists in Andhra Pradesh.

APPENDIX II

Estimated composition of feed raw materials for calculation of diet formulations.

RAW MATERIALS

DRY FEEDS

	Wheat Atta	*Broken Rice*	*Soya Meal*	*Fish Meal*	*Shrimp Head Meal*	*Squid Meal*
Dry matter	89.0	89.5	90.0	87.4	91.4	91.0
Crude protein	12.5	7.0	43.5	43.8	39.1	78.7
Ether extract	1.3	0.5	1.0	1.6	1.7	1.1
Crude fibre	2.5	0.5	5.5		–	
Ash	1.7	1.0	5.5	12.3	36.1	2.4
Calcium	0.05	0.01	0.30	6.1	10.1	0.11
Phosphorus	0.34	0.10	0.60	0.91	2.03	0.47
Methionine	0.20	0.27	0.80	0.54	0.58	3.37
Methionine + Cystine	0.44	0.37	1.40	1.04	0.94	4.67
Total Lysine	0.35	0.27	3.00	2.33	1.94	5.80
Avail Lysine	0.29	0.24	2.70	2.20	1.73	5.43

** includes chitin nitrogen.

WETLOCALAPFEED
(Estimated composition of raw materials)

	Cooked beef	*Trash fish*	*DOB*	*Rice bran*	*GNC*	*Soya meal*	*Dried* fish	*Wheat* **flour**
Dry Matter	75.0	75.0	90.0	90.0	90.0	90.0	85.0	88.0
Composition at appx. 10 per cent moisture content.								
Crude Protein	75.0	61.0	14.0	12.5	40.0	42.0	50.0	13.5
Ether extract	11.5	6.0	2.0	13.0	6.0	2.5	8.0	3.0
Crude Fibre	–	–	12.0	10.0	7.5	5.5	–	3.0
Ash	3.5	23.0	8.0	11.0	5.7	5.5	30.0	2.0
Calcium	0.3	6.2	0.1	0.1	0.1	0.3	8.2	0.1
Phosphorus	0.3	3.0	1.1	1.0	0.6	0.6	4.0	0.3
Methionine	1.0	1.9	0.2	0.2	0.5	0.8	1.5	0.2
Methionine * Cystine	3.0	2.5	0.3	0.3	1.1	1.4	1.9	0.4
Total Lysioe	5.3	5.0	0.5	0.5	1.4	3.0	4.6	0.4
Available Lysine	5.0	5.0	0.3	0.3	1.3	2.7	4.2	0.3

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APPENDIX III

Derivation of dry feed costs

Raw Materials	Cost/kg I Rs	Inclusion %	Costs (IRs) Doughballs	Costs (IRs) Pellets
Wheat Atta	4.0	28.75	–	
Wheat Atta	4.0	19.25	77	77
Soya meal (44%CP)	4.1	39.00	160	160
Soya flakes (52%CP)	7.0	31.00	–	
Broken rice	2.0	5.00	IO	IO
Fishmeal	4.6	10.00	46	46
Shrimp head meal	4.0	10.00	40	40
Squid meal	23.0	5.00	115	115
Fish oil	22.0	3.00	66	66
Soya lecithin	80.0	2.00	160	160
Mineral premix	92.0	2.00	184	III4
Vitamin premix	106.0	1.00	106	106
Choline chloride	65.0	0.2s	16	16
Plaster of Paris	3.0	2.00	6	6
Sodium Alginate	90.0	1.50	135	135
Total Raw Material Costs (Rs/100kg)			II21	1121
Rs/kg			II.21	II.21
Pulverization cost			0.65	0.65
General manufacturing cost(estimated)			1.00	1.50
Product cost ex-mill			12.86	13.36
Profit t Transport, (IS per cent)			1.92	1.99
Sales price feed delivered (Rs/kg)			14.78	15.35

CP = Crude Protein

APPENDIX IV

Feeding schedule (Large pond trial)

The shrimp feeding schedule for the trial was based on anticipated shrimp survival (%) and feeding rates (%) of biomass), and estimated animal weights.

Provisional Feeding Regime · Per pond

Week no.	Est. survival %	No. of shrimp in pond	Est. shrimp weight (g)	Est. biomass in pond (kg)	Feed rate % bodyweight	Doily feed/pond (kg)	Feed size
0	100	75,000	0.13	9.7	10	0.97	St
l			0.5	37.5	10	3.75	
2			1.0	75.0	10	7.5	
3	90	67,500	2.5	168.8	10	8.4	
					10	+ 8.5	Gr
4			3.0	202.5	10	20.2	
5			4.0	270	10	27.0	
6			6.0	405	7	28.4	
7	80	60,000	7.0	420	7	29.4	
8			9.0	540	6	32.4	
9			11.0	660	6	39.6	
10			13.0	780	5	39.0	
II	70	52,500	15.0	788	5	39.4	
12			18.0	945	4	37.8	
13			21.0	1102	4	44.1	
14			23.0	1207	3	36.2	
15	65	48,750	26.0	1268	3	38.0	
16			28.0	1365	3	41.0	
17			30.6	1492	3	44.8	
18			33.5	1633	3	49.0	
19			36.5	1779	3	53.4	
20			39.0	1901	3	57.0	

St = starter crumb

Gr = grower granules

Fi = finisher pellets

Using these figures : cumulative feed total = 4801 kg

liveweight gain = 1901 kg

Hence estimated apparent FCR = 2.52

Note : Weeks l-5, feed according to this table.

Weeks 6-harvest according to cast net sampling.

During the first 5 weeks of the trial the shrimp were considered to be too small for handling for the assessment of survival and weight and the revision of daily feeding rates,

APPENDIX V

Calculation of labour costs for daily feeding

	fellers	Doughball	AP jeed
a. Time for feed collection(hrs) : (fresh beef and fish)			3
b. Time for preparation :			
2 x 15 minutes (hr)	–	0.5	
2 men x 3 hrs (hr)			6
c. Time for feeding :			
4 x 15 minutes (hr)	1		
2 x 30 minutes (hr)		1	1
d. TOTAL TIME (hr)	l	1.5	10
e. Time cost per day at Rs 2.50 per hour (I Rs) :	2.5	3.75	25
f. No days of feeding :	154	155	152
g. TOTAL LABOUR COST FOR FEEDING DURING FEEDING TRIAL (Rs)	385	581	3800

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APPENDIX VI

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Newsletters *(Bay of Bengal News)* which are issued quarterly and which contain illustrated articles and features in non-technical style on BOBP work and related subjects.

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