Dietary feeding strategies for marine shrimp: a review

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Introduction

In common with poultry or salmon, shrimp have a dietary requirement for 40 or so essential nutrients (for review of the dietary nutrient requirements of shrimp see Boonyaratpalin, 1996; Cuzon et al. 2004; Conklin & Tacon, 2001; D'Abramo, Conklin & Akiyama, 1997; Kanazawa, 1995; O'Keefe, 1998; Shiau, 1998; Teshima et al., 1993; Wang & Liang, 2001). However, in marked contrast to existing commercial poultry and salmon farming operations where animals are raised almost exclusively within intensive farming systems and fed nutritionally-complete artificially compounded diets for their entire life cycle (Beveridge, 2004; Leeson & Summers, 1997), shrimp are currently farmed under a wide range of different production systems and fed an equally diverse array of different foods and feeding strategies throughout their life cycle (Cuzon et al. 2004; Jory et al. 2001; Tacon, 2002).

Farming systems

Farming systems and feeding strategies currently employed for marine shrimp vary with shrimp size (larval, nursery, juvenile, adult), species, country and the financial resources of the farmer. For example, farming and feeding strategies used by farmers for the on-growing of shrimp from post-larval (PL) to market size currently include:

1) Extensive outdoor farming systems, with no additional nutrient input through fertilization or feeding;

Shrimp species:	*L. vannamei, P. monodon, P. chinensis, P. indicus*
Rearing unit:	large earthen ponds, lagoons or enclosures (up to 100 ha)
Water exchange:	tidal or pump, generally low water exchange, < 5%/day
Stocking rate:	low, usually < 5 shrimp m^{-2}/m^{-3}
Aeration:	none
Labor inputs:	low, usually < 0.1 persons/ha
Feeding regime:	none
Shrimp production:	< 500 kg (head-on)
Production cost:	US $ 1-2/kg live shrimp

2) Extensive tidal/running water outdoor farming systems (earthen ponds – all sizes) with fertilizer and/or complete/supplementary diet feeding;

Shrimp species:	*L. vannamei, P. monodon, P. chinensis, P. indicus*
Rearing unit:	large earthen ponds, lagoons or enclosures (up to 100 ha)
Water exchange:	tidal or pump, generally low water exchange, < 5%/day
Stocking rate:	low, usually <5-10 shrimp m^{-2}/m^{-3}
Aeration:	none
Labor inputs:	low, usually < 0.1 persons/ha
Feeding regime:	fertilization and/or complete/supplementary diet feeding
FCR range	0.9-1.3
Shrimp production:	< 1,000 kg (head-on)
Production cost:	US $ $ 1.70-2.50/kg live shrimp

3) Semi-intensive static/running water outdoor farming systems (earth ponds – all sizes) with fertilizer and/or complete/supplementary diet feeding;

Shrimp species:	*P. monodon, P. chinensis, L. vannamei*

Rearing unit:	earthen ponds, size range < 1 to 20 ha
Water exchange:	pumping, 5-20% water exchange/day
Stocking rate:	12-25 shrimp m^{-2} (10-20 shrimp m^{-3})
Aeration:	partial/continuous aeration, particularly at end of culture
Labor inputs:	low to moderate, 0.1-0.5 persons/ha
Feeding regime:	fertilization and/or supplementary/complete diet feeding
FCR range	1.2-1.75
Shrimp production:	1,000-3,000 kg shrimp/hectare/ year
Production cost:	US $ 2.20-3.30/kg live shrimp

4) Intensive outdoor running/static water farming systems (outdoor earthen/lined ponds, raceways, cages) with fertilizer and/or complete/supplementary diet feeding;

Shrimp species:	*P. monodon, L. vannamei, F. dorarum, P. aztecus, F. merguensis*
Rearing unit:	earthen ponds, size range < 1 to 20 ha
Water exchange:	pumping, 5-40% water exchange/day; although not always, as in the case of closed culture systems
Stocking rate:	40-140 shrimp m^{-2} (25-75 shrimp m^{-3})
Aeration:	partial/continuous aeration, particularly at end of culture
Labor inputs:	high, 0.4-2 persons/ha
Feeding regime:	fertilization and/or supplementary/complete diet feeding
FCR range	1.4-2.0
Shrimp production:	above 10,000-40,000 kg shrimp/hectare/year
Production cost:	US $ 3.5-5.0/kg live shrimp

5) Intensive indoor farming systems (indoor tanks, raceways, lined ponds) with fertilizer and/or complete/supplementary diet feeding.

Shrimp species:	*P. monodon, L. vannamei, P indicus, P. esculentus*

Rearing unit:	plastic or concrete tanks of 100-1500 cubic meters or lined ponds of < 1 ha
Water exchange:	pumping, 2-5% water exchange/day; although not always, as in the case of closed culture systems
Stocking rate:	200-2000 shrimp m^{-2} (120-750 shrimp m^{-3})
Aeration:	continuous aeration, particularly at end of culture with oxygen
Labor inputs:	high, 1-3 persons/ha
Feeding regime:	fertilization and/or supplementary/complete diet feeding
FCR range	1.4-3.0
Shrimp production:	above 40,000-340,000 kg shrimp/hectare/year
Production cost:	US $ 4-7.5/kg live shrimp

At present no precise statistical information exists concerning the proportion of current global shrimp production that is realized within these different farming systems, either by species or country; total global shrimp aquaculture production simply being reported as 1,292,476 mt in 2002 (FAO, 2004).

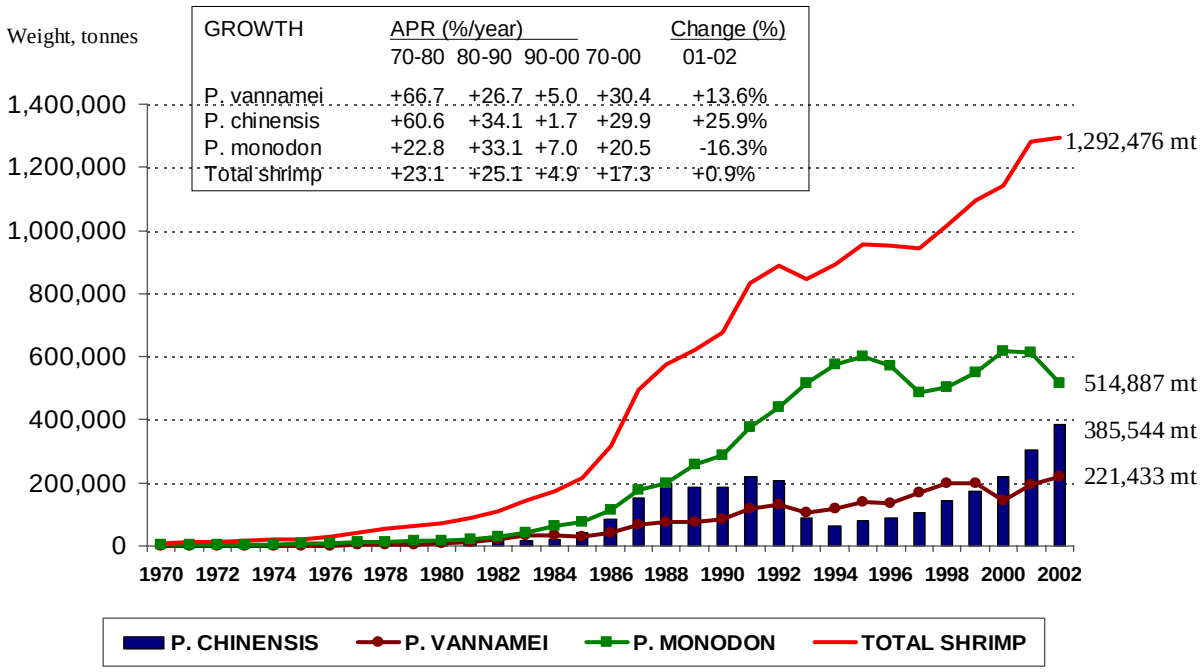

Figure 1. Marine shrimp production by major species group

(Source: compiled from FAO, 2004)

Feeding systems and compound aqua feed production

As with farming systems, at present there is no precise statistical information available concerning the percentage of farmers using fertilizers, supplementary feeds or complete compounded diets. Despite this, it has been estimated that the total aquafeed production in 2002 was about 2.1 mmt; this estimate is based on the assumption that approximately 85% of total farmed shrimp production in 2002 was based upon the use of industrially compounded aquafeeds and an average economic species FCR of 1.9 for marine shrimp (Tacon, 2004).

The above estimate also approximates to the summation of the estimated major shrimp feed markets by major producing countries in 2002, with the bulk of the bulk of culture

shrimp and aquafeed production being located within the Asian and Latin American region.

Table 1. Major estimated shrimp feed markets (values given in tonnes)

	2000	2001	2002	2003
China	276,000	350,000	500,000	700,000
Thailand	486,000	545,000	525,000	532,000
Indonesia	152,000	200,000	250,000	300,000
Viet Nam	65,000	80,000	150,000	220,000
Brazil	25,000	48,000	80,000	145,000
India	100,000	90,000	115,000	140,000
Ecuador	105,000	98,000	110,000	100,000
Bangladesh	75,000	60,000	80,000	90,000
Mexico	55,500	70,000	80,000	90,000
Philippines	30,000	50,000	60,000	70,000
Taiwan[1]	50,000	55,000	57,000	60,000
Malaysia	25,000	30,000	40,000	50,000
Honduras	27,000	20,000	25,000	30,000
Colombia	7,600	20,000	25,000	30,000
Venezuela	15,000	20,000	25,000	30,000
Others	50,000	75,000	100,000	150,000
Total	1,544,100	1,811,000	2,222,000	2,737,000

Taiwan[1]: A large proportion of aquafeed production in Taiwan is exported to neighboring countries, including mainland China

Feed composition varies widely within and between countries (Devresse, 1995), reflecting species and farming systems differences, the increasing demand by farmers for cheaper feeds (as compared with possibly more expensive and/or more cost effective feeds), and the almost total lack of practical information concerning the dietary nutrient requirements of shrimp under practical culture conditions (for review see Tacon, 1996, 2002).

Coupled with often marked differences within countries between farmers and culture systems, concerning on-farm feed management (ie. feed storage and application methods; for review see Jory et al. 2001), the shrimp industry (implies homogenuity by name rather than by farming practice) is currently in a quandary which way to go to remain profitable in view of increasing global shrimp production, increasing global concern for the environment, increasing feed ingredient prices, decreasing shrimp prices, and increasing country import restrictions due to perceived food safety risks and/or farming/marketing practices.

The future and lessons from the past

The bottom line in any commercial farming operation is cost and profitability, and the consequent need to tailor production systems (and therefore production costs, including feeds and feeding costs) to what the market is willing to pay for the final product.

It is clear from the farming systems descriptions listed above that production costs vary widely depending upon the farming system employed, ranging from as low as US $ 1-2/kg live shrimp for conventional extensive outdoor farming systems (with no external nutrient input through fertilization or feeding) to US $ 4-7.5/kg live shrimp for intensive indoor farming systems (with fertilizer and/or complete/supplementary diet feeding). The problem is further compounded by the fact that in some countries the development of the sector may be further constrained by other factors. To name but a few these may include land availability and cost, water availability and cost, power availability and cost, labor availability and cost, fertilizer/feed availability and costs, national farm planning regulations and environmental controls (including effluent controls), import/export costs and incentives, and proximity to existing markets.

The upshot of the above is that some countries, due to space limitations and high service costs, have no choice but to pursue more intensive farming practices if they wish to engage shrimp production and complete in the global market place. It is not the aim of this paper to discuss the relative merits and demerits of the different farming systems and

approaches, but to simply emphasize a few simple ground rules concerning the development of practical shrimp feeds:

- Always tailor the feeds to the intended shrimp species and farming system, including shrimp stocking density and water management (and therefore natural food availability);
- Shrimp do not eat once or twice during a 8-h working day and will eat continuously if offered food on a little and often basis (as they do in the wild in the absence of predators);

  Shrimp, with unrestricted feed access, have the capacity to grow very fast under both clear-water and pond-water culture conditions. For example, growth rates achieved by the senior author with Pacific white shrimp *Litopenaeus vannamei* grown at moderate/high density (55/m^2 or 71/m^3) with a standard high quality fishmeal-based 35% crude protein diet have averaged 1.44 g/week within outdoor clear-running water tanks (animals growing from 1.98 g to 13.48 g over a 8-week period at 26.4-29.1^oC – unpublished data) to 2.1g g/week within outdoor zero-water-exchange tanks (animals growing from 1.58 g to 18.89 g over a 8-week period at 28.2-31.3^oC, and with an average weekly growth rate of over 3 g/week observed from week 4 to 6 – Figure 2, Tacon et al. 2002).

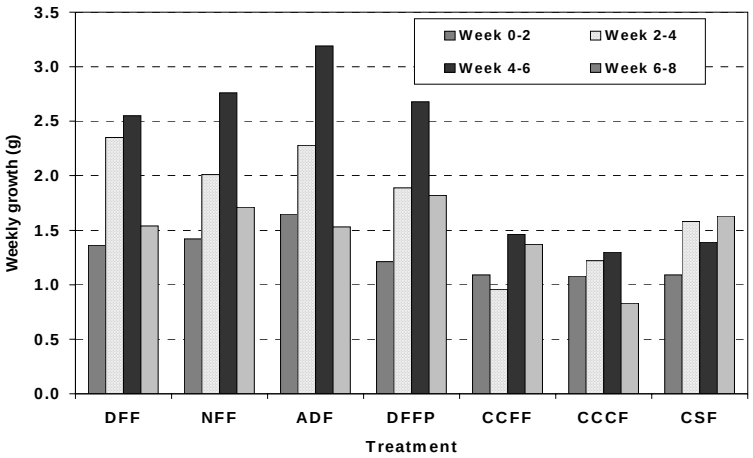

Figure 2. Mean weekly shrimp growth of different treatments, from Tacon et al 2002

(where DFF = day feeding, NFF = night feeding, ADF = all day feeding)

Shrimp have the unique ability to harness food and nutrient particles suspended in the water column and through benthic foraging, in addition to that provided through compound aquafeeds. In this respect it is essential that we recognize the key nutritional role played by micro-organisms in the nutrition and health of shrimp reared under green-water or zero-water-exchange culture conditions (Figure 3: for review see Bratvold & Browdy, 2001; Burford et al. 2004; Cuzon et al. 2004; Decamp et al. 2002, 2003; Lee & O'Bryen, 2002; McIntosh, 1999, 2000a, 2000b, 2001; McNeil, 2000; Moss et al. 1992, 2001, 2002; Tacon et al. 2002).

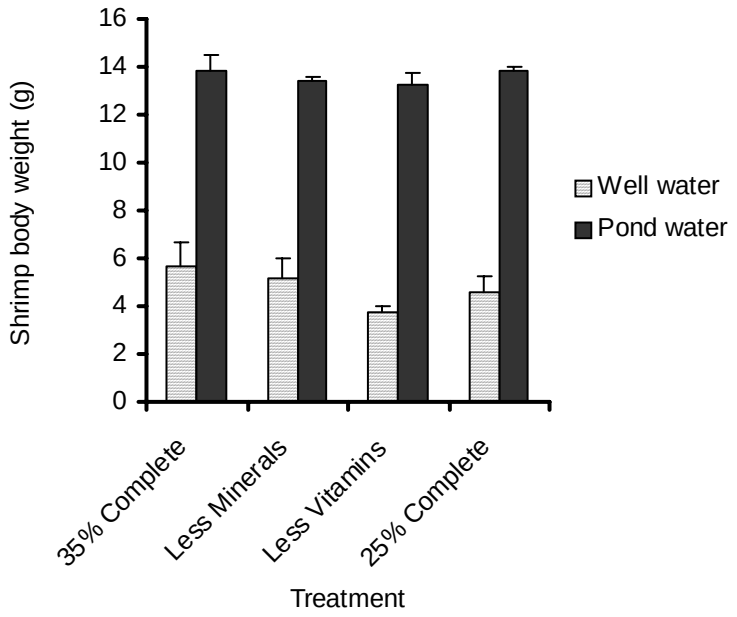

Figure 3. Final body weight of shrimp fed either a 35% protein complete diet or with deletion of either the trace minerals or vitamin premixes or fed a 25% protein complete diet, and reared either with a clean flowing water (shaded areas) or pond water (solid areas). Values are mean of three observations (error bars represent $\pm$ 1 standard deviation; from Decamp et al. 2002).

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