Reducing Feed Costs in Semi-Intensive Aquaculture Systems in the Tropics

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In aquaculture, feed is often the single largest operating cost item. With culture intensification the costs of food and feeding go up primarily because of the relatively large percentage of animal protein (usually fish meal) that has to be incorporated into the diets.

Fish are reputed to need a high proportion of protein in their diets because they metabolize protein as an energy source. However, because fish are poikilothermic (they adapt to the environmental temperature), expend less energy to maintain posture in water, and excrete primarily ammonia, which diffuses into water easily, considerable energy is saved making it still profitable to culture fish. In addition, fish also have the ability to use significant amounts of secondary protein sources of plant origin.

In the tropics, fish culture is mostly extensive and/or semi-intensive in nature. However, with the increasing trend towards intensification, research is needed to develop low-cost feeds. The approach commonly adopted is the use of readily available agricultural byproducts. Use of such byproducts is not new: in mainland China the use of silkworm pupae as a supplement feed for carp is as old as the tradition of fish culture itself. Nevertheless, current conflicting demands for space and water resources and the resulting need for intensification call for development of low cost feeds.

Feed development involves a number of basic components:

- the nutrient requirements of the species to be cultured must be known;
- agricultural byproducts must be readily available at reasonable cost;
- the fish/shrimp must be able to digest such materials;
- the feeds must be stable;
- the feeds must be readily accepted and efficiently utilized by the fish/shrimp.

Two means of reducing feed costs in semi-intensive aquaculture systems in the tropics have so far received little attention:

- experimentally-determined optimal protein requirements for the cultured species are not always incorporated into practical diets, thus saving on feed costs;
- apart from developing low-cost diets, different feeding strategies and/or good husbandry methods can lead to significant savings in feed costs.

Economically Optimal Dietary Protein Levels

The optimal dietary protein level (at a particular protein:energy ratio) is the level of protein at which maximal growth is obtained (Fig. 1). The growth/protein response curve, determined for a number of species (e.g., *Salmo gairdneri*, *Oreochromis mossambicus*, *O. niloticus*, and *Cyprinus carpio*) is analogous to the basic catch/effort curve in fish population dynamics.

An earlier study by Zeitoun and colleagues (J. Fish. Res. Board Can. 33: 167-172, 1976) on rainbow trout showed that the economically optimal dietary protein level, the level which gives the highest maximum economic return, was significantly lower than the biologically optimal dietary protein level.

The optimal protein requirements of fish vary both from species to species and within a given species depending on such factors as age, size, environmental

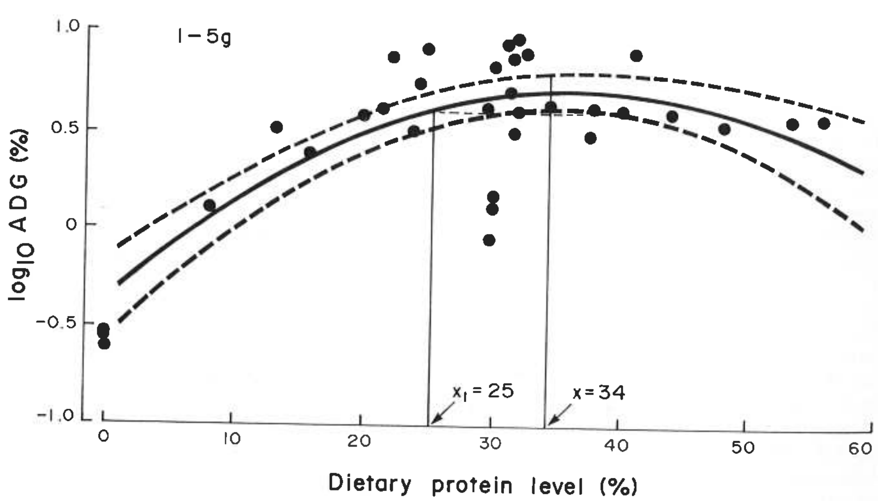

Fig. 1. The fitted curve of growth rate (% average daily growth) of different species of tilapias of 1-5 g body weight in relation to dietary protein level. X - the dietary protein level of which growth is maximum, X_1 - economically optimal dietary protein level (modified from S.S. De Silva et al. 1989 as cited in text).

Table 1. The estimated % ADG, number of days required to increase the weight of fry from 1 to 5 g (a), estimated FCR and PER of a fry of initial weight 1 g, and the amount of feed required to raise 1 million fry from 1 to 5 g in a hatchery based on FCR estimations and the unit cost of feed.

Protein (%)	ADG[1] (%)	a (days)	FCR[2]	PER[3]	Feed required (tonnes)	Feed costs per kg	(Rs) Total
12	3.76	43.7	2.68	2.70	10.72	10.11	108,379
16	5.07	32.5	2.55	2.57	10.20	11.23	114,546
20	6.46	25.7	2.43	2.43	9.72	11.53	112,071
24	7.74	21.5	2.30	2.30	9.20	12.19	112,748
28	8.76	19.1	2.18	2.17	8.72	13.78	120,161
32	9.35	18.0	2.05	2.03	8.20	15.13	124,066
36	9.40	17.9	1.92	1.90	7.68	17.44	133,939
38	9.22	18.2	1.86	1.83	7.44	18.59	138,309
40	8.91	18.8	1.80	1.76	7.20	20.21	145,512
42	8.49	19.7	1.74	1.70	6.96	21.23	147,761
44	7.96	21.0	1.67	1.63	6.68	22.35	149,298

Relationships used for estimating 1, 2 and 3:

1. log ADG = 0.03 + 0.055 (Protein) - 0.394 log (BW) - 0.0008 $(\text{Protein})^2$
2. FCR = 3.226 - 0.0313 (Protein) - 0.1733 (BW)
3. PER = 2.563 - 0.0334 (Protein) + 0.5378 (BW)

conditions, etc. However, it is generally accepted that carnivorous species such as salmonids have a higher protein requirement than omnivorous species such as tilapias. These aspects were reviewed recently (A.G.J. Tacon and C.B. Cowey, 1985, in Fish Energetics - New Perspectives, ed. P. Tytler and P. Calow, p. 155-183).

The protein requirements of four species of tilapias, viz. *O. niloticus*, *O. mossambicus*, *O. aureus* and *Tilapia zillii*, were reviewed (S.S. De Silva et al. in Aquaculture, Vol. 80, 1989) based on studies in which more than 60% of the dietary protein was supplied by fishmeal, and the gross energy content was between 17.5 and 20.0kJg^{-1} fed with a ration thought to be in excess of the daily requirements. Most of the data concerned two size groups, fish below 1 g and those of 1-5 g. Surprisingly, irrespective of the species, data on growth/protein fell into two curves for the two sizes. Using Zeitoun et al.'s methodology, the optimal and economically optimal dietary protein requirements were computed for the latter group (See Fig. 1). The economically optimal dietary protein level was found to be around 25% compared to 34% for the biologically optimum level.

Multiple regressions obtained for relationships between body weight and average daily growth, food conversion ratio (dry weight of food eaten - increase in wet body weight) and protein efficiency ratio (PER: wet body weight gain - dry protein intake) and between dietary protein level, average daily growth and FCR from the same data were highly significant. Using these relationships, the food and number of days needed to grow a tilapia fry from 1 to 5 g were computed for a series of hypothetical diets of varying protein content. There was a considerable cost saving on feeds (10.1%) by feeding the fish 8% less protein (28%): the economically optimal dietary level, even though it involves 1.2 days of extra rearing, as opposed to feeding the optimal or the protein level (36%) which gave maximum growth.

The results obtained using two independent methods of analysis were close and clearly indicate that, especially in developing countries where labor costs are comparatively low, a significant saving in feed costs can be made by feeding diets with a lower protein content than that which is thought to be the optimal dietary protein requirement, without significant loss in growth or yield.

In the tropics, direct and indirect `feed inputs' from the environment can also be significant. In shrimp ponds, most added food may be used by bacteria rather than the shrimp (e.g., D.J.W. Moriarty, Microb. Ecol. 12:259-269, 1986). Unfortunately, there have been few controlled studies on this aspect. It may be possible to lower the dietary protein content further for most cultured species in the tropics and thereby reduce feed costs without significantly lowering growth rates or yield.

Mixing Feeding Schedules

In animal husbandry, considerable feed cost savings are realized through proper feed management. Daily feed intake and digestibility are variable for all animals, including fish.

It has been demonstrated, under laboratory conditions for Nile tilapia and in ponds for common carp, that by adopting mixed feeding schedules, where a high protein diet is alternated with a low protein diet, one can obtain growth rates not inferior to those for fish maintained continuously on a high protein diet. (S.S. De Silva, Aquacult. Fish. Manage. 16: 331-340, 1985). Somewhat comparable observations were reported for *O. niloticus* x *O. aureus* hybrids in intensive culture systems by feeding duckweed in addition to commercial pellets.

The use of mixed feeding schedules is an area which appears to have extensive scope and needs further research. One of the difficulties in planning such experiments is the large number of possible combinations of low and high protein alternative feedings. The experiments must be carefully planned and the schedules based on the limited information available for other species. It is important however, to realize that mixed feeding schedules have much potential for reducing feed costs without lowering growth rate and yields and represent a challenging area for simple but useful research in aquaculture in the tropics.

The broad concepts presented in this article will undoubtedly provoke `traditional fish nutritionists.' I am of the view that in tropical aquaculture, which is mostly extensive to semi-intensive, formulation of the "balanced diet" is not the priority; it is exploring means to reduce operating costs and making equally effective diets which are well within the economic reach of the small-scale farmer. This is not to say that in the tropics fish do not require balanced diets. What is often forgotten is that in tropical systems, fish have access to significant amounts of (essential?) nutrients from natural sources. This is evident from the wide range of protein levels which have resulted in equally good growth in fin and shellfish species reared under different conditions.

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