FISH FEED TECHNOLOGY

A.G.J. Tacon,
Fisheries Department, FAO, Rome, Italy

1. INTRODUCTION

The role of 'Fish Feed Technologist' in aquaculture development should be defined at the outset. *The fish feed technologist is concerned with the study of the food and feeding of farmed fish.* This includes the food and feeding of fish under extensive, semi-intensive and intensive culture conditions. All too often it is believed that fish feed technology deals only with the feeding of fish within intensive culture systems, with its consequent use of 'complete' pelleted rations and associated manufacturing equipment. However, the crucial role played by natural pond organisms in the nutrition of fish within 'village level' or semi-intensive systems contrasts markedly from the intensive culture system where natural food organisms play little or no role in the nutrition of fish. Clearly, each particular culture system must be considered as being unique and evaluated on its own merits. In fact one of the major stumbling-blocks in the past to the development of a feeding technology for use at the rural or 'village level' has been due to the direct application of technologies used within intensive culture systems (for which most information and expertise exists). This paper will endeavour to highlight the research needs for the development of an appropriate 'village level' feeding technology.

2. FEEDING OPTIONS AVAILABLE TO THE BASIC VILLAGE LEVEL FARMING UNIT

In this discussion paper the basic village level fish farming unit is regarded as consisting of a single 100 m^2 earthen pond owned or operated by one or more family units. The aim of the farming system being to produce fish for home consumption using locally available resources at a minimum cost, with the possible benefit of an additional cash income from fish sales. It is anticipated that no cash funds would be available to the farmer or family unit for the purchase of fry, fertilizers, feeds or farm equipment other than that obtained through normal wage earnings.

The food and feeding of fish cultivated within such a system can be viewed at four different levels of refinement or input:

2.1 No fertilizer or feed inputs - basic rearing system where fish growth is totally dependent on the natural food population within the pond ecosystem. Fish growth will therefore vary depending on the natural productivity of the water body and fish stocking density. Fish stocking densities of $< 1/m^2$ are generally used with this rearing system.

2.2 Fertilizer input only - inorganic and/or organic fertilizers are applied to the pond so as to enhance the natural production of fish food organisms and so increase the fish production capacity of the pond. Organic fertilizer is used here in the context as resulting from livestock production and consisting of untreated (other than drying) animal faecal matter which is not generally directly consumed by fish. In view of the higher cost and limited availability of inorganic fertilizers in Africa, it would appear to be more advantageous to use organic fertilization regimes (possibly through fish/animal integration farming techniques) within 'village level' fish ponds. Recently, anaerobic and/or aerobic composted agricultural by-products have been employed as organic pond fertilizers with some success (M.J. Vincke, personal communication 1985).

2.3 Fertilization and supplementary feed input - this feeding strategy is typical of a semi-intensive rearing system. Here, in addition to the use of fertilizers for the production of natural fish food organism within the pond, low grade/value agricultural and animal by-products are used directly as an external supplementary fish feed. Supplementary feeds are defined here as low value agricultural and animal by-products (including faecal/agricultural composted materials) which can be directly consumed by fish. However, when used in excess these products may also exert a fertilization effect on the water body. With this feeding strategy, higher fish stocking densities are possible ($2/m^2$) and consequently fish yield/unit area.

2.4 Formulated 'complete' diet as the sole feed input - this feeding method is typical of an intensive culture system. In contrast to the above feeding strategies fish growth is totally dependent on the external provision of a manufactured high quality diet containing a predetermined nutrient profile or the use of a single food item of high nutrient value (i.e. trash fish). In view of the much higher stocking densities employed with this feeding strategy little or no nutritional benefit is gained by the fish from natural food organisms within the pond (the amount of natural food being available/fish at high stocking densities being very low). Although considerably higher fish yields can be achieved with complete diet feeding the capital and operating costs of fry and feedstuff procurement and feed manufacture are generally well above the financial ceiling of the individual village farmer. However, the main constraint to this feeding strategy appears to be the availability of suitable feed ingredients of sufficient quality and quantity within the village community.

The ultimate choice of the feeding strategy to be used will depend to a large extent upon the feeding habit of the fish species chosen (herbivore, omnivore, carnivore), the local availability of fertilizers and feeds, the market value of the fish species farmed, and on the financial status of the farmer. However, of the four feeding strategies mentioned it is generally believed that the most appropriate at the village level is one that uses a combination of pond fertilization (preferably by integration with livestock) and supplementary feeding. This semi-intensive feeding method has the necessary flexibility in that fish growth is not dependent on a single food source but on a combination of different feed types. It is essential that the feeding strategy chosen has this flexibility as fertilizer and feed inputs may vary over a growing season depending on availability and the financial status of the farmer. From a nutritional viewpoint supplementary feeds generally provide the fish with an energy source for growth, whereas the natural pond organisms provide the essential nutrients for the maintenance of the growth processes. Supplemental feeding also offers other advantages to the farmer:

2.4.1 Facilitates the use of agricultural and animal by-products which are currently not being utilized by the community as a feed source for human and/or livestock consumption, with consequent improvement in land productivity.

2.4.2 Facilitates faster fish growth.

2.4.3 Permits the use of higher fish stocking densities.

2.4.4 Higher fish yields and crops are possible over the growing season.

It should be emphasized however that the benefits of supplemental feeding will depend upon the agricultural/animal by-products used, the fish or fish species cultured, fish stocking density, and the natural productivity of the water body. In addition, each pond ecosystem must be considered as being unique (depending on climate, location, soil type, water quality and fertilizer input) and so it should be remembered that the success of a particular supplementary feeding regime in one location need not necessarily apply to another. This is in sharp contrast to the intensive culture system where strict controls are normally placed on water quality and feed inputs.

RESEARCH NEEDS FOR THE DEVELOPMENT OF A 'VILLAGE LEVEL' FEEDING STRATEGY IN AFRICA

Particular emphasis will be placed in this discussion paper on the identification of research needs for the development of a supplementary feeding based farming strategy.

3. IDENTIFICATION AND SELECTION OF FEED INGREDIENTS SUITABLE FOR FISH FEEDING

In view of shortage of feedstuffs in Africa for human and conventional livestock consumption, emphasis must be placed on identifying and utilizing hitherto unused agricultural and animal by-products within the community. For the 'village farming unit' ingredient selection must therefore be based on low quality and value products, and fish species selected which feed low on the aquatic food chain. By utilizing agricultural and animal by-products which are not currently used for human and livestock feeding the village fish farmer would be seen to be an asset to the community rather than a competitor with the traditional agricultural or livestock farmer.

A survey should be conducted for each potential community so as to identify hitherto unutilized or unutilizable resources. Products which may be considered in this category include:

- kitchen waste
- brewery waste
- 'spoiled' animal feeds
- plant leaves/tubers/roots/seeds
- maize cobs
- mill sweepings,
- abattoir waste (animal offal, blood, rumen contents)
- aquatic macrophytes
- composted agricultural/livestock manure
- fruit – spoiled peelings
- oilseed hulls/residues

Final selection of potential feed ingredients should be based on the following criteria: in order of importance, these include a) cost (if at all); b) availability (both in quantity and time; it should be possible to use different 'categories' according to the seasonality of products); c) handling or processing requirement prior to feeding; and d) nutritive value (composition). In the case of feed processing and handling particular emphasis must be placed on using locally available materials and customs (i.e. grinding techniques, composting, drying, mixing, storage, cooking).

4. FEED FORMULATION

In contrast to 'complete' diet feeding, where rations are formulated to a pre-set nutrient level for each fish age class, the formulation of a supplementary diet is dependent on the standing crop of fish within the pond and the consequent availability of natural food organisms. For example the studies of Hepher (1979) have shown that 'for conditions at the Fish and Aquaculture Research Station at Dor, Israel, there was no difference in carp growth rate in ponds when fed cereal grains (sorghum), a protein rich pellet containing 22.5% protein up to a standing crop of 800 kg carp/ha. There was no difference between the effects of pellets containing 22.5% protein or pellets containing 27.5% protein up to a standing crop of 1400 kg carp/ha.' Similarly, no beneficial effect of dietary vitamin or mineral supplementation was observed with tilapia or carp either in ponds or cages (within the pond) at stocking densities of $2/m^2$ and $100/m^3$ respectively (ca. 400 g fish; S. Viola personal communication, Ashrat, Israel, 1985). Although it should be remembered that these results apply to the local conditions of soil, climate and pond productivity in Israel, the results of these feeding trials will also apply to the African village level fish farm.

From the above discussion it follows that dietary energy is the first limiting factor at low fish stocking density (when natural food availability/fish is high), whereas at high stocking density dietary protein and other essential nutrients also become limiting and therefore have to be supplemented. From a farming viewpoint it can be seen that the protein and nutrient content of the diet will have to be increased with increasing fish growth (standing crop) and diminishing natural food availability. To date, little work has been conducted in this subject area in Africa.

At its basic level supplemental feeding merely involves the feeding of a single food item throughout the culture period. Such a feeding strategy is typical of a 'village level' fish pond where fish stocking densities are normally low and available feed resources poor. Clearly much work needs to be undertaken on the development of supplementary fish feeds for use at higher fish stocking densities. However, caution should be given to the extrapolation of results obtained from large ponds to smaller ponds (and vice-versa) in view of the possible surface area effect on natural food productivity.

5. FEED PRESENTATION

The success of a particular supplementary feeding regime will depend to a large extent upon the physical form of the diet fed (dry/wet mash or pellet) and the cost of the finished feed. At its simplest level feed presentation merely involves administering the feed in its fresh or ground state to the pond. This feeding strategy is most suited to ponds having a low stocking density (or standing crop) and high natural productivity. However, at high stocking densities there is no doubt that pelleted feeds (dry or moist) are more beneficial and economic in terms of feed conversion efficiency (wet fish gain/unit of dry feed input) and fish growth. At low stocking densities however the beneficial effect of pelleting may not be so great. For example, in the Central African Republic no difference was observed in the growth response of pond reared *Tilapia nilotica* fed a 30% protein supplementary diet either in ground or pelleted form (miller, 1979). During this 62-day feeding trial low stocking densities were employed ($2/m^2$; initial and final fish standing crop of 480 and 1200 kg/ha., respectively) and fish fed at 4% of their estimated body weight once daily (9.00 a.m.). In view of the exceedingly high cost of the pelleting prices reported, feed input cost/kg fish gain using the pelleted feed was found to be almost double that of the ground meal.

Under these circumstances the additional costs of pelleting were not compensated by an equivalent increase in fish production. Clearly special attention must be paid to the physical form of the supplementary diet used and the economic cost of processing.

6. FEEDING LEVEL AND FREQUENCY

In contrast to 'complete' diet feeding, no accurate feeding tables exist for the feeding of individual supplementary fish feeds which take into account fish species, age, class, stocking density and natural food availability (for use under African conditions). This situation must be remedied if maximum benefit is to be gained from supplementary feeding. For example, at the species level, it has been suggested that the supplementary feeding rate for tilapias should be lower than that for common carp (Cyprinus carpio) (Hepher and Pruginin, 1982). Similarly, the poor fish performance observed by Miller (1979) when feeding a pelleted ration may have resulted from the feeding regime employed (fish fed once daily) and the poor water stability of the pelleted ration used (disintegration after 5 min. water immersion). Clearly, optimal feeding rates and frequency of feed presentation must be determined.

7. ECONOMICS OF THE FEEDING STRATEGY EMPLOYED

For the basic 'village level' fish farm to run profitably it is essential that the correct feeding strategy is employed. Simple economic analyses should be undertaken to ascertain the profitability of individual feeding regimes. For example, Table 1 shows hypothetical analysis of two identical fish farming units, one receiving manure as the sole feed input and the other receiving pelleted feed as the sole feed input.

Table 1: Profitability of two feeding systems in a pond environment using identical fish stocking and management techniques.*

	Major feed input	
	Pelleted feed	Manure
Total fish yield (kg/ha/day)	10	5
Total manure or feed input (kg, dry wt./ha/day)	20	25
Food (input) conversion efficiency	2	2
Unit cost of manure or feed ($/kg)	1	0.1
Input cost/kg fish produced ($)	2	0.5
Total input cost/ha/day ($)	20	2.5
Profit/ha/day (where "y" is price/kg fish)	10 y − 20	5 y − 25
If price of fish (y) is $1.0/kg, then profit/ha/day will be	−$10	+$2.5
If price of fish (y) is $4.0/kg, then profit/ha/day will be	+$20	+$17.5
For equal profits to be attained from feeding and manuring, then	10 y − 20 = 5y − 2.5 Solution 7 = $3.5	
Under the above hypothetical conditions when the price of fish is higher than $3.5/kg, it is more profitable to grow them on pelleted feeds, when it is lower it is more profitable to grow them on manure.		

**Example solution based after Wolfarth and Schroeder (1979)*

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