FINFISH NUTRITION RESEARCH IN ASIA:

Proceedings of the Second Asian Fish Nutrition Network Meeting

Edited by
Sena S. De Silva

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Editor's Preface

In view of the increasing emphasis and intensification of the age-old, traditional aquacultural practices in most of Asia there is a growing need for research into aspects of finfish nutrition. A primary concern in this respect is the need to develop low-cost feeds using locally and readily available ingredients within the reach of the rural, small-scale fish farmers. The IDRC has been directly involved in supporting a number of research projects on finfish nutrition with this objective.

The First Nutrition Workshop, hosted by the IDRC was held in September 1983 and basically dealt with some of the methodological approaches to finfish nutrition and management. This volume encompasses the proceedings of the Second Finfish Nutrition Workshop held in June 1986. The workshop was held in conjunction with the First Asian Fisheries Forum which brought together nearly 400 fisheries scientists from the region. It was organized to gather those scientists whose research interests were on finfish nutrition and to work towards a consensus on the present status of the art and future strategies of finfish nutrition for the region.

This set of proceedings, however, does not attempt to deal with all aspects of on-going finfish nutrition in the region nor a complete strategy for the region. It will be followed by the proceedings of the third workshop scheduled for May 1988 which is expected to deal specifically with methodological strategies relevant to the region. We hope this series of proceedings would serve as a useful reference of direct relevance to those engaged in finfish nutrition research in the region.

S.S. De Silva

Foreword

The International Development Research Centre (IDRC) of Canada has been supporting fisheries research in developing countries since 1973. A major portion of this support has been for aquaculture research. Increasingly, IDRC's funding has been focused on a series of disciplinary regional networks in Asia such as disease, breeding, genetics and nutrition. As a part of their activities, these research networks have organised regular meetings of the researchers who are encouraged to exchange information and plan future programmes in a complementary fashion. This publication is a record of the second meeting of Asian fish nutritionists which was held concurrently with the Asian Fisheries Society "Fish Asian Fisheries Forum" in Manila, May 26-31, 1986. The proceedings of the first meeting was published in Cho, C.Y., Cowey, C.B. and Watanabe T., 1985, *Finfish Nutrition in Asia: Methodological Approaches to Research and Management*, International Development Research Centre, 1985.

IDRC is very happy to have collaborated with the nutrition researchers in this workshop and we would like to extend our sincere thanks to Dr S. S. De Silva for his work in editing this publication.

F Brian Davy
Associate Director (Fisheries)
IDRC
Tanglin P O Box 101
Singapore 9124

5 November, 1987

Introduction

The workshop was the second on Finfish Nutrition sponsored by the IDRC and was held in Manila between 1st and 2nd June, 1986. The first workshop was held in September, 1983, in Singapore. The second workshop was planned to coincide with the First Asian Fisheries Forum which brought together nearly 400 scientists from the region, amongst whom were most of the researchers on finfish nutrition in the region. It was therefore advantageous for these researchers to meet as a group, as recommended at the 1983 workshop.

The workshop brought together a total of 32 scientists and observers from 7 countries. The main theme of the workshop was to determine and recommend strategies for future finfish nutrition research, appropriate and relevant to the region; to identify species or species group; and to determine and recommend the type of research needed with respect to each group after taking due cognisance of, and giving consideration to the experiences and advances that have occurred in animal nutrition research.

Three keynote addresses were made which basically formed the backbone of the discussions and deliberations which followed; Dr C. Devendra on "General Approaches to Nutrition Research", and two on "Non-conventional Feed Resources" by Drs Kok Leong Wee and Shim Kim Fah. Dr Sena S. De Silva reviewed, briefly, the ongoing finfish nutrition research in the region. In addition, one representative from each country presented a resumé of the current areas of ongoing finfish nutrition and highlighted those aspects which needed further and urgent investigations. All these are presented in the text which also fully covers the important points that were discussed.

PART I

Summary of Ongoing Finfish Nutrition Research in Asia

SENA S. DE SILVA

Fish culture originated in Asia. As a result of its development through the years, the "art" of fish culture has almost reached perfection; a fact which is exemplified by the quantum of production in the region which at present amounts to 5.244 million metric tons or 74.2 per cent of the total production from culture practice in the world (Chua, 1986). However, in the region, the production per unit acreage of water remains decimally low, except in Japan and Taiwan and also perhaps in isolated cultural practices in India, Thailand and the Philippines. With increasing constraints being imposed on the multiple use of the areas available for fish culture and for water resources, the need for scientific innovations in fish culture in Asia is becoming a priority area of research amongst fisheries scientists in the region; an inevitable need with a shift to a more intensive form of culture. This does not imply that a major scientific breakthrough relevant to fish culture has not been made in the region; the artificial propagation of most of the major species cultured in the region has been successfully carried out.

It is conceded that in fish culture operations the highest recurring cost is the feed cost (Wee, present volume). Therefore, it is not surprising that a significant quantum of research effort is being directed to finding ways and means of reducing this cost, and also evaluating suitable diets for the large array of species that have a potential for culture in the region.

In this brief presentation an attempt has been made to explore the trends in the type of finfish research carried out in the region. In doing so it was assumed that a very significant

Table 1: The species on which aspects of nutrition were presented.

Finfish	Shellfish
Chanos chanos	Penaeus orientalis
Oreochromis mossambicus	P. monodon
O. niloticus	P. vannameri
Heteropneustes fossils	Metapenaeus lammeri
Clarias batrachus	Macrobrachium rosenbengi
Poecilia reticulata	
Ctenopharyngodon idella	
Hypophthalamichthys molitrix	
Catla catla	
Labeo rohita	
Cirrhinus mrigal	
Acanthopagrus schegli	
Lutjanus argentimaculatus	

proportion of researchers in the field of nutrition would have submitted their findings for consideration and presentation at the First Asian Fisheries Forum, and therefore an evaluation of these presentations would be tantamount to a reasonable picture of the ongoing work in the region.

A total of 35 presentations were made at the Forum on aspects of nutrition. These included food and feeding in the wild to those in culture systems and in experimental studies. The presentations on nutrition amounted to approximately 12.5 per cent of the total presentations that were made.

Of the presentations on nutrition, 25 were on finfish and 10 on shellfish shrimps. The species dealt with are given in Table I. It should be noted that in certain presentations, groups of species were covered. The authors came from eight countries in the region.

The major areas of investigation were divided into three categories (Table 2).

The detailed breakdown of areas of investigation on finfish is given in Table 3.

The work presented was mainly with respect to adult fish (Table 4).

Table 2: Major areas of investigation and the number of presentations made in each area.

	Finfish	Shellfish
Feeding ecology	05	02
Digestion/physiology	05	04
Feed development	08	04
Others	07	—

Table 3: Detailed areas of investigation and the number of presentations made in each case on finfish nutrition.

Artificial feeds ..... Ingredient substitution	03
Performance	06
Natural feeds e.g. Zooplankton, plants etc.	05
Dietary requirements — amino acids, fatty acids etc.	04
Husbandry	02
Digestive physiology	03
Broodstock	00
Efficiency of utilization	02

Table 4: The work presented in relation to the developmental stages of the organisms.

	Finfish	Shellfish
Larvae	02	02
Juvenile	06	01
Adult	17	07
Eggs	—	—

Conclusions

It is evident that a reasonable and an acceptable proportion of scientists are engaged in nutritional research. However, it is disheartening to note that most of the work is concentrated on the adult stage of the life cycle whilst minimal emphasis has been laid on larval and juvenile stages, where the growth potential is highest. It is also evident that broodstock management nutrition, which obviously is a long-term experimental strategy, has been completely neglected. One other important area of research which was not presented was that on digestibility. Even though a reasonable number of presentations were made on new feed resources, none of them dealt with the digestibility of the resources. Such studies would undoubtedly open avenues for other researchers to incorporate such resources into their experimental diets and thereby prevent duplication of research effort in the region.

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Chua, Thia-Eng (1986). *Aquaculture Production in Asia: A Reassessment*. NAGA 9(2): 13-15.

General Approaches to Animal Nutrition Research and their Relevance to Fish Production in the Asian Region

C. DEVENDRA

Abstract

The paper attempts to discuss the general approaches to animal nutrition research and their influence on research in fish nutrition and production in the Asian region. It briefly describes the historical aspects and the establishment of approximately 40 nutrients now required by the animal body. The objectives of animal nutrition research are:

(i) identification and definition of the feed resources;
(ii) assessment of nutritive value;
(iii) utilization in efficient and economic feeding systems; and
(iv) determination of nutrient requirements.

These objectives are discussed with reference to their relevance to research in fish nutrition, and especially in relation to available feeds (forages, energy and protein concentrates, crop residues, agro-industrial by-products and non-conventional feeds) in Asia and feed efficiency. The importance of feeding standards is stressed, and their determination needs to consider species, age, physiological state of production and extent of muscular activity. In this context, feeding trials ought to be designed to achieve nutrient variables that can combine a demonstration of predictable responses and determination of nutrient requirements. A strategy for fish feed formulation and production is discussed, involving an initial exploratory phase and a second continuing phase on refinements. These phases provide for greater efficiency in the utilization of the feed resources for the feeding and nutrition of fish in extensive,

intensive and integrated systems. The emphasis on the latter phase can, however, ensure an impact on the maximization and expansion of economic fish production per hectare in the region.

Introduction

The principal constraint in animal production systems is feed. The reference to feed includes such important factors as quantitative and qualitative issues, digestion and metabolism in the animal body. These important factors thus need to be considered in the wider context of fluctuating feed supplies, variations in nutritive value and relevance to feeding systems in the Asian region. Undernutrition and malnutrition prevent animals from expressing their genetic potential and result in decreased protein production at a time when such protein supplies are in ever increasing demand to keep pace with human population growth. Surplus nutrition, on the other hand, is wasteful of precious nutrients, increases the cost of production and is not cost-effective. A balance thus needs to be made to ensure that appropriate nutrient supply can match predictable responses in the animal body which, in regard to products, (e.g. meat, milk or fibre) are economic.

In general, it is especially important in seeking efficiency in feeding systems for a specific situation to maintain an appropriate species, to aim for a realistic potential level of production, to take advantage of the available dietary ingredients and identify the objectives clearly in terms of production and profitability. Concerning fish nutrition, reference is made to the discussion on methodological approaches to research and development by Cho, Cowey & Watanabe (1985).

The intent of this paper is to provide some background about the general approaches and principles of research on animal nutrition involving farm animals of economic significance to man. It has been suggested that such treatment in the paper will be of potential value in providing an understanding of how research has been initiated, developed and made to ensure maximum productivity from animals.

Historical aspects

This history of nutrition stemmed from the realization that nutrition involves chemical reactions and physiological processes. Lavoisier the French chemist was the first to establish the chemical basis of nutrition with his famous respiration experiments before the French revolution. It was recognized in the early 19th century that nutrition involved the need for carbohydrates, proteins and fats, and eventually also of macro and micro minerals. The former included mainly calcium and magnesium, and the latter sodium, fluorine, iron, potassium and sulphur. During the last 70 years, the need for yet another nutrient was made by the discovery and isolation of many vitamins, based on work with rats. These developments together have now established that the animal body requires approximately 40 nutrients.

Developments in the establishment of nutritive value of feeds and how the various chemical reactions and physiological processes are involved in bodily functions have been possible because of the contributions of the various branches of science, notably chemistry, biochemistry and physiology. Attendent to this are the contributions of animals as test subjects, for example in detecting deficiencies of nutrients, imbalances in the diet or the effects of various dietary variables. The laboratory rat, for example, has contributed to our knowledge on vitamins, amino-acids and minerals. Likewise, mice, guinea pigs, hamsters and dogs have also been used extensively as laboratory animals. Of the farm animals, goats, cattle, sheep, pigs and chickens have been used variously to evaluate the value of feeds, effect of dietary variables and the potential capacity of dietary ingredients in suitable proportions to sustain the requirements for maintenance, growth and reproduction.

In the past, research on nutrition has been essentially *ad hoc* and macro in approach. Today the science of nutrition is one of detail, precision and completeness in terms of the requirements of the body. We can now understand better the value and inter-relationships of different nutrients to ensure efficient metabolic function and high performance. This expanding development has been greatly facilitated by physics, electronics and instrumentation. Examples in this connection are the use of spectrographs, radio isotopes, scintillation counters and electron microscopes in the analyses of feed ingredients.

Objectives in Animal Nutrition Research

It is essential to define and constantly keep in perspective the objectives of animal nutrition research. These are as follows:

A. Identification and definition of the feed resources;
B. Assessment of nutritive value;
C. Utilisation in efficient and economic feeding systems; and
D. Determination of nutrient requirements.

It is appropriate to discuss each of these factors briefly.

Identification and definition of feed resources

An understanding and assessment of the feed resource base seeks to identify and clearly define the available feed resources within a particular situation, district, state and the country as a whole. This is essentially a feed inventory of all available feeds produced, which needs to be compiled as completely as is feasible. The inventory should identify and then quantify the feeds produced by considering *inter alia* the following aspects:

(i) Quantities and kinds of materials available. This involves the use of statistical data and other sources of information, for example the area of the crop, average yield per hectare and extraction rates. These ancillary data need to be defined. Where assumptions are used these also need to be stated.
(ii) Brief physical description (e.g. bulky, roughage, slurry, wet or dry).
(iii) Location of production.
(iv) Seasonality of production.
(v) Present use by animal category.
(vi) Alternative uses if any (e.g. as fertilizer).
(vii) Potential for processing.
(viii) Cost of collection, handling, transportation and processing.
(ix) Impact on prevailing and future utilization.

For purposes of classification, five broad groups of feeds have been identified:

(i) Forages (grasses and legumes);
(ii) Energy and protein concentrates;
(iii) Crop residues;
(iv) Agro-industrial by-products; and
(v) Non-conventional feeds.

The first group includes all types of grasses, shrubs and legumes that are of potential value to animals. Examples are elephant or Napier grass (*Pennisetum purpureum*), Guinea grass (*Panicum maximum*), cassava leaves (*Manihot enculenta Crantz*) and leucaena (*Leucaena leucocephala*).

Energy and protein concentrates include such energy sources as cereals (maize, wheat and barley), root crops like cassava and sweet potatoes, and also fats such as tallow, lard and palm oil. The protein concentrates refer mainly to fish meals and cakes, for example soybean meal.

Crop residues and agro-industrial by-products constitute a group which is very important in most countries, and which is probably also under-utilized. By virtue of being indigenous and therefore traditionally used, the potential value rests in not only reduced cost of production, but also the possibility that their intensive use can encourage possible expansion of components of the animal industry. In recent years therefore, this group has been the focus of wide and concerted research effort throughout the Asian region. The best example of this can be seen in the efforts to increase the utilization by ruminants of rice straw after urea or ammonia treatment or by microbial degradation to improve the nutritive value.

Crop residues are produced from crop growth and production and are usually fibrous materials. They may or may not be agricultural by-products. Agro-industrial by-products on the other hand, are feed materials that are produced usually from agro-based industries on a commercial basis. Whereas crop residues are mainly utilizable by ruminants (buffaloes, cattle, goats and sheep) usually at the farm level, agro-industrial by-products on the other hand, are less bulky and better utilized by non-ruminants (pigs, poultry and ducks) and also fishes. The differences are mainly due to nutritive quality, with crop residues being deficient in energy, nitrogen (protein) and micro-nutrients and agro-industrial by-products generally having higher contents of each of these nutrients. Examples of these two categories of feeds and the approximate nutritive values are given in Table 1.

The fifth category, non-conventional feed resources include all those types of feeds that are not traditionally used by animals or even fishes. By definition, non-conventional feed resources (NCFR) refer to all those feeds that are not traditionally used in animal feeding and are not normally used in commercially produced rations for livestock. NCFR include feeds from animal and perennial crop production and also residues and wastes from animal sources and the processing of food for human consumption.

Table 1: Nutritional characteristics of some crop residues and agro-industrial by-products in the Asian region.

Feed source	Moisture (%)	Cr. prot. (%)	Cr. fibre (%)	OM. digest. (%)
Crop residues[1]				
Cassava leaves[2]	73.6-78.8	21.7-26.6	8.1-23.2	55.1-61.0
Gliricidia[2]	80.8	24.6	21.8	50.4
Groundnut vines	71.3	9.2	24.1	60.0-68.0
Leucaena forage[2]	75.3-79.2	20.0-25.0	16.9-25.3	51.1-54.1
Maize stover	12.8-16.3	5.0	28.3	61.0
Pigeon pea forage[2]	71.1-74.8	20.0-25.6	17.6-22.6	47.2-55.4
Rice straw	9.0-9.2	3.3-4.5	28.8-33.6	48.1-56.4
Sebania[2]	13.4	22.6	18.4	52.8
Sugarcane tops	72.0	3.8	38.0	43.0
Sweet potato vines	99.3	13.3	17.2	60.2
By-products[1]				
Bagasse	3.9-4.7	2.9-6.9	10.3-39.3	49.0
Brewers grains	9.8-10.8	24.0-27.4	15.9-17.1	60.0
Cocoa pod husks	89.6	6.0	31.5	45.0
Coconut cake[3]	10.0	18.0	12.0	78.0
Coffee seed hulls	8.0	6.9	45.6	31.0
Molasses	24.5	1.6	—	108.0
Palm Kernel Cake[4]	5.7	14.2	20.2	66.8
Palm oil mill effluent	78.0-89.0	9.6	11.5	58.1-64.2
Palm press fibre	13.8	4.0	36.4	30.8
Pineapple waste	6.8	4.9	20.8	76.0
Poultry litter	6.4	40.4-45.7	18.0-21.2	54.2
Rice bran	9.3-11.4	11.4-17.4	10.4-20.0	62.0
Rice hulls	6.7-9.7	1.5-2.8	14.3-41.4	37.0
Wheat middlings	12.7	20.5	9.0	69.0-71.4

[1] – non-conventional feeds; [2] – are not really crop residues; [3] – expeller pressed; [4] – solvent extracted; [+] – on dry matter basis

Non-conventional feedstuffs have a number of characteristics that are peculiar to them (Devendra, 1985). These are as follows:

(i) They are the end products of production and consumption that have not been used, recycled or salvaged.
(ii) They are mainly organic and can be in a solid, slurry or liquid form.
(iii) Their economic value is often less than the cost of their collection and transformation for use, and consequently they are discharged as wastes.
(iv) The feed crops which generate valuable NCFR are excellent sources of fermentable carbohydrates, e.g. cassava and sweet potato, and this is an advantage to ruminants because of their ability to utilize inorganic nitrogen.
(v) Fruit wastes such as banana rejects and pineapple pulp, by comparison have sugars which are very beneficial in terms of their energy potential.
(vi) Concerning the feeds of crop origin, the majority are bulky poor-quality cellulosic roughages with a high crude fibre and low nitrogen contents, suitable for feeding to ruminants.
(vii) Some of the feeds have deleterious effects on animals, and not enough is known about the nature of the active principles and ways of alleviating the effects.
(viii) They have considerable potential as feed materials, and, for some, their value can be increased if there were economically justifiable technological means for converting them into some usable products.
(ix) More information is required on chemical composition, nutritive value, toxic factors and value in feeding systems.

It has been estimated that, in Asia and the Pacific, NCFR account for approximately 194.1×10^6 tonnes which is about 45 per cent of the total availability from field and plantation crops. Approximately 80 per cent of the NCFR is field crops and 93 per cent of the feeds in tree crop cultivation (Table 2) is principally suited for feeding ruminants.

Crop residues, agro-industrial by-products and NCFR are essentially of three categories:

(a) Energy-rich feeds (e.g. bananas, citrus fruits and pineapple wastes).

(b) Protein supplements such as oilseed cakes and meals, by-products of animal processing (e.g. feather meal and poultry litter), low quality pulses and fishmeals.
(c) By-products from cereal milling and milk processing.

Assessment of nutritive value

The assessment of nutritive value aims at establishing a clear understanding of the nutrients available in the feed, the extent of this availability in metabolic terms and the attractiveness of the feed to animals. The following procedures are important:

(i) Proximate analyses (to include minerals);
(ii) In vitro digestibility;
(iii) In vivo digestibility;
(iv) Evaluation of toxic principals; and
(v) Amino acid profiles;

Table 2: The availability of non-conventional feed resources in Asia and the Pacific (Devendra, 1985).

Category	Availability (10^6 tonne)
Field Crops	189.9
Tree Crops	4.2
Total	194.1$^+$

+ Represents 44.9% of the total availability from field and plantation crops.

The assessment of digestibility enables the determination of digestible energy (DE) and metabolisable energy (ME). It is also possible to calculate the nutritive value of the feed based on the proximate analyses data. The following expressions of energy value are in use:

(i) Starch Equivalent (SE) — United Kingdom
(ii) The Scandinavian Fodder Unit (SFU) — Denmark
(iii) Fattening Fodder Units (FFU) — Denmark
(iv) The French system of Fodder Equivalents — France
(v) Rostock NEF system — Germany
(vi) Net Energy of Lactation system — Netherlands
(vii) California system — U.S.A.
(viii) Total Digestible Nutrients (TDN) — U.S.A.
(ix) Metabolisable Energy (ME) — United Kingdom

(x) Digestible Energy (DE) — United Kingdom

At present the feeding systems based on ME and DE are used mostly for non-ruminant animals and also for fish, whereas the net energy systems (e.g. SE, SFU or FFU) are more applied and reserved for fattening. Of these systems, the ME system is possibly the most widely used presently.

With respect to proteins, the following indices are used to describe quality:

(i) Digestible crude protein (DCP);
(ii) True protein (TP);
(iii) Protein efficiency ratio (PER);
(iv) Gross protein value (GPV);
(v) Protein replacement value (PRV);
(vi) Biological value (BV);
(vii) Biological assays;
(viii) Protein equivalent (PE); and
(ix) Degradability.

Of these indices, DCP and BV are used very widely. Recently, increasing use has also been made of degradability in the rumen.

Feeds should be evaluated with animals and also with fishes (species and physiological state) to which the information will be ultimately applied. This implies that the extrapolation of data across species may be inaccurate and therefore not desirable.

Utilisation in efficient feeding systems

Once a feed has been identified and there is adequate information on nutritive value, the next step is an assessment of its value in feeding systems. The following aspects are considered essential for this assessment:

(i) Voluntary intake (specifying animal species and level of feeding);
(ii) Digestibility coefficients (specifying animal species, level of feeding, supplementation and any processing);
(iii) Feeding trials which specify the proportion of the feed incorporated and relate this to predictable responses; and
(iv) Any observed side effects, e.g. off flavours.

Animal performance is usually measured by such parameters as feed efficiency, growth rate and milk production. Growth rate, biomass production and reproductive capability apply to fish.

Nutrient requirements
The nutrient requirements refer to the defined needs of the body in terms of energy, protein, minerals and vitamins to enable it to survive and produce. The extent to which animals and fish can maximize production is directly related to the level and quality of dietary nutrients supplied above the maintenance requirements.

Feeding trials need to be undertaken which are well controlled and carefully monitored especially in regard to the use of feed ingredients and diets over time. In particular, the following issues will need to be carefully defined as the results are specific to a particular situation:

(i) species of animal or fish;
(ii) age of animal or fish;
(iii) physiological state of production (maintenance, growth reproduction); and
(iv) extent of muscular activity (confined or grazing).

It is possible to undertake the utilization and effectiveness of feeds in efficient feeding systems with the determination of nutrient requirements. Digestibility coefficients are also determined in relation to voluntary intake, feeding level and type of treatment.

Based on this approach, there exists today several nutrient requirement standards that are widely used throughout the world. These include, for example, the A.R.C. Nutrient Requirements of Farm Animals, 1. Poultry (1963), and 3. Pigs (1967); A.R.C. Nutrient Requirements for Livestock (1980); and N.R.C. Nutrient Requirements for Goats (1981). Kearl (1982) has published nutrient requirements for ruminants in the developing countries based on a review of the literature. In recent years, there have been concerted attempts in several countries to develop their own feeding standards, especially for ruminants. Similarly there also exists the N.R.C. (1983) requirements for warm-water fishes and shellfishes.

Importance of feeding standards
Very recently, the question has been asked (Jackson, 1981), "who needs feeding standards" and the same author replied "no one really needs them". Jackson's conclusion is based on the fact that the feeding standards dictate high levels of grain use, which is not the case in the developing countries, and that the existing

feeding standards are inadequate for application to small farm systems that are characteristic of Asia (Devendra, 1983). Such a view is also endorsed by some, for example, Preston (1985), who advocates that production should simply be matched to available resources, including feed resources for maximising animal performance based on an understanding of rumen fermentation, digestion and metabolism in the animal.

Jackson's view has been refuted and challenged by Minson (1982) who argues that feeding standards "form the basis of our quantitative understanding of animal production whether under grazing or stall feeding conditions".

It is relevant to keep in mind that the objective of feeding standards is to provide to animals amounts of nutrients that are essential for maintenance and a stated level of production. This approach ensures that the objectives of production and profitability are met by the application of feeding standards. This situation is also true for fish (Halver, 1979), for example, the rainbow trout (Lall and Bishop, 1979).

The focus of feeding trial experiments should not exclusively be directed towards determining nutrient requirements. Rather, it should be directed towards predictable responses to a diet or to incremental amounts of added dietary nutrients within which it will be feasible to determine the nutrient requirements.

Strategy for fish feed formulation and production

In practice, diet formulation and development usually follow the pathway of using traditional feed ingredients to determine performance and also nutrient requirements. This phase can be termed exploratory, whereby natural and traditional feed ingredients, based on a knowledge of nutritive value, are formulated for use. The understanding of available natural or traditional feeds dictates the justification for and extent of supplementation. Based on the effective utilization of the formulated diets, it is feasible in turn to determine the nutrient requirements.

The second continuing phase can be termed one of refinements which will consider additionally important issues such as the use of NCFR, nutrient variables (energy, protein, minerals and vitamins), supplementation, import substitution and economic considerations. Very rarely is the second phase included into the phase one effort, mainly because of inadequate confidence, and knowledge of extent of the nutrient needs and the level of performance of the particular animal.

The two steps in sequence thus provide for a more assured pathway of identifying nutrient requirements with production, and therefore the development of an orderly strategy for the development of fish feed formulations. Such a strategy has the final objective of ensuring maximum and economic production per hectare. This includes integrated crop-animal systems and, specifically, the future potential of aquaculture. Figure 1 is a schematic representation of the strategy. The strategy is necessarily aimed at intensification but does not preclude more extensive culture systems.

A review of the types of feed ingredients now being used for fish nutrition studies in various laboratories enables two general conclusions to be drawn:

(i) With very few exceptions, the feeds that are currently being used are identical to those used by animals. This means that there is really no need for placing much more emphasis on proximate analyses. However, it is essential to ensure continuing work on the inherent availability of the nutrients to fishes, especially that of amino acids and minerals.

(ii) Rapid progress in fish nutrition work can be achieved by placing more emphasis in the Phase II efforts in Figure 1 of examining refinements which can stimulate and make an impact on production.

Issues of practical diet formulation

There are a number of practical diet formulations that are obviously essential in fish nutrition. It is not intended for reasons of brevity to discuss these in detail, since in any case, some aspects of this have been previously considered (Halver, 1976; Lovell, 1979; Hastings, 1979). It is proposed to consider only two aspects that are relevant:

(i) use of indigenous feed; and
(ii) economic considerations.

(i) Use of indigenous feeds

The utilization of indigenous feed ingredients assumes that there exist substitutes for the traditional energy (e.g. maize) and protein sources (e.g. fish meal) that are normally consumed by fish. This is clearly an area in which fish nutritionists can borrow

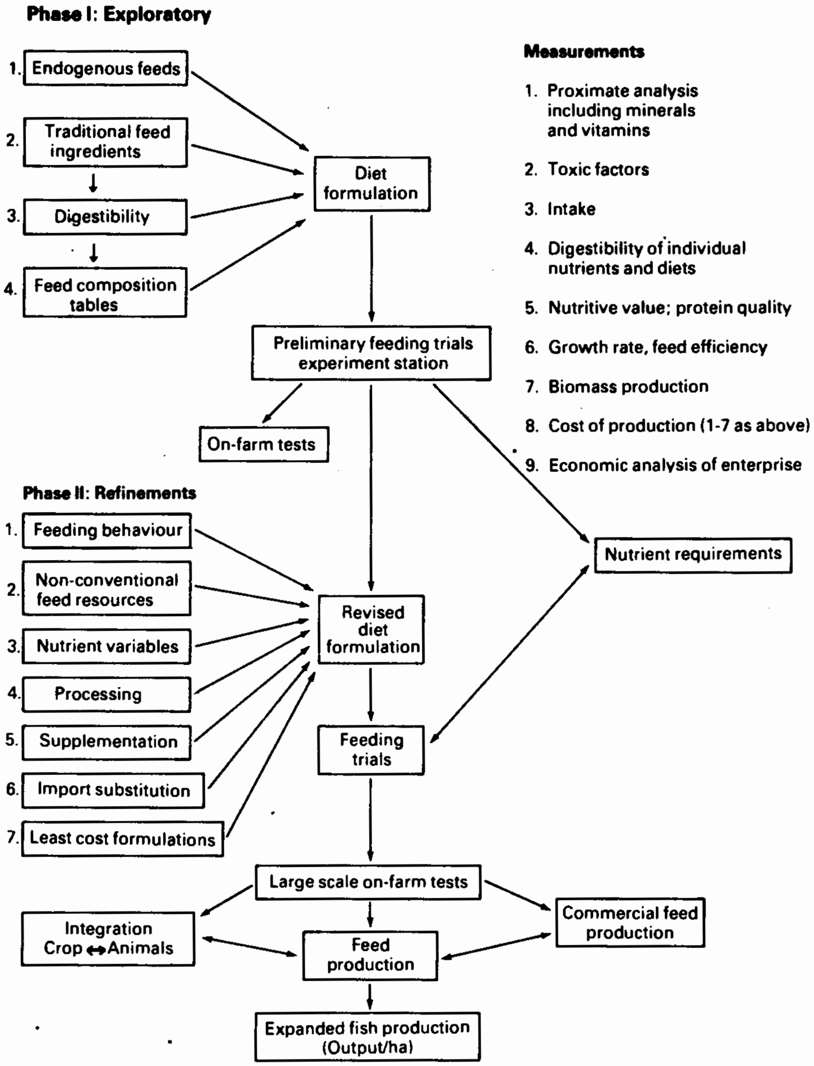

Fig. 1: A strategy for fish feed formulation and production.

heavily from the advances that have been made in the same context with the nutrition of pigs, poultry and ducks. Table 3 lists the more important energy and protein feed ingredients that are found in Asia and which have potential use in fish feeding and nutrition.

In this context it is encouraging to note that attempts are already underway to explore, for example, the value of such feeds as carpet grass (*Axonopus compressus*) and napier grass (*P. purpureum*) for the grass carp (*Ctenopharyngodon idella*), and yam leaves (*Colocasium antiquorum*) for the kalui (*Osphronemus goramy*), together with processed fish meal in Singapore (Chou, 1985). The latter, for example, showed that use of processed Singapore fish meal gave a better performance in young seabass (*Lates calcarifer* Bloch) than the meal from elsewhere. Broken rice has been used in Thailand (Chuapoehum and Pothisoong, 1985), Malaysia (Pathmasothy, 1985) and Sri Lanka (Wanniga-ma, Weerakoon and Muthukumarana, 1985).

Table 3: Some important energy and protein feeds in Asia (+non-conventional feeds).

Energy feeds		Protein feeds
Bananas	waste⁺	Blood meal
Cassava	— chips	Cassava leaves⁺
	— waste	Castor seed cake⁺
Maize	— bran	Coconut cake
	— germ meal	Cottonseed cake
Millet	— broken grains	Feather meal (Hydrolysed)
Rice	— broken grains	Fish meal
Sago	— waste	Gliricidia leaves⁺
Sugarcane	— molasses	Groundnut cake
Sweet potatoes		Leucaena (ipil-ipil) leaves⁺
Wheat	— broken grains	Meat meal
	— bran	Palm kernel cake
	— middlings	Pigeon pea leaves⁺
		Rice bran
		Sal seed cake⁺
		Soybean meal

(ii) Economic considerations

Since as in the case with non-ruminants, protein is the most expensive component of the diet it is logical, therefore, to explore all possible ways to decrease this cost, hence the cost of production and the margin of profits. Thus, successful results in this context have been reported by Gropp et al. (1979) on the partial or complete substitution of 70 per cent fish meal by a mixture of poultry by-product meal and hydrolysed feather meal in the rainbow trout (*Salmo gairdneri*). Likewise also, poultry by-products and alkali yeast gave equally good results. Similarly, squid meal has been used successfully to replace rice bran for shrimp growth.

Apart from the immediate benefit of reducing the cost of production and increasing profitability, successful import substitution tends to reduce the drain on foreign exchange, especially as it concerns those feeds that are imported at high cost. Also, the dependence on fish meal as the major feed ingredient is constrained by dwindling supplies in the world market, rising costs and competition with the demand for concurrent feeding to pigs, poultry and lactating ruminants.

Table 4: Weight gain and feed efficiency of rainbow trout for experiment E XII/75 (104 experimental days, 17.4 mean water temperature) to test dietary replacement of fish meal by Alkane Yeast. After Gropp et al., 1979.

	Percent replacement of fish meal protein			
Poultry by-products	50	50	50	50
Alkane yeast	—	25	50	50+AA+
Gain (g)	210	218	216	221
(relative figures)	(100)	(104)	(103)	(105)
Feed efficiency	1.38	1.34	1.36	1.32
(relative figures)	(100)	(97)	(98)	(95)

+ amino acids.

Feed Efficiency

It may be of interest to refer to and make brief comparisons between the efficiencies of converting animal feeds into human foods. Table 5 shows the percentage of gross energy and protein in the feed of domestic animals as food producers.

The position with fish does not appear to be well documented, but Brett (1971) has reported gross efficiencies from 10-40 per cent. The higher values for energy in fish suggest an efficiency which is clearly superior in comparison to the energetic efficiency of most domestic animals. A similar position exists with protein. The limited results emphasise that the fish uses energy and protein in the feed very efficiently.

Table 5: Efficiency of converting animal feeds into human foods. After Maynard et al., 1979.

	Percentage recovered	
Animal product	**Energy**	**Protein**
Cattle (milk)	15-20	15-36
Poultry (eggs)	10-18	10-30
Pigs (pork)	14-20	14-20
Poultry (broilers)	6-11	17-23
Cattle (beef)	3-8	4-15
Fish	10-40*	40+

*Brett, 1971; + Hastings, 1979.

Conclusions

Improved efficiencies in diet development and nutrition by the fisheries sector are essential for further progress in fish production. Traditional concepts of fish nutrition developed in classical studies essentially in western environments are important and essential. However, these must also serve as important guidelines for pragmatic application in real farm situations in Asia where both the fish genetic and available feed resources are quite different. In particular, there is need for modifications and refinements to traditional diet formulations in order to take advantage of indigenous feed ingredients and appropriate feeding systems that can ensure high performance and profitability. Such an approach needs necessarily to be coupled with objective innovations to maximise production. This is because the long-run perspective of fisheries supply and demand is for increases in real fish prices which are expected to be associated with reduced consumption below the potential demand and difficulties in the management of important fisheries (F.A.O., 1981).

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Alternate Feed Sources for Finfish in Asia

KOK LEONG WEE

Introduction

Fish culture activities can be conveniently classified into intensive systems utilizing high stocking densities and intensive management techniques. Species reared in such systems are mainly carnivorous species such as seabass (*Lates calcarifer*), grouper (*Epinephelus tauvina*), and snakehead (*Channa* spp.); omnivorous and herbivorous species are also farmed intensively. These include tilapias (*Oreochromis* spp.), common carp (*Cyprinus carpio*), and milkfish (*Chanos chanos*). Using this system, the provision of a complete feed, whether it is a natural feed such as trash fish or artificial such as compound feeds, is essential. The extensive system is the other extreme in which there are no pond inputs or management effort. This system is commonly used to culture those species of fish low on the food chain. Lying in between these two systems is the semi-intensive one in which fish are provided with supplementary feeds, an incomplete diet such as rice bran or broken rice, or pond waters are fertilized using organic or inorganic fertilizers to produce food organisms, or both.

The current trend in fish culture is towards one of increased intensification of culture systems whereby provision of feeds becomes necessary and success therefore depends significantly on the availability of well balanced, nutritionally complete and cost-effective compounded feeds. This is best illustrated in Taiwan where, over the course of 15 years, intensive culture of eel, shrimp, tilapia and milkfish in freshwater ponds became prevalent, and was accompanied by a corresponding increase in the total production of formulated fish feed from only 12,000 metric tons in 1973 to 186,000 metric tons in 1984 (Chuang et al., 1986). However, at present, the intensive culture of most of the carnivorous species still utilizes trash fish as feed since compound feeds have not been formulated for these fishes or are not commercially available.

Formulated fish feeds for omnivorous and herbivorous fish species are available in almost all the countries in Asia where the aquaculture industry is well developed. The cost of such feeds is however, relatively high, as most of the commonly used feed ingredients such as fish meal, corn, wheat middling are generally imported and the prices are rising annually. It follows therefore, that there is considerable interest in research to produce cheap fish feeds. One way is to reduce the cost of the most expensive component of the feed, i.e. the protein source which is normally fish meal, and more recently soybean meal, either through seeking a direct replacement for fish meal or by utilizing the protein sparing property of non-protein energy resources through the utilization of so-called non-conventional feed resources which Devendra (1985) defined as "all those feeds that have not been traditionally used in animal feeding and or are not normally used in commercially produced rations for livestock". The term non-conventional feed resources (NCFR) would include novel sources such as single-cell protein, resources recovered from wastes from chemical, microbiological, and agro-industrial processes. However, the delimitation of an NCFR is not always clear as a traditionally used ingredient in one region may be considered non-conventional in another by virtue of its non-availability.

Conventional or traditionally used ingredients in fish feeds

It is extremely difficult to gather information from feed mill companies for proprietary reasons. Cho et al. (1985) have compiled a list of the commonly used ingredients in fish feeds (Table 1). The ingredients used in fish and shrimp feeds are relatively simple in Taiwan (Chuang et al., 1986, Table 2) and Malaysia (Pathmasothy, 1983, Table 2). Although data from other countries are not available, it is not unreasonable to assume that similar ingredients are used to produce fish and shrimp feeds.

Table 1: Composition (%) of common ingredients in fish diets (adopted from Cho et al., 1985).

Ingredient	Crude Protein	fat	fibre	Ca	Methionine + cystine
Alfalfa meal	17.0	3.0	24.0	1.3	0.5
Blood meal, animal	80.0	1.0	1.0	0.3	2.4
Brewer's dried yeast	45.0	0.4	1.5	0.1	1.5
Corn, yellow	8.9	3.5	2.9	0.01	0.3
Corn gluten feed	21.0	2.0	10.0	0.3	1.0
Corn gluten meal	60.0	2.0	2.5	0.02	3.0
Corn distiller's dried soluble	27.0	9.0	4.0	0.4	1.2
Feather meal, poultry	85.0	2.5	1.5	0.2	3.6
Fish meal, herring	70.0	10.0	1.0	2.0	2.9
Meat and bone meal	45.0	8.5	2.5	11.0	0.8
Poultry by-product meal	58.0	14.0	2.5	4.0	2.0
Rapeseed meal	36.0	2.6	13.2	0.7	1.2
Soybean, full fat, cooked	38.0	18.0	5.0	0.3	1.1
Soybean, meal, dehulled	48.0	0.5	3.0	0.2	1.5
Wheat middlings	17.0	3.6	7.0	0.2	0.3
Whey, dehydrated	12.0	0.7	—	0.9	0.5
Fish protein concentrate	80.0	0.3	1.0	3.5	4.7
Soybean protein concentrate	68.0	0.3	3.6	0.3	2.8
C201-Guelph reference diet	40.0	15.0	3.4	0.8	1.6
C202-Guelph reference diet	40.0	17.0	3.0	0.7	1.7

Table 2: List of some ingredients commonly used in the formulation of complete diets for fish and shrimp in Malaysia[1] and Taiwan[2].

Malaysia	Taiwan
Fish meal	Fish meal[3]
Soybean meal	Soybean meal
Prawn meal	Rice bran
Groundnut meal	Wheat flour
Palm kernel cake	Starch (gelatinized)[4]
Broken rice	Others
Sago	
Cassava	

[1] Pathmasothy (1983); [2] Chuang et al (1986); [3] Includes white brown fish meal; [4] Mainly used in eel feed as binder.

Alternate feed sources

Fish meal replacers

The primary source of dietary protein is supplied by fish meal (averaging 30-40 per cent of the diet). This is the most expensive component of fish feed. Therefore it makes economic sense to seek replacements for fish meal. In this context, animal protein sources such as meat and bone meal, blood meal, poultry by-product meal, and hydrolysed feather meal have been evaluated. Results show only limited success in replacing fish meal; reduced feed conversion efficiency and growth were reported when substituted at a high dietary level. Hence, these ingredients are only recommended for incorporation at low levels (5-15 per cent) and are termed secondary protein sources (Tacon and Jackson, 1985). Plant proteins have also been evaluated as possible fish meal replacers (Table 3). The results show great variation in the degree of success for partial or complete replacement of fish meal depending on the species of fish and types of ingredients used. Problems encountered in utilizing these NCFR include:

(1) imbalanced amino acid profile; and
(2) presence of endogenous anti-nutritional factors, some of which are presented in Table 4.

Fortunately, these anti-nutritional factors, the main limiting factors to their use at high dietary inclusion levels within fish feeds, can be inactivated or destroyed by heat treatment processes which, in the same process, increases the bioavailability of proteins through the rupture of cell walls, releasing the contents and also cooking the carbohydrates present which improves the digestibility. However, care must be taken to ensure that proteins are not lost through denaturation or combination with other nutrients (sugar) during the heating process. Most plant proteins, although containing relatively high protein levels, are deficient in certain essential amino acids, notably the sulphur-containing methionine. This imbalance of amino acids however, can be corrected through the use of a combination of oil seed meals and other ingredients to supplement the deficiency or through the addition of synthetic amino acids. It is worth noting that these oil seeds are produced not for meal as a feed ingredient but for oil, the meal being a by-product. Therefore, Tacon and Jackson (1985) suggested the

Table 3: Use of plant oilseeds and pulses in complete diets for fish.

Oilseed/pulse	Fish	Max. incl. lev.
Cottonseed		
– glanded, solvent extracted meal	Oreochromis mossambicus	35%
– glanded, solvent extracted meal	O. aureus	<26%
– glandless, full fat meal	O. aureus	<21%
– glandless, solvent extracted meal	O. aureus	<23%
– glanded, solvent extracted meal	Oncorhynchus tshawytscha	34%
– glanded, solvent extracted meal	O. kisutch	22%
– glanded, solvent extracted meal	Ictalurus punctatus	17%
– glanded, solvent extracted meal	O. aureus/niloticus	20%
– glanded, solvent extracted meal	Cyprinus carpio	20%
Rapeseed		
– solvent extracted, standard	O. mossambicus	<42%
– solvent extracted, toasted	C. carpio	28%
– solvent extracted, canola meal	Salmo gairdneri	22%
– solvent extracted, canola meal	S. gairdneri	20%
– solvent extracted, canola meal	O. tshawytscha	16-20%
Sunflower		
– solvent extracted, standard	O. mossambicus	70%
– solvent extracted, standard	S. gairdneri	36%
Indian mustard		
– seed cake, roasted	C. carpio	20%
– seed cake, unroasted	C. carpio <20%	
Broad bean (= faba bean)		
– bean meal, standard	S. gairdneri	20%
Sweet lupin		
– lupin meal, standard	S. gairdneri	20%
Ground nut		
– expeller cake, standard	O. mossambicus	17%
– unspecified	I. punctatus	25%
Soybean		
– solvent extracted, standard	O. mossambicus	18%
– full fat, expanded (puffed)	O. niloticus	50%
– hexane extracted, standard	O. niloticus	42%
– solvent extracted, standard	O. niloticus/aureus	20%

Table 3 (continued)

Oilseed/pulse	**Fish**	**Max. incl. lev.**
– full fat, extruded (jet sploder)	I. punctatus	50%
– solvent extracted, toasted	C. carpio	35%
– full fat, extruded (jet sploder)	O. tshawytscha	<17%
– soy protein concentrate (Haypro)	S. gairdneri	19%
– full fat, extruded (jet sploder)	S. gairdneri	73%
– full fat, expanded (puffed)	S. gairdneri	50%
– full fat, toasted	S. gairdneri	32%
– hexane extracted, extruded	S. gairdneri	36%
– soy protein concentrated (Haypro)	S. gairdneri	27%
– hexane extracted, standard	S. gairdneri	26%
– full fat, micronised	S. gairdneri	<10%
Leucaena leucocephala		
– dried leaf meal	O. mossambicus	<10%

Dietary level recommended by researcher at which there is no loss in growth performance or feed efficiency compared with the control fish meal based diet employed. Table taken from Tacon and Jackson (1985).

Table 4: Anti-nutritional factors present in plants commonly used for animal feeding.

		Anti-nutritional factors*
Cereals	Barley, Hordeum vulgare	1,2,5,8,25
	Rice, Oryza sativum	1,2,5,8,13,25
	Sorghum, Sorghum bicolor	1,4,5,7,18,25
	Wheat, Triticum vulgare	1,2,5,8,11,18,22,25
	Corn, Zea mays	1,5,8,19,25
Root tubers	Sweet potato, Ipomoea batata	1,19
	Cassava, Manihot utilissima	1,4,25
	Potato, Solanum tuberosum	1,2,4,8,18,19,21
Legumes	Broad bean, Vicia faber	1,2,5,7,22
	Chick pea, Cicer arietinum	1,4,5,8,11,25
	Cowpea, Vigna unguiculata	1,2,5,11,25
	Grass pea, Lathyrus sativus	1,9
	Haricot bean, Phaseolus vulgaris	1,2,4,5,6,11,12,18,25
	Horse gram, Macrotyloma uniflorum	1,2
	Field bean, Dolichus lablab	1,2,4

Table 4 (continued)

		Anti-nutritional factors*
	Lentil, Lens culinaris	1,2,6,25
	Lima bean, Phaseolus lunatus	1,2,4,5,7
	Lupin, Lupinus albus	1
	Mung bean, Phaseolus aureus	1,5,6,11,13,25
	Field pea, Pisum sativum	1,2,4,5,6,12
	Pigeon pea, Cajanus cajan	1,2,4,5,25
	Rice bean, Vigna umbellata	2
	Runner bean, Phaseolus coccineus	1, 2
	Jack bean, Canavalia gladiata	1,2,4,6
	Velver bean, Stizobolium deeringianuum	1,22
	Winged bean, Psophocarpus tetragonolobus	1,2
	Guinea bean, Arbus precatorius	1,7
	Guav bean, Cyamopsis psoraloides	1
	Alfalfa, Medicago sativa	1,6,8,12
	Blackgram, Phaseolus mungo	1,5
	Ipil, Leucaena leucocephala	23
Oilseeds	Groundnut, Arachis hypogaea	1,2,5,6,8,25
	Rapeseed, Brassica campestris	1,3,5,7,25
	Indian mustard, Brassica juncea	1,3,13,25
	Soybean, Glycine max	1,2,3,5,6,8,11,12,14, 16,17,25
	Sunflower, Hellianthus annuus	1,7,20,25
	Cottonseed, Gossypium spp	5,8,10,12,24,25
	Linseed, Linum usitatissimum	4,8,13,15
	Sesame, Sesamum indicum	5,25
	Crambe, Crambe abyssinica	3

* 1, Protease inhibitors; 2, Phytohaemaglutinins; 3, Glucosinolates; 4, Cyanogens; 5, Phytic acid; 6, Saponins; 7, Tannins; 8, Ostrogenic factors; 9, anthyrogens; 10, Gossypol; 11, Flatulence factor; 12, Anti-vitamin E; 13, Anti-thiamin; 14, Anti-vitamin A; 15, Anti-pyridoxin; 16, Anti-vitamin D; 17, Anti-vitamin B; 18, Amylase inhibitor; 19, invertase inhibitor; 20, Arginase inhibitor; 21, Cholinesterase inhibitor; 22, Dihydroxy-phenylalanine; 23, Mimosine; 24, Cyclopropenoic fatty acids; 25, Possible mycotoxin. Table taken from Tacon and Jackson (1985).

use of full-fat oil seeds as an ingredient, in particular full-fat soybean meal to make use of the high lipid content (18-20 per cent by weight) since soy oil contains a high proportion of linoleic acid (18.2 n-6), an essential fatty acid for some species of fish. The soybean meal stores well owing to the presence of soy lecithin which acts as an anti-oidant. Soy lecithin is also a rich source of choline and inositol, a good emulsifier, a rich source of available phosphorus and behaves as an excellent feed conditioner.

Single-cell proteins (SCP)

The following passage on single cell proteins was taken from a paper by Tacon and Jackson (1985) on the utilization of conventional and non-conventional protein sources in practical fish feeds, with the kind permission of Dr Albert Tacon.

Single-cell protein is a term applied to a wide range of algae, fungi (including yeasts), and bacteria which are produced by fermentation processes for use as animal feed. Compared with conventional plant and animal feed proteins, these micro-organisms offer a number of advantages as protein producers:

(a) their production can be based on raw carbon substrates which are available in large quantities (coal, petro-chemicals, natural gas) or on agricultural or cellulosic waste products which would otherwise cause environmental pollution;
(b) the majority of micro-organisms cultured are highly proteinaceous (40-70 per cent crude protein, dry weight, depending on the species);
(c) they have a short generation time; under optimum culture conditions bacteria can double their cell mass within 0.5-2 hour, yeasts within 1-3 hour and algae within a 2-6 hour period;
(d) they can be cultivated in a limited land space and produced continuously with good control, independently of climate; and
(e) to a certain degree their nutritional composition can be controlled by genetic manipulation.

In view of the potential of SCP for protein production, it is perhaps not surprising that considerable attention has been focused on the use of these proteins as a dietary replacement for fish meal within compounded fish feeds.

By far the greatest research effort has centred on the use of yeast SCP and, in particular, the alkane/petrochemical yeast *Candida lipolytica* ('Toprina'). Despite the encouraging results of Tiews et al. (1979) with rainbow trout in which DL-methionine supplemented alkane yeast was found to produce equivalent growth to a fish meal based ration, the majority of studies to date involving the use of alkane yeast as the sole or principal source of dietary protein have generally resulted in reduced weight gain and feed efficiency compared to fish meal protein. Nevertheless, in practice, alkane yeast has been successfully incorporated in the production of salmonid rations, replacing up to 25-50 per cent of the fish meal component (equivalent to a dietary yeast SCP inclusion level of 15-30 per cent by weight) with no loss in growth or feed efficiency.

Similar results have also been obtained with bacterial SCP and, in particular, the bacterium *Methylophilus methylotrophus* ('Pruteen', 'Hoechst AG') studies indicating that methanol bacterial SCP can replace up to 75 per cent of the fish meal protein (equivalent to 20-30 per cent bacterials SCP by weight) in a salmonid production diet (Tacon and Jackson, 1985).

Despite the common use of unicellular algae and yeast SCP as live food organisms for a variety of fish and crustacean larvae (Appelbaum, 1979; Watanabe et al., 1983), relatively few studies have been reported on the direct use of dried algal meal within compounded fish feeds (Stanley and Jones, 1976). In general, dried algae SCP (*Spirulina masima*) has been found to have a lower feed value for fish than yeast SCP, bacterial SCP, or fish meal (Matty and Smith, 1978; Atack and Matty, 1979). However, the studies of Appler and Jauncey (1983) with *Oreochromis niloticus*, and Hepher et al. (1979) and Meske and Pfeffer (1978) with common carp, indicate that certain dried algal meals (*Cladophora glomerata, Scenedesmus obliqus, Chlorella* sp., *Oocystis* sp., *Euglena* sp.) may offer particular promise as a partial dietary replacement for fish meal within practical fish rations at relatively low dietary inclusion levels (<20 per cent algae SCP).

In comparison with conventional feed proteins, a significant proportion of the nitrogen (N) present within SCP is in the form of non-amino acid N-containing compounds and, in particular, as the purine and pyrimidine bases of nucleic acids and nucleotides, and to a lesser extent as polymeric (N-acetyl) hexosamines. Thus, Kihlberg (1972) reported total nucleic acid values of 5-12 per cent for yeasts and 8-16 per cent by weight for bacteria, as a percentage of dry matter. It has been suggested by some workers that the high nucleic acid content of SCP may be deleterious to fish at high dietary inclusion levels (Sanchez Muniz et al., 1978). For example, in rainbow trout, low and intermediate nucleic acid intakes (equivalent to <25 per cent bacterial SCP inclusion level) were found to have no deleterious effect on the growth and food conversion efficiency of fish, although at a high nucleic acid inclusion level (equivalent to a bacterial SCP intake of 50 per cent) feed intake, growth and food conversion efficiency were found to be adversely affected (Tacon and Cooke, 1980). However, although these authors found a significant increase in serum urea concentration and liver uriease activity within fish fed the highest nucleic acid inclusion level tested, there was no indication of a nitrogen "sparing" action within fish fed nucleic acid supplemented rations. On the basis of this preliminary feeding trial, it would appear that nucleic-N is of no nutritive value to fish provided with an adequate supply of alpha-amino acid N and, as such, should not be included within estimations of dietary crude protein content (N × 6.25) or calculations of net protein utilization (NPU) based on total N intake. Clearly the exact role of nucleic acids and polymeric (N-acetyl) hexosamines in the nitrogen economy of fish warrants full investigation.

At present, one of the major factors influencing the use of SCP in compounded fish feeds has been the economic cost of SCP production and, in particular, the choice of substrate and cost of harvesting the product from a dilute suspension. However, provided that SCP remains stable in composition and competitively priced with respect to other animal protein sources, it will always remain a much needed fish meal replacer for use within fish feeds.

Fish silage

Fish silage can be defined as a liquid product made from whole or parts of fish that are liquefied by the action of enzymes in the fish in the presence of an added acid. The enzymes break down fish proteins into smaller soluble units and the acid helps to speed up their activities while preventing bacterial spoilage. The process is simple and the capital investment required is relatively low compared with fish meal production. It can be produced on both small and large scale and it therefore has potential applications at the village level. Its use as an animal feed ingredient is not new and it has been widely used as a dietary ingredient for poultry and pigs. Methods to produce fish silage can be categorized into:

(1) those using acids, either mineral and/or organic to lower the pH and to produce the conditions necessary for silage production; and
(2) those employing a process of fermentation with the generation of organic acids to conserve the product.

At the Asian Institute of Technology, silage was produced from tilapia reared on septage as a means of utilizing these 'trash' tilapia by both the acid and the fermentation methods. These silages were subsequently mixed with other ingredients (fish meal, soybean meal and cassava) and fed to *Clarias macrocephalus*, and produced growth comparable with the control diets (trash fish and compound feed pellets). It should be noted that the protein content of the silages ranged from 11.6 to 15.5 per cent and, when used alone, was not sufficient to meet the fish's protein requirement; hence other protein sources were included (Wee et al., 1986). It has also been shown that with storage, the level of the amino acid tryptophan was reduced and oxidation of unsaturated lipids may occur (Jackson et al., 1984).

Microbial enrichment of cassava

Cassava is traditionally considered an energy providing ingredient in animal feeds. The low cost of cassava as a result of overproduction has led to renewed interest in investigating new ways of utilization. Microbial enrichment may be one way to increase its nutritive value. The process involves the fermentation of cassava by the moist-solid fermentation technique using cassava chips, inorganic and organic compounds as substrates, with either *Rhizopus* or *Aspergillus* isolates as inocula. The production of fermented cassava has currently reached the pilot-plant stage, while large-scale production awaits the results from the long-term nutritional and safety evaluation experiments and the screening of fungi which have higher ability to convert carbohydrates and non-protein nitrogen to true protein (Hutagalung and Tan, 1976).

The improved product of fermented cassava contains 20 per cent protein and it is reasonably adequate in most essential amino acids, with the exception of sulphur-containing amino acids, particularly methionine. Inclusion rates of the order of up to 30 per cent of the rations for broiler, and up to 40 per cent for laying hens and pigs have been found satisfactory (Hutagalung and Tan, 1976). It is envisaged that fermented cassava will make a significant contribution both as a feed supplement for monogastrics and as protein where a good supply of carbohydrate is available.

Miscellaneous non-conventional feed resources

The preceding sections dealt with alternative feed sources as ingredients in fish feeds per se. However, there are numerous NCFR which have potential not so much as ingredients but to supplement and to complement the natural food production in the pond, particularly in the culture of omnivorous and herbivorous species in semi-intensive systems. These NCFR can be divided into 2 basic groups:

(1) Wastes from agriculture or food processing industries:

- Chicken processing waste

  Bones from chicken processing factories have been used either alone or in combination with water hyacinth to feed the silver striped catfish, *Pangasius sutchi*, in Thailand. Chicken viscera have also been used as complete feeds for the walking catfish, *Clarias batrachus*, and snakehead, *Channa striata*.

- Food manufacturing waste

  Spoilt biscuits, bread crusts and noodle waste have been used as supplementary feeds for tilapia and *P. sutchi*, acting as an energy-rich source to spare protein derived from natural food organisms for growth.

- Rice milling waste

  Broken rice from rice mills are normally cooked and mixed with trash fish and fed to snakehead and catfish. Rice bran has value as an ingredient as well as a supplementary feed.

From the above-mentioned examples, it is clear that these types of feed will only benefit a few individuals whose farms are located in areas where such industries are sited.

(2) Whole food organisms as a larval feed and as common feed for "grow out".

The use of whole invertebrate food organisms as a feed for fish is not a recent innovation; for example, Hickling (1962) reports the use of silk worm pupae as a traditional feed for carp in China and Japan. Similarly, within numerous aquaculture systems the feeding of live zooplankton (rotifers, copepods) is seen as an essential component for the mass propagation of certain larval and exotic fish species (particularly for those fish species where the dietary nutrient requirements are still poorly understood, or where it has not been possible to use an effective dry diet). The use of live zooplankton as a larval food has been comprehensively reviewed by Watanabe et al. (1983).

Considerable interest has recently been focused on the use of selected macro-invertebrates (insect larvae, oligochaetes) as a means of breaking down and utilizing "waste streams" (animal manures, domestic sewage, agricultural wastes) which would otherwise have little or no direct feed value within a compound diet. By virtue of their ability to utilize and upgrade waste nutrients into a "palatable" nutrient-rich package, these food organisms may constitute a potential (although limited) feed source for fish (Table 5). Despite the encouraging results obtained with the majority of food organisms tested, it should be noted that the value of these potential food sources to the fish feed compounder will depend upon their market availability and cost of production and processing prior to feeding. At present macro-invertebrates play a very minor role within integrated aquaculture systems, with available waste streams being used directly for pond fertilization. Aquatic macrophytes such as water spinach and duckweeds may also serve as valuable feeds for herbivorous fish.

Conclusions

The present stage of the art in fish nutrition reviewed with regards to identification of novel feedstuffs for fish feeds reveals that of the many ingredients evaluated to replace fish meal, only limited success has been reported. It would appear that it is not possible to completely replace fish meal. It is not surprising considering the highly superior nutritive quality with its well-balanced amino acid profile, sources of valuable fatty acids, vitamins and minerals.

There is of course a real dilemma as to the priority for research; whether to conduct research on developing feeds for carnivorous species which fetch a good price or on species low

Table 5: Use of macro-invertebrates in fish feeds-summary (p-pupae; l-larvae; a-adult; wh-whole; f-frozen; dm-dry meal).

Organism	Form & mode fd.	Fish
Insecta		
Musca autumnalis (face fly)*	p;wh(f);dm	Ictalurus puntcatus
Hermecia illucans (soldier fly)*	l;wh/ch(f)	I. punctatus/ Tilapia aurea
Musca domestica (house fly)*	l:dm	S. gairdneri/ Oncorhynchus kisutch
Calliphora erythrocephala (fly)*	l;w (live)	Anguilla anguilla
C. erythrocephala*	l;w(f)/dm	Oreochromis spilurus
Tenebrio molitor (beetle)	l;w (live)	A. anguilla
Bombyx mori (silk work)	p;dm	Oncorhynchus keta
Chironomous spp. (chironomid)*	l;w (live)	Clarias fuscus/ Ophicephalus spp.
Chironomous spp. (chironomid)	Em (live)	Mystus seenghala
Termise spp. (termite)	a/l (live)	Oreochromis/Tilapia
Crustacea		
Gammarus lacustris	a;wh (live)	Salmo gairdneri
Euphausia superba (krill)	a;dm	O. keta
E. superba (krill)	a;dm	S. gairdneri
E. superba (krill)	a;dm	Cyprinus carpio
Oligochaeta (terrestrial)*		
Perionyx excavatus	a;dm	Oreochromis niloticus
Eisenia foetida	a;wh(f)/dm	Salmo gairdneri
Allolobophora longa	a;wh (f)	S. gairdneri
Lumbricus terrestris	a;wh (f)	S. gairdneri
Eudrilus eugeniae	a;dm	S. gairdneri
E. eugeniae	a;wh(f)/dm	Oreochromis spilurus
Allolobophora foetida	a;dm	Oncorhynchus keta
Dendrodrilus subrubicundus	a;dm	S. gairdneri
Oligochaeta (aquatic)*		
Tubifex tubifex	a;wh (live)	Anguilla japonica
T. tubifex	a;wh (f)/dm	O. spilurus
T. tubifex	a;wh (live)	Anguilla nebulosa
Lumbricillus rivalis	a;wh (live)	Pleuronectes platessa
Limnodrilus hoffmeisteri	a;wh (live)	Anguilla anguilla
L. cervix/Tubifex	a;wh (live)	A. anguilla

Organism	Form & mode fd.	Fish
Gastropoda (aquatic)		
Scenomelania canalis & Melanoides sp.	a;ch/dm	O.mossambicus

* Organisms which have been cultured in a waste substrate. Table taken from Tacon and Jackson (1985).

on the food chain which would increase protein production for a greater number of people but which have a poor market price.

However, successful feeding trials have been reported on the identification of NCFR to replace the conventional energy source. There is promise in this subject area as most tropical developing countries are agriculture based, producing large amounts of cereal grains which can be used directly (although this would be inefficient use) or whose waste after processing could be used as ingredients.

In considering alternative feed resources, in particular non-conventional feed resources, the following points need to be taken into account:

(i) In the initial stages of developing a fish feed manufacturing industry, it is logical to adopt well-tested and proven formulae designed and developed specifically for salmonids in temperate regions. In the Asian context, the ingredients used may be non-conventional but traditional in Europe or North America. Hence, wheat middlings, corn and other cereal grains have been used in Asian fish feeds and these have to be imported, adding to the costs. It would be beneficial for feed manufacturers and nutritionists to look for replacements for these 'exotic' ingredients from locally available feedstuffs such as cassava or sago starch. A list of available feedstuffs needs to be drawn up in each country to determine which can effectively replace those normally imported items without loss of performance. It would be undesirable to look for ideal replacements which may ultimately increase the total cost, i.e. economic criterion must be included in the consideration.

(ii) Most of the finfish farming industry in Asia is semi-intensive, using pond fertilization and/or supplementary feeds, as opposed to intensive culture of mainly carnivorous species using complete feeds. As such, the thrust of fish nutrition research should be directed towards investigating the relative contributions of natural foods and supplementary feeds. Numerous studies have shown increased production in fertilized ponds with supplementary feeds; presumably there is a critical standing crop (biomass) of phyto- or zooplankton at which fish growth is limited and additional nutrients need to be provided. The NCFR should be looked at in this light, as energy providing feeds which spare the protein-rich natural food organisms for growth.

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By-product Utilization in Live Food Culture for Tropical Aquarium Fish

SHIM KIM FAH

Introduction

ASEAN countries have become the world's greatest producers and exporters of tropical aquarium fishes. A major difficulty faced by this expanding industry is the supply of live food. Live food such as *Moina, Tubifex,* blood worms etc. are required constantly in large quantities for successful breeding of these fish and are also essential for their growth. The large quantity of wastes produced by the pig and poultry industry have been utilized for the culture of these live foods. However, at the present moment, the tropical fish exporting industry is being threatened by a shortage of live foods. This shortage is affecting tropical fish breeding in farms. Although some fish farmers have switched to feeding the fry with dry foods, the results are not as good as when natural food is used. Shim and Bajral (1982) studied the nutritional value of artificial and natural foods for tropical fish and found that *Moina* is a good protein source for the fish fry and *Tubifex* is essential for the brooder fish. Thus there is an urgent need to find out ways and means to produce these live foods in large quantities at a low cost. Since large quantities of food wastes are available in the food factories in Singapore, and Singapore imports a lot of cereal by-products for her animal feed industry, it is quite possible to cultivate live foods using these low-cost materials. Techniques of large-scale production of live foods, principally in Singapore, are described in this report.

Culture of *Moina*

The waterfleas, *Moina* sp. (*Cladocera, Moinae*) are very transparent creatures with thin, flexible and collapsible exoskeletons. The female is the most common sex present and measures approximately 0.4 mm when newly hatched and is about 1.5 mm long when fully grown. The eggs are laid immediately after one moult and the young individuals are ready to be released just before the next moult. At ordinary temperatures, the whole process takes about two days but is speeded up at higher temperatures. It is believed that a shortage of food is the main cause for the production of resting eggs. These eggs cannot develop immediately and they need to be fertilized by the males. Male waterfleas are almost always smaller than females and they are usually shorter lived.

The nutritional value of *Moina* is considered to be high. It contains about 93.5 per cent of moisture and about 6.5 per cent dry matter. On a dry weight basis, *Moina* contains 70 per cent crude protein, 16.4 per cent crude fat, 9.9 per cent ash and about 3.7 per cent nitrogen free extract. *Moina* serves as an effective live food for most of the tropical ornamental fishes. Furthermore, the high calcium content of *Moina* makes it an important diet for the brooder fishes. Calcium is an essential element for the brooder fishes during stages of reproduction.

Very little is known about techniques for the mass cultivation of cladocerans. Large-scale production of *Moina* using pig manure has been described by Shim (1985). The feeding habits of *Moina dubia* and its role in the stabilization of sewage have been studied (Parabrahman, Khan and Lakshminarayana, 1967). Krishnamoorthi (1967) found a large number of *Moina dubia* in the oxidation ponds and they feed voraciously on the algae present in the water which are very rich in organic and nutrient matter. Mass cultivation of *Daphnia magna* has been attempted in ponds (Heisig, 1979) and it has been reared in fish tanks on rice bran (De Pauw, Laureyeys and Moraleds, 1981). Rice bran, wheat bran and soybean meal have also been used for the culture of *Moina* (Lee et al., 1985). It was found that these by-products could successfully support the growth of a *Moina* population. The most suitable pH level of the water for the growth of a *Moina* population was in the range of 5.5-7.5. The pH in most of the tanks, with the exception of those with soybean meal as media, fell below 5.0 and this proved to be very unsuitable for the growth of *Moina* populations.

Culture of Blood worm

Blood worms are larvae of the non-biting midges of the family Chironomidae (Order Diptera, Class Insecta). In Singapore, over fifty species have been recorded (Letha, 1969). Not all the chironomid larvae are red in colour. Surface forms are greenish, others are whitish and only those that contain haemoglobin are red. The chironomid larvae and pupae are highly nutritious and nourishing and constitute one of the staple food items in the ration of many fishes in the natural environment. The importance of chironomid larvae as live food for tropical fish culture is well known in the ASEAN countries. Most carnivorous aquarium fish, such as oscar, discus, Siamese fighting fish and cichlids will devour chironomid larvae when offered. Chironomid larvae have been reported to be very adequate for growth in fishes (Johnson, 1929; Ling, 1966; Yashouv, 1970). It has been found that if carps are provided with blood worms as supplementary food, they gain better weight and the growth rate is more uniform (Yashouv, 1956). Very young blood worms have also been demonstrated to promote efficient growth in *Mugil capito* fry (Yashouv and Ben-Shackar, 1967).

The supplies of blood worms have always been unreliable because their populations show seasonal fluctuations (Letha, 1971). In the past, as long as half a century ago, attempts to propagate the blood worms under laboratory conditions have been carried out in many countries (Salder, 1935; Embody, 1921). The main difficulty was the inability to induce swarming and mating of the chironomid midges in captivity.

Chironomid egg masses contain between 50 to 700 eggs. Under tropical conditions the incubation period varies from 24 to 48 hours. The newly hatched larvae are not more than 1 mm long but they measure up to 10-15 mm when they reach the last stage of the larval period. Each larva moults four times before it reaches the pupal stage. After two days or so they come up to the surface of the water and emerge as adults. The adult chironomid only lives 3 to 5 days and mating and oviposition take place during this period. The adults occur in large numbers in the vicinity of ponds, lakes and streams because eggs are laid in water and the young stages are aquatic.

In Hong Kong, chironomid larvae are grown on chicken manure (Shaw and Mark, 1980). The yield is about 28 g/m^{-2} per week which is much lower than the yield of 250 to 375 g/m^2 per $week^{-1}$ obtained by Yashouv (1970) who grew chironomid larvae on chicken manure in pans within a greenhouse provided with aeration. Horse manure has also been used to fertilize the pool for blood worm culture, but the average yield of the best pools was 11 g/m^{-2} $week^{-1}$ which is only a fraction of the maximum yields obtained from other midge culture systems (McLarney et al., 1974).

To produce blood worms in large quantities the costs must be taken into consideration. Thus by-products from food processing factories are suitable for this purpose. The attempt to rear blood worms with various by-products such as wheat bran, rice bran, soybean meal and coconut refuse have been carried out with satisfactory results (Koh and Shim, 1980; Teo et al., 1985).

Culture of *Tubifex*

Tubifex are small, reddish worms up to 2 cm long, which occur in enormous numbers in the mud at the bottom of ditches and streams. They live with the front end of the body in the mud, foraging deep for food while the posterior end waves ceaselessly above the mud for respiration. Large numbers often congregate into patches when the surface of the mud appears red.

Tubifex worms found in streams have long been regarded by many fish breeders and hobbyists to be the best feed for fish, particularly for faster growth and reproduction. In fact, the present aquarium fish industry in the Republic of Singapore depends very much on the availability of these worms to supply the aquarium fish industries.

With the increasing local demands for *Tubifex* worms and the great potential for export markets, the Primary Production Department has looked into ways to encourage the culture of *Tubifex* worms on a mass production basis in confined spaces. A simple method of *Tubifex* culture has been developed at the Freshwater Fisheries Laboratory in Sembawang (PPD, 1972). The culture beds are made of bricks and concrete and a mixture of pig manure, soil and fine sand of the correct proportion (1:8:1) is needed for use as the medium for culture. A yield of 1 kg/m^2 per month can be obtained in this manner.

Tubifex farmers in Singapore adopt a different method for culturing the worms. The water from the fish ponds are drained to the bottom leaving just sufficient water to cover the mud. Rice bran is spread evenly over the surface and left to ferment. Three days afterward the *Tubifex* worms are inoculated. Care must be taken not to let the pond mud dry completely. After one month the pond can be refilled with water up to 4 to 6 inches above the mud, after which most of the worms will congregate on the mud surface where they can be easily harvested. The cycle can be repeated after three days.

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General Discussion

There was general agreement that the approach to finfish nutrition is similar to that of higher vertebrates and that the finfish nutritionists can avoid the problems encountered and benefit from the experiences of animal nutritionists. However, it was apparent that problems of finfish nutrition are more acute and more difficult to solve in relation to specific objectives. For example, the extent to which a fish could obtain nutrients from natural feed materials occurring in the water (e.g. pond, cage) is difficult to quantify especially in extensive systems, which makes it difficult to define a balanced diet for such systems.

The strategy for feed formulation presented by Dr Devendra was accepted as a useful approach for fish feed formulation and production. The appropriateness of formulation of wholesome diets for finfish culture was highlighted. Initial discussion focused on the need for supplementary feeds.

Although not of direct interest to most of this group, it was recognized that major increases in fish yields can also be obtained by research on techniques to promote natural food production. It was agreed that to a great extent the finfish culture operations in existence in the region now and likely to be in the future depended and will depend on feeds that will act as supplements. In this context, it is essential to separate endogenous feed materials produced in the system and utilized by the cultured fish from the exogenous feeds introduced which are essentially dietary supplements. These interacting components need careful consideration and further research. In other words, it is necessary to aim for the preparation of a complete diet for purposes of finfish culture in the region and establish the mechanisms for such a preparation including delivery systems for the present farmer. This approach also needs to determine the type of supplementary diets needed for particular fish species, utilizing maximum amounts of locally and easily available ingredients which the fish-farmers could themselves prepare.

The question of nutrient leaching of supplementary feeds were also discussed. Some felt that this matter should be given priority, but others felt that leaching enhances the growth of endogenous food material in the culture system. It was agreed that at this juncture, research on leaching is not a priority.

The complete replacement of the fish meal component from fish feeds have not been reported for any fish species. Research should therefore, aim at evaluating the maximum replacement level of the fish meal component using non-conventional feed resources which are extremely diverse, ranging from plant products which are readily available in the region to compost or even microbially enriched cassava. A word of caution was expressed in the use of plants such as water hyacinth in preparing a compost suitable for fish feeds because of the relatively high tendency of this plant to accumulate heavy metals. It was also highlighted that the commodity ('trash fish') is not only becoming increasingly costly but its availability is suspect in most countries in the region. As the trash fish forms the base for fish meal it was thought opportune to investigate other animal wastes/by-products such as shrimp waste, bone meal, etc, as a replacement for the fish meal.

The question of the protein requirements of different fish species also received attention. The view that all non-carnivorous species that have been hitherto studied have a requirement range of 35-50 per cent dietary protein was strongly expressed. It was apparent that the reported protein requirements based on laboratory studies on the same species and even for similar stages of the life-cycle are at times significantly different. Such differences occur due to the differences in the dietary material used and the non-standardization of the techniques used by different researchers. It was agreed that a useful first step would be to summarize the available data for each species reared under specific diets, dietary regimes and experimental conditions.

PART II

Other Addresses

Contributions to Nutritional Aspects of Feeding and Digestion in Fish

T.J. PANDIAN

Abstract

The protein requirement of fish is nearly 2-3 times higher than that of terrestrial vertebrates. A larger body size of fish, *ad libitum* feeding and supplementation of diet with fat reduce the protein requirement of fish. The requirement of herbivorous/omnivorous fish that are usually cultured in Asian countries, is in the range of 25 per cent dry weight of food. It appears that herbivorous fish feed to satisfy their protein requirement, but the carnivores feed to satisfy their energy requirements. The nitrogen content of food holds a positive correlation to absorption efficiency (Ae) in fish; the relation is significantly ($P<0.001$) correlated ($r = >0.9$). Hence the efficiency is predictable from the nitrogen content of food with less than 8 per cent error, using the equation:

$$\log Ae = 1.3706 + 0.5807 \log N$$

Introduction

Fish culture in Asia has been more of an art than a scientific venture. In Asia, we have been traditionally culturing herbivorous/omnivorous fish like carps, tilapias, milkfish and mullets. The nutritional aspects of feeding and digestion in some of these fish are still not completely understood. This paper is a contribution to these aspects of fish nutrition and is based on our previous reviews (Pandian, 1987; Pandian and Vivekanandan, 1985).

Fish are aquatic ectotherms; hence they do not require to expend energy on maintaining the body temperature (Nijkamp et al., 1974) and require relatively less energy for maintenance of position in water (Cowey, 1975). These have lowered the total food energy requirement of fish. On the other hand, ammonia, the primary end-product of nitrogen metabolism of fish, is rapidly and continuously being disposed of by passive diffusion through the gills; consequently fishes derive more metabolizable energy (20.2kJg^{-1} protein) from catabolism of protein than do terrestrial animals (19.7kJg^{-1} protein), which must convert ammonia into urea or uric acid at an additional cost of 88.4 or 177.6kJmol^{-1} respectively (Martin and Blaxter, 1965). Smith and Rumsey (1976) calculated that metabolizable energy available would be 19.5, 15.5 and 13.8kJg^{-1} protein digested in ammonotelic, ureotelic and uricotelic animals. The primary sources of metabolic energy in fish are lipid and protein rather than lipid and carbohydrate, as in other animals. Hence protein acts both as a structural component and as an energy source (Brett and Groves, 1979). These two opposing metabolic trends have led not only to the decrease in food energy intake but also increase in the uptake of protein energy to total energy ratio.

Protein Requirements

A detailed analysis of Love's (1980) summary of the diet of 600 fishes shows that 85 per cent of the species are carnivores, 6 per cent herbivores, 4 per cent omnivores, 3 per cent detritivores, and 2 per cent scavengers and parasites (Pandian and Vivekanandan, 1985). The protein requirement of carnivorous, omnivorous, herbivorous and detritivorous fishes is uniformly high and is in the range of 35-70 per cent dry weight of food (Table 1). The protein requirement of most commonly cultured fish in Asia like the carps, tilapias and milkfish is also in the range of 35-54 per cent.

While the idea of higher protein requirement is an established fact, the very high values reported by most workers appear questionable for one or more of the following considerations: firstly, instead of feeding the fish to satiation, most workers have arbitrarily restricted the feeding rate to a ration of mostly between 2 and 10 per cent body weight d^{-1} (Table 1). A fixed feeding regimen is known to affect the dietary protein requirement. Thus, Ogino (1980) reported a decrease in the dietary protein requirement of juvenile carp and rainbow trout from 60-65 per cent to 30-32 per cent when the feeding rate was increased from 2 to 4 per cent body weight d^{-1} (Fig. 1). In view of

Table 1: Protein requirements of some fishes (adopted from Pandian 1987).

Species	Mid body wt. (g)	Food	Feeding rate (% body wtd^{-1})	Protein require-ments (% dry wt. food)
Carnivores				
Anguilla japonica	4.4	Caesin	ad lib	45
A. anguilla	—	—	—	62
Channa micropeltes	21	Fish meal	1.8	52
Chrysophrys aurata	8.9	Caesin/amino a.	3.3	38
Chrysophrys major	—	—	—	55
Fugu rubripes	3.2	Caesin	3.2	47
Morone saxatilia	6.0	Fish/soy meal ad lib	2.8	55
Oncorhynchus tshawytscha	—	—	—	48
Pleuronectes platessa	22.3	Cod muscle ad lib	1.8	50
Salmo gairdneri	12.6	Caesin/gelatin	1.7	43
S. salar	—	—	—	40
Salvelinus alpinus	—	Fish meal	—	40
Seriola quinqueradiata	—	—	—	55
Omnivores				
Cyprinus carpio	13.6	Fish meal	2.9	54
Ictalurus punctatus	—	—	—	40
Micropterus salmoides	3.5	Fish/gelatin/ amino acids	2.9	40
M. dolomieui	3.6	Fish/gelatin/ amino acids	2.4	45
Tilapia aureus	4.4	Fish/soy meal	3.5	36
Herbivores				
Chanos chanos	0.11	Caesin	8.2	39
Ctenopharyngodon idella	0.34	Caesin		42
Tilapia mossambicus	5.1	Fish meal	4.7	42
T. niloticus	0.31	Fish meal	6.4	35
T. zilli	2.6	Caesin	3.6	35
Detrivores				
Mugil auratus	0.5	Mixed diet	6.0	70
M. capito	3.0	Mixed diet	—	70

the above relationship between feeding rates and protein requirement, and the arbitrary manner in which feeding rates and frequencies were set by most workers, one may question the very high level of protein requirement observed for the omnivorous *Ctenopharngodon idella* fry, which is ascribable to the lowest feeding frequency, arbitrarily fixed by Dabrowski (1977).

Secondly, almost all the researchers have chosen young individuals to estimate the protein requirement of fish or the obligate requirement of animal food in herbivorous/omnivorous fish. Of 25 species, for which protein requirement has been estimated (Table 1), the mean of mid-body weights of 13 species is 2.8 g (range: 0.1 to 6.0 g) and that for another 3 species is 17.5 g (range: 8.9 to 22.3 g). The protein requirement of tilapias is shown to decrease from 35-50 per cent in an individual weighing < 1 g to 23 per cent in that weighing > 50 g (Table 2), (also see Page and Andrews, 1973). Interestingly, De Silva et al. (1984) recorded the protein content of the natural food of adult *Oreochromis mossambicus* as 24.5 per cent. In addition, fish are known to change their feeding habits with growth and development (e.g. *Lagondon rhomboides*; Adams, 1976). Therefore, detailed studies on protein requirements in relation to growth are urgently required for carps, tilapias, milkfish and mullet, which are some of the leading candidates for aquaculture in Asia.

Thirdly, addition of lipids, capable of satisfying the essential fatty acid requirements of a fish results in protein sparing. Reductions in dietary protein requirement of fish owing to the protein sparing action of lipids in carnivores and both lipids and carbohydrates in omnivores have been demonstrated (Watanabe, 1982; Table 3). The energy density of the feeds tested for dietary protein requirements averages to 18.3 ± 1.43 (range: 15.6 to 20.8kJg^{-1} feed) and indicates the presence of a low percentage of lipid in the feed.

The observations of Yurkowski and Tabachek (1979) imply that the natural food organisms of *S. gairdneri* are capable of sparing protein from metabolic expense and reducing the dietary protein requirement of this carnivorous fish to 35 per cent as it happens to *S. gairdneri* fed on lipid rich synthetic diet (Watanabe et al., 1979). Similar studies are desirable for tropical species.

Table 2: Body weight and protein requirements of tilapia (adopted from Pandian 1987).

Species/ Wt. range	Body weight (g)	Protein requirement (% dry wt. of food)
Range 0-19		
T. mossambicus	0.5	35-50
T. aureus	0.3-0.5	36
T. niloticus	0.3-0.8	35-40
Range 1-59		
T. zillii	1.7	30-35
T. mossambicus	1-3	29-38
T. zillii	3-5	32-40
T. mossambicus	1-10	37-42
Range 5-25g		
T. niloticus	9	25-30
T. hornorum	14.5	25-30
T. aureus	21	26-36
T. mossambicus	10-30	25-30
>25 g		
T. mossambicus	25-40	20-25
T. niloticus	50-70	20-25
Tilapia	50-300	23

Table 3: Protein sparing action of dietary lipid and carbohydrate fish (adopted from Pandian, 1987).

Species	Changes in diet composition (% dry wt.) Pro. : Fat : Car.	Estimated reduct. in protein reqmt. (% dry wt.)
Salmo gairdneri	49 : 5 : 30	−18
	36 : 15 : 30	
Seriocola quinqueradiata	71 : 8 : 0	−19
	55 : 17 : 0	
Octalurus punctatus	40 : 18 : 5	−17
	36 : 32 : 15	
Cyprinus carpio	42 : 6 : 25	−15
	32 : 5 : 45	
O. carpio	42 : 6 : 25	−30
	32 : 30 : 15	

Calorie Counting

Excellent studies have been undertaken to test whether fishes fed to satisfy their energy or protein requirements. Fishes like *Carassius auratus* and *S. gairdneri* increased the frequency of actuation and overate to approximately compensate the level of kaolin dilution in the synthetic diet, when they were allowed to feed on the diet containing different concentrations of kaolin in a demand feeder system (Razin and Mayer, 1961; Grove et al., 1978; see Table 4). This observation has also been confirmed by the findings of Bromley and Adkins (1984) on *S. gairdneri;* Bromley and Adkins reported compensation of not only the feeding rate but also the energy intake. *S. gairdneri* and other fish, which feed by "counting the calorie", can tolerate dilution of the synthetic or natural diet by cellulose or kaolin only to a maximum of 30-33 per cent.

Table 4: Effect of energy density and kaolin dilution of food on demand feeding rate of Salmo gairdneri (60 g) at 18C (Grove et al., 1978; modified). Absorption rate was calculated considering 90% absorption efficiency for diet component of the diet kJg^{-1} dry wt.; b-times fish^{-1}d^{-1}; c– % body wt. day^{-1}; d-Jg^{-1}day^{-1}; e-Jgday^{-1}).

Test food	Energy density (a)	Actuation frequency (b)	Feeding rate (c)	Feeding rate (d)	Absorption rate (e)
Salmon pellet	20.1	26	2.8	55.9	50.3
75% diet + 25% kaolin	17.6	40	4.7	82.3	55.5
67% diet + 33% kaolin	13.6	52	5.9	79.8	48.1
50% diet + 50% kaolin	9.2	48	6.4	59.2	26.6

Incidentally, in the voluntary feeding system of Bromley and Adkins (1984), *S. gairdneri* also maintained a constant protein feeding rate of about 3.4±0.2mgNfish^{-1}d^{-1}. This incidental observation poses the question, whether the fish feeds to satisfy its energy or protein requirement. Statistical analysis described in Table 5 suggests that the dietary protein level may determine the feeding rate of herbivores but not carnivores (also see Jobling, 1981).

The feeding rate of several herbivores and omnivores are known to decrease with increasing protein content in the food.

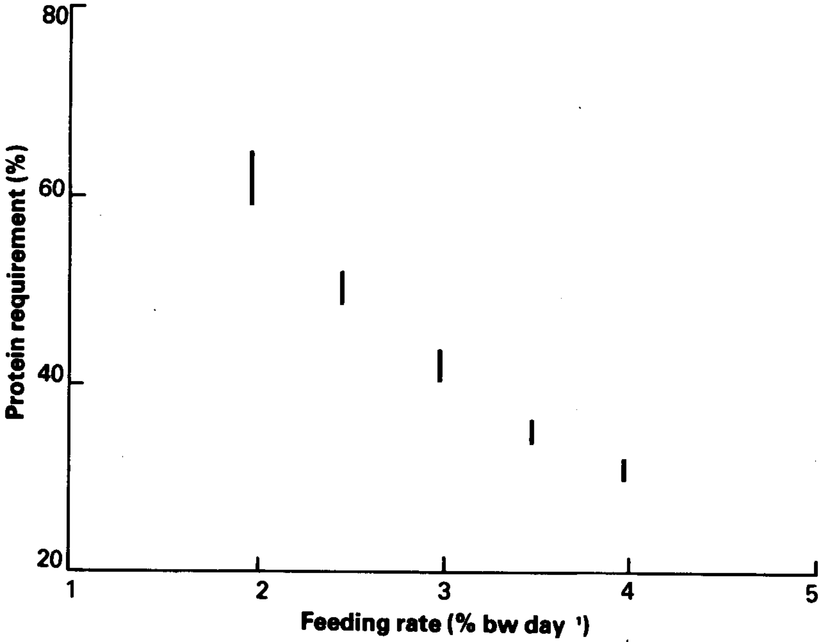

Fig. 1: Relationship between Feeding Rate and the Dietary Crude Protein level needed to satisfy the protein requirement of common carp and rainbow trout (12-13 g protein per kilogram body weight per day; Ogino, 1980). Each vertical line represents the combined limits of protein requirement for both species at each feeding level.

Fischer (1970) observed that the feeding rate of *C. idella* is 7 or 16 per cent body wtd^{-1}, when fed exclusively on animal or plant feed. Similar observations have also been reported for omnivores like *Rutilus rutilus* (Hofer et al., 1982, 1985). Shireman et al. (1978) observed a feeding rate of 5.4, 7.6, 8.5 and 12.9 per cent body wt d^{-1}, when fed catfish chow (31 per cent protein), duckweed, catfish chow-ryegrass (22 per cent protein) and ryegrass (12 per cent protein), respectively. The data of Shireman et al. offer scope to test whether *C. idella* feeds to satisfy its protein or energy requirement. Statistical analyses show that the feeding rate of *C. idella* is more significantly correlated with the protein rather than the energy content of food:

Protein content of the feed vs feeding rate:

$$3 \text{ g} : Y = 2645.75 + 50.55 \text{ protein } (r = 0.978)$$
$$63 \text{ g} : Y = 1620.69 - 29.616 \text{ protein } (r = 0.977)$$

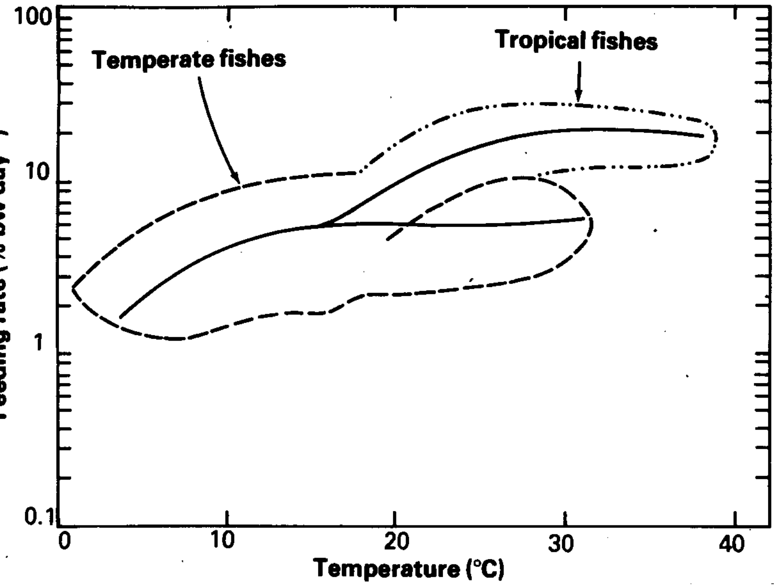

Fig. 2: Relationship between temperature and feeding rate of fish from temperate and tropical zones. Dotted lines indicate general range of variability within each zone (from Pandian and Vivekanandan, 1985).

Energy content of the feed vs feeding rate:

3 g : Y = 4906.98 − 244.10 energy (r = 0.914)
63 g : Y = 2691.47 − 125.23 energy (r = 0.815)

With the available information, it may be tentatively concluded that carnivorous fishes feed to satisfy their energy requirement but the herbivores feed to satisfy their protein requirement.

Whereas the protein requirement of herbivorous fishes like *O. mossambicus* is about 25-30 per cent (Table 2), the protein content of their natural food is only in the range of 24.5±2.8 per cent (De Silva et al., 1984). Hence, herbivores economize their protein expenses by (i) reabsorbing digestive enzymes and (ii) reducing protein metabolism. The herbivores, especially those with relatively long intestines, reabsorb over 90 per cent of the digestive enzymes, as against 40 per cent observed for carnivores (Hofer and Schiemer, 1981). The fraction of food nitrogen lost as ammonia is in the range of 3-5 per cent for herbivores (Caulton, 1978a; Hofer et al., 1985), which is less than half of that (7±3 per cent) reported for carnivores (Brett and Groves, 1979).

Feeding Rate of Fishes

Temperature has an important effect on the food intake of fish belonging to different climatic zones. Data provided by a number of authors for temperate fish (32 species inhabiting the area between 70°N and 27°N) and tropical fish (12 species in areas between 21°N and 7°N) are plotted semi-logarithmically in Fig. 2. The feeding rate of temperate species ranged from 1.8 to 17.3 per cent body wtday^{-1} (mean 5.9 per cent) and that of tropical species from 4.1 to 36.0 per cent (mean, 16.7 per cent).

The feeding rate for the tropical fish is therefore about 180 per cent greater than the mean value for the temperate species. Brett and Groves (1979) showed that tropical fish operate at a higher maintenance level in accordance with the higher environmental temperatures. The tropical fish incur an energy expenditure of 2.1kJkg^{-1}h^{-1}. The present finding suggests that temperature elevates not only the maintenance level but also the feeding rate in tropical fish. However, the elevation in feeding rate (180 per cent) is nearly 2.5 times greater than that (70 per cent) observed for the maintenance metabolism. Clearly, a considerable fraction of the 110 per cent difference may contribute to faster, if not more efficient, growth; a characteristic of tropical fish (also see Table 5).

Digestion & Absorption

As most aquaculturally important Asian fish are herbivores or omnivores, it is useful to have an idea of the physiology of digestion and absorption. The consistent presence of intestinal micro-flora to degrade complex algal polysaccharides has so far not been demonstrated (Trust and Sparrow, 1974; Prejs and Blaszczyk, 1977). In the total absence of cellulase, the cellulose-containing cell wall is known to be broken by one of many mechanisms. In general, browsers like the cichlids and channids use the chemical mechanism and hence avoid ingesting inorganic material, especially coral. Grazers like mugilids and acanthurids pick up large quantities of sand or coral, while feeding by rasping, sucking and/or biting into substrate; particulate calcium aids these fishes in food trituration.

A simple, widely applicable method of estimating absorption efficiency will greatly help to economize the feed cost in aquacultural programmes. In many developing Asian countries, such economic measure will greatly reduce the production cost of fish. Absorption is measured as the differences between ingestion and egestion. Absorption efficiency (Ae) is an index of the proportion of food that is transferred from the gut lumen into the body of the animal. Faeces is the non-absorbed fraction of food (true faeces), which consists of settable, suspended and dissolved components, as well as the metabolic residue of body origin like mucous cells, digestive enzymes, other secretions and micro-flora (Cho et al., 1982). A majority of workers have estimated the settable and suspended faeces, which partly include a large part of the residues, by filtering the entire aquarium water to retain all faecal particles down to 1 (e.g. Pandian, 1967; Elliott, 1976). An estimation of dissolved component of faeces of *S. trutta* by subjecting the aquarium water to COD analysis indicated that the dissolved faeces may contribute 1.4 per cent of total faeces (Elliott, 1976). The metabolic residues are usually small about 0.3 per cent of the consumed food (see Pandian, 1967), which is approximately equivalent to about 5 per cent of faeces (assuming 85 per cent absorption efficiency, Winberg, 1956). As the errors, namely the addition of metabolic residues to the particulate faeces, and the loss of dissolved faeces, nullify each other, the faecal values reported by the majority of workers may hold good and be precise.

On being voided, the semi-solid faecal pellets: (i) lose material immediately, and (ii) may undergo decomposition; for instance, *Stenobrachius leucopsarus* loses 46 per cent of faecal matter due to decomposition at 21.5°C within a period of 16 days (Robinson and Bailey, 1981). Some fishes eat their own faeces (e.g. *O. mossambicus*; Narayanan, 1981); hence the recovery of faeces in a given experimental situation may not be complete. The very process of collection of faeces is also cumbersome and time-consuming. The difficulties involved in the processes of recovery and collection of faeces have apparently led several workers to resort to indirect procedures to estimate faecal output and absorption efficiency. Table 6 summarizes the advantages and

Table 5: Some parameters that determine food consumption in fishes. For each species the range, the mean and the cv are given in order. Comments are based on cv values.

Species weight	Food			Feeding rate (Cr) (Jg^{-1} day^{-1})	Comments
	Energy (%)	Protein (%)	PE : TE ratio		
Scopthalmus	7.8-13.2	35	0.50-0.85	1528-2451	Energy density
maximas	10.8	35	0.63	2093	determines Cr
24.5 ± 1.6g	16.7	0	18.4	19.4	
Salvelinus	18.4-19.1	27.6-43.6	0.28-0.44	446-466	Energy density
alpinus	18.8	35.7	0.36	449	determines Cr
35.5 ± 2.94g	1.5	18.0	19.0	449	
10C					
Salmo gairdneri					
144 ± 21g	18.5-19.5	43.0-46.0	0.42-0.47	356-378	Protein density
					determines Cr
	Expt. 1				
	19.0	44.0	0.44	367	
	5.3	2.0	4.7	3	
	18.5-27.5	43.0	0.29-0.47	356-400	

Table 5 (continued)

Species weight	Food			Feeding rate (Cr) (Jg^{-1} day^{-1})	Comments
	Energy (%)	Protein (%)	PE : TE ratio		
	Expt. 2				
	20.7	44.0	0.41	373	
	18.4	2.8	17.1	5	
Salmo	18.5-20.6	33.0-66.0	0.33-0.61	448-693	Protein density
gairdneri	19.5	49.0	0.47	587	determines Cr
20 ± 3g	4.1	25.0	22.0	15	
Ictalurus	14.6	15-65	0.19-0.84	383-514	Protein density
punctatus	14.6	40	0.52	468	determines Cr
	0.0	47	47.0	11	
Ctenopharyngodon					
idella	16.3-17.8	12-36	0.14-0.36	960-2100	Protein density
3g	16.9	25.5	0.27	1435	determines Cr
	4.7	42	38.0	34	
63g	16.3-17.8	12-36	0.14-0.36	690-1270	Protein density
	16.9	25.5	0.27	900	determines Cr
	4.7	42	38.0	30	
Tilapia					
mossambicus	13.5-15.7	8.7-57.3	0.12-0.69	65-1335	
4 ± 0.99 g	14.7	33.5	0.42	319	
27C	5.5	52.5	49.0	145	

Table 6: Methods used for estimation of absorption efficiency in fishes. {(+) – faeces recovery required; (–) faeces recovery not required modified after Pandian and Marian, 1985a)}

Method	Required estimates	Comments
Gravimetric	(+)	Time consuming but most often used procedure
Artificial markers		
Chromic oxide	(–)	Requires even distribution; tested usually in dry pelleted diet; hence has limited applicability
Radiotracer		
14_c	(–) food and faeces analysed	Time-consuming procedure; requires uniform distribution of 14_c in the diet; reliable only when 15% labelled algae
51_{cr}	(–) food and faeces analysed	Not yet tested in fishes
Natural markers		
Colour of the food	(+)	Very limited application
Lignin	(–) stripped for faeces food & faeces analysed	Application restricted to herbivores eating lignin-containing food
Indigestible	(–) stripped for faeces; food and faeces analysed	Application restricted to diets containing crude fibre
Ash	(–) ash estmn. from food and voided faeces	Applicable to all fishes but of questionable reliability
Nitrogen	(–) food alone analysed	Applicable to all fish

limitations of available methods of absorption efficiency in fishes. Of the marker substances listed, chromic oxide and ash require a brief discussion.

Chromic oxide is insoluble in water and hence has been successfully employed to determine absorption efficiency of fishes (e.g. Windell et al., 1978); when used as a marker, chromic oxide, however, must be evenly distributed throughout the food, usually in a dry pelleted diet. Thus, the use of chromic oxide as a marker of absorption efficiency has limited applicability, and it is not surprising to note that chromic oxide has been successfully used only by those who have experimentally fed the fish with a synthetic dry pelleted diet (e.g. Austreng, 1978). As the rates of passage of chromic oxide and experimental food in the digestive tract differ (Bowen, 1979), the use of chromic oxide in herbivores/detritivores, in which it is indeed difficult to estimate absorption efficiency, is questionable; there are arguments for (Foltz, 1979) and against (Bowen, 1979) the applicability of chromic oxide as a marker of absorption efficiency in fishes. Secondly, stripping, a method adopted for faeces collection, is known to significantly contaminate faeces with urine; (protein) absorption efficiency values arrived at following faeces stripping are usually underestimated by 10 per cent. Recently, Buddington (1980) and De Silva and Perera (1983) have compared the accuracy of the results obtained using different marker methods and concluded that hydrolysis-

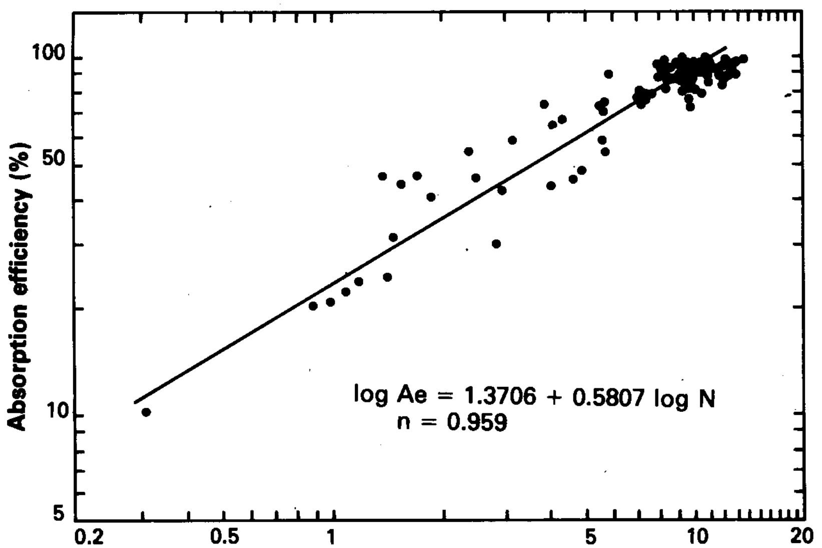

Fig. 3: Regression shows the relationship between the nitrogen content of food and absorption efficiency fishes (from Pandian and Marian, 1985a).

resistant organic matter (HROM; chiefly cellulose and chitin) is a better reference market than chromic oxide, crude fibre (CF) and hydrolysis-resistant ash (HRA). However, they have not made simultaneous estimates of the efficiency following the direct gravimetric procedure in order to establish the extent of reliability of HROM as a reference marker.

Following Conover (1966), ash has been used as a reference marker by several authors (e.g. Bowen, 1981). In his original experiments, Conover assumed that the ash content of the food, largely silicious diatom tests, would not be affected by the passage through the gut of the feeding animal. Evidence for ash absorption have been presented by Buddington (1980), Montgomery and Gerking (1980) for fish (see also Vivekanandan and Pandian, 1976). Application of correction factors to this source of error has been suggested (Johannes and Satomi, 1967; Pavlyutin, 1970). However, it complicates the ease with which Conover's original ash ratio method is applied. Comparing ash with HROM as a reference index of the efficiency, Buddington (1980) and De Silva and Perera (1983) have shown that HROM may be regarded as a more accurate index. Following gravimetric and ash ratio methods, Lobel and Ogden (1981) made simultaneous estimates of the efficiency of the corallivorous fish *Sparisoma radians* and concluded that the ash ratio method is not a reliable one, as the efficiency values obtained were 68 per cent for the ash ratio method and 12 per cent for the gravimetric method.

Pandian and Marian (1985a) considered nitrogen, a non-inert moiety of the food, as a possible index of absorption efficiency. From over 100 values reported for about 50 fish species, it has been observed 'that the nitrogen content of food holds a positive correlation to absorption efficiency; the relation is significantly ($P < 0.001$) correlated ($r = 0.9$; Fig.3). Hence absorption efficiency (Ae) of fishes is predictable from the nitrogen content of food with less than 8 per cent error, using the equation:

$$\log Ae = 1.3706 + 0.5907 \log N.$$

The fact that food nitrogen can also be used as a predictor of absorption efficiency in reptiles, aquatic insects, polychaetes and amphibians (Pandian and Marian, 1985b, c, d, e) indicates the scope for this indirect procedure is wider and greater.

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Non-conventional Feed Resources in Aquaculture: An Overview of Work Done in the Philippines

JULIA B. PANTASTICO

Introduction

As the pressure to produce more fish protein for the hungry people of Southeast Asia accelerates, tapping of non-conventional feed resources (NCFR) becomes more urgent. Fish farmers in the Philippines have become more innovative and resourceful in utilizing whatever agricultural by-products are available in their particular location. Their primary objectives are to hasten fish growth and increase production while at the same time reducing feed cost. For those reasons, there is a need to conduct studies that would provide a scientific basis for the utilization of NCFR. Among the priority problem areas are: screening of more leaf proteins, finding ways and means of improving the quality of NCFR, developing pond management techniques to optimize use of NCFR, and feeding experiments on the acceptability of NCFR for different fish species.

This paper attempts to review the experimental results on NCFR obtained thus far in Southeast Asia with emphasis on work done in the Philippines. The topic shall be confined mostly to utilization of plant materials especially leaf proteins including single-cell-protein (SCP) sources of algal origin.

Single-cell Protein (SCP) as NCFR

SCP production has become very attractive since the 1950's because of the high theoretical yield per unit area compared to conventional agricultural produce (Table 1). Note that mass

Table 1: Gross and net organic production of various natural and cultivated systems in g dry weight produced $m^{-2}day^{-1}$ (from Ryther, 1959).

	Theoretical gross	Potential net
Average radiation (200-400 g cal cm^{-2} day^{-1})	23-32	8-19
Maximum radiation (750 g cal cm^{-2} day^{-1})	38	27
	B. Mass Outdoor *Chlorella* culture	
Mean		12.4
Maximum		28.0
	C. Land (Maximum for entire growing seasons	
Sugar cane		18.4
Rice		9.1

production of *Chlorella* exceeded the mean and maximum theoretical potential based on the amount of solar radiation available for photosynthesis. Heden (1969) also gave a very optimistic view about SCP production when he computed that unit capital investment is improved five fold by microalgal pond production compared with rice. However, these predictions were not realized for lack of appropriate technologies for harvesting algal biomass. There were three methods of harvesting proposed to solve the problem at a workshop held in Singapore (IDRC 1980).

For growing fish to marketable size, the technology of SCP production has been modified and this is being referred to as "effluent aquaculture" (Walrath and Netter, 1976). In Thailand, microalgal pond production is integrated with recycling domestic sewage and agriculture (Edwards et al., 1981). Problems arise because of the quality of the harvested fish which may not meet the WHO standards for human consumption.

Species Used

Algal SCP used in aquaculture has expanded to no less than 40 species (De Pauw, 1981). In the People's Republic of China, India, Taiwan and the Philippines, there is widespread use of freshwater and brackishwater species of selected phytoplankton for larval rearing. Among them are *Spirulina platensis, Navicula* *notha, Oscillatoria quadripunctulata, Chroococcus dispersus* as larval feed for freshwater species (Pantastico et al., 1985, 1986a, b), *Nitzchia closterium, Chaetoceros* sp., *Skeletonema costatum* etc. for larval rearing of *P. monodon* from zoea to postlarval stages (SEAFDEC, AQD Annual Rept. 1978).

Some have been evaluated as "poor" species because of the production of toxic metabolites and the presence of thick cell walls (De Pauw, 1981). In other cases, the presence or absence of enzyme systems in the fish itself may determine the effectiveness of selected live food organisms for specific kinds of fish (Moriarity, 1973).

Production Schemes

For hatchery/nursery operations, there is the need for a controlled culture system to produce specific algae. This is a very tedious process requiring high capital investment. However, successful larval rearing may depend on the presence of suitable species as natural feed. In the case of prawn (*Penaeus mondon*), a controlled laboratory for natural food production is included in the hatchery set-up. Another system involves the enrichment method using organic and inorganic fertilizers to induce "blooms" of naturally occurring algae (De Pauw and Leenheer, 1979). Here, a mixture of species grows, some of which may not be desirable for larval rearing.

Several designs have been developed in the 1960's in the USA (Oswald and Golueke, 1968) for the large-scale production of microalgae for harvesting. This so-called High-Rate-Algal-Pond (HRAP) underwent major improvements (Moraine et al., 1979; Dodd, 1980). There is still no satisfactory design that would be efficient and economical to use under tropical conditions.

Proximate Composition

The nutritive value of *Chlorella* and *Scenedesmus*, the two genera being almost synonymous with SCP, is well documented. The protein content can be as high as 65 per cent with the component amino acids comparable to that of higher plants (Endo and Shirota, 1972; Lubitz, 1963). However, the level of methionine is lower than in soybean meal (Combs, 1952). Digestibility of *Chlorella* for humans ranged from 75-89 per cent (Takechi, 1971).

A summary table on the proximate analysis of some promising SCP, consisting primarily of freshwater algae, is presented in Table 2. In general, chemical analyses are incomplete except for well-known species. A more comprehensive study is urgently needed to provide baseline information in feeding experiments involving SCP.

Based on available data summarized in Table 2, it should be noted that SCP's are generally higher in crude protein than soybean meal (up to 40 per cent) and remarkably high in vitamins, especially β-carotene, thiamine and riboflavin. However, the net protein utilization, digestibility coefficient and biological value as well as the protein efficiency ratio are generally lower than in casein (Becker, 1981). *Chlorella* and *Scenedesmus* are high in crude fibre which affects their digestibility. In contrast, *Spirulina* has a crude fibre content lower than that of soybean meal (5-10 per cent).

The total digestible nutrients of four major groups of algae was computed for milkfish which showed that the green algae, primarily *Chaetomorpha*, has the lowest value when in its fresh form (Tang and Hwang, 1975). The authors concluded that the filamentous blue-green algae and diatoms are the best food for milkfish.

Feeding Experiments

Finfishes

Several experiments were conducted by the author and co-workers on the acceptability of microalgae and zooplankton for larval rearing of milkfish, tilapia and Chinese carps (bighead, silver). Acceptability was evaluated based on growth, survival and assimilation rate studies using C^{14}-labelled algae. The more salient findings are as follows:

(a) For tilapia (*O. niloticus*) fry, the diatom *Navicula* and blue-green algae *Chroococcus* were most acceptable (Pantastico et al., 1985). Increasing amounts of these species were assimilated as the tilapia fry grew to fingerling stage. On the other hand, feeding with *Euglena* and *Chlorella* resulted in very low growth increments and poor survival.

(b) Milkfish fry were fed with unialgal cultures of five species of freshwater algae: *Navicula, Oscillatoria, Euglena, Chlorella* and *Chroococcus* (Pantastico et al., 1968a). Continuous

Table 2: Summary of Chemical Composition of Some Single-Cell Protein Sources.

Medium	CP	Amino Acid Assay of Dried *Chlorella*[a]	
		Nutrient	Pilot Sample (%)
Chlorella			
Sterilized molasses[b]	23.8	Arginine	2.06
Sterilized rice hull[b]	45.6	Histidine	0.62
Sterilized rice straw[b]	36.9	Isoleucine	1.75
Hog manure[c]	23.83	Leucine	3.79
Chicken manure[c]	19.02	Lysine	2.06
Carabao manure[c]	18.25	Methionine	0.36
		Phenylalanine	1.81
		Threonine	2.12
		Tryptophan	0.80
		Valine	2.47

Spirulina etc.	CP	CC	CF	TL
S.platensis[d]	56 – 71	10 – 18	3 – 8	9 – 14
S.maxima[d]	60 – 71	8 – 13	1	4
Scenedesmus[f]	50 – 55	10 – 15	5 – 12	8 – 12}
Chlorella[f]	40 – 55	10 – 15	5 – 10	10 – 15}

(CP — % crude protein; CC — % carbohydrate; CF — % crude fibre; TL — % total lipids; all expressed as % of dry weight; a — Combs, 1952; b — Zafaralla et al., 1981; c — Martinez et al., 1981; d — Paoletti et al. 1980; e — Durand–Chastel, 1980; f — Becker, 1981.)

feeding with *Oscillatoria* gave the highest weight and survival of milkfish fry. Increasing concentrations of *Oscillatoria* in the rearing medium enhanced the growth of milkfish fry. Assimilation rate studies with C^{14}-labelled algae supported the data on growth and survival.

(c) Larval rearing of silver carp showed that the cyanophyte, *Spirulina*, was the best live food organism compared to *Oscillatoria* and *Anabaena* (Pantastico et al., 1968b). However, highest survival was attained when fry were fed with *Oscillatoria*.

(d) Mixed feeding of bighead carp (*Aristichthys nobilis*) fry consisting of zooplankton (*Brachionus, Monia*) and phytoplankton (*Oscillatoria*) proved better than feeding with monospecific cultures of live food organism (Baldia et al., 1985). Based on assimilation rate data, both zooplankton and phytoplankton were acceptable. However, acceptability of phytoplankton occurred at a later stage, i.e. eight days after hatching.

In actual nursery operations of the above species, ponds are fertilized with organic manure, inorganic fertilizers and some land vegetation (weeds, vegetable wastes) to provide nutrients for growth of microalgae and zooplankton. For carp postlarvae, it has been observed that natural food in the ponds gets exhausted so that continued manuring as well as supplemental feeding becomes necessary (Jhingran and Pullin, 1985).

Leaf Proteins and Aquatic Weeds as NCFR

Feeding Experiments

Utilization of the fast growing, giant ipil-ipil tree has been the subject of much research and development efforts. In agriculture, its value in feed formulations to reduce cost has been proven. More recently, this plant has also attracted attention as a potential feed for fish farming. The high protein content of ipil-ipil leaves (up to 26 per cent) could very well substitute for the more expensive animal protein in fish feeds.

Feeding trials conducted by Filipino researchers took into consideration the reported mimosine content of IILM (Camacho and Dureza, 1977). Treated and untreated leaf meals were incorporated in pelletized feeds for *O. mossambicus*. The treatments consisted of drying the leaf meal, then heating for two hours at 80°C or soaking in ferrous sulphate solution for one week. Results showed that growth, feed conversion and survival of the fish in aquaria were not significantly different among the treated lots and the control. These results together with that on other leaf proteins experimented on are summarised in Table 3. The proximate composition of some of the leaf protein used in nutritional studies are given in Table 4.

The value of *Azolla* as NCFR in aquaculture is still being studied. Results of Almazan et al. (1986) on Nile tilapia fingerlings with increasing dried *Azolla* incorporated in to the diets showed poor growth and FCR. On the other hand, Pantastico et al., (1986c) obtained contradictory results in their cage culture experiments on Nile tilapia with supplemental feeding of *Azolla*.

Floating, submerged or emergent weeds are very much utilized by different fish species in the aquatic environment (Nat'l Acad. Sci 1976). Among these are *Hydrilla, Chara, Elodea canadensis, Potamogeton* spp. and other submerged weeds which have been shown acceptable to grass carp and tilapia. A high FCR of 4.5 (dry weight basis) was reported when *Hydrodictyon* sp. and *Cladophora* sp. were fed to *Tilapia guineensis* at 4.8 per cent of fish body weight (Philippart et al., 1979). On the other hand, feeding with *Lemna minor* gave an FCR of 33 although growth was highest in this type of aquatic weed compared to that of *Hydrilla* or *Chara* (Rifai, 1979).

Proximate Analysis of Leaf Meal and Aquatic Weeds

Leaf meals are the cheapest sources of proteins that may well alleviate the feed shortage problem in the aquaculture industry. In the Philippines, extractability of proteins from different plant sources were conducted by various workers (Reyes and Madamba, 1982). The leaf protein concentrates which are highly digestible since they no longer contain fibrous materials may be used as fish meal supplements.

Investigations on the protein quality of leaf meals show that amino acid composition of unfractioned or whole leaf proteins from different species is similar and this is not affected by age of plant or fertilizer treatment (Reyes and Madamba, 1982). The protein scores of the isolate proteins are comparable to those of standard proteins. However, it is low in methionine, similar to the SCP *Chlorella*, but high in lysine (Table 5). Leaf protein concentrates (LPC) contained more lysine that the lysine-corn and more methionine than soybean protein which makes LPC comparable to animal protein. Extracted proteins also contain high amounts of carotene, Vitamin E and K and unsaturated fatty acids.

The amount of minerals in aquatic plants varies from 8-60 per cent (dry weight) coming from sand, silt and encrusted insoluble carbonates from the water (Nat'l Acad. Sci. 1976). Although sand and silt can be washed off from the plant, they form part of the total harvest. P, Mg, Na, S, Mn, Cu and Zn in aquatic weeds are generally similar to terrestrial plants. However, aquatic weeds are richer in Fe, Ca, and K than land forages.

Table 3: Summary of findings on the utilization of leaf proteins and other NCFR in Aquaculture.

Type of NCFR/ Experiments	Results	Experimental Unit	Workers
Ipil-ipil (Leucaena leucocephala) leaf meal, IILM.			
Tilapia (T.mossambica) fed with a) pellets containing IILM heated to 80°C or soaked in ferrous sulphate solution for one week to remove mimosine, or b) control pellet, i.e. IILM not heated or soaked.	Growth, feed conversion and survival not significantly different in control and treated lots.	ponds	Camacho & Dureza, 1977
T.nilotica fed with finely ground IILM at 3, 6 and 9% of fish biomass.	Increasing amounts of feed proportionately increased growth rate and protein content of tilapia.	aquaria	Pantastico & Baldia, 1979
IILM fed at 25% and 50% of daily ration to tilapia.	Weight gain highest at 25% while least cost of feed/ gain in weight obtained at 50% level.	aquaria	Cruz, 1982
IILM given at 33%, 66%, and 100% of the daily ration. Control fed rice bran alone.	Nile tilapia showed faster growth with increasing levels of IILM in the feed compared to the control.	Cages Laguna Lake	Pantastico & Baldia, 1980

Sexually mature Nile tilapia given test diets with or without IILM.	Mature breeders lost weight, showed significantly low GSI and low fry production with IILM.	aquaria	Santiago et al., 1983b
Breeders given isonitrogenous diets containing 0, 20, 40 and 50% IILM.	Male and female tilapia lost weight as dietary IILM increased it 40%. At 80%. IILM, fry production was significantly low.		Santiago et al., 1983b
IILM incorporated at 12.5% and 18.8% of the ration to T.nilotica fingerling	IILM did not affect growth but gave low survival compared to soybean meal.	aquaria	Santiago et al., 1983b
Gabi (Colocasia esculenta) leaf meal, GLM			
GLM pellets given at 25% and 50% levels.	Nile tilapia showed high feed conversion efficiency and weight gain with GLM feeding. Optimum level was 25%.	cages	Cruz & Fabian, 1980.
Mulberry (Morus sp) leaf meal, MLM			
Fourteen different rations containing rice bran, copra meal, sorghum cracked rice, IILM, MLM, soybean meal and fish meal given to Nile tilapia.	Incorporation of MLM up to 23% of the ration did not improve weight gain and feed conversion.	aquaria	Cruz & Laudencia, 1978.

Table 3 (continued)

Varying combination of leaf meals with rice bran fed to Nile tilapia. Cassava (Manihote sculenta) centrosema (Centrosema pubescens) and Siratro (Phaseolus atropurpureus).	Highest weight gain and yield obtained at 60% MLM + 40% rice bran.	aquaria	Cruz, 1982
Various leaf meal, dried and finely ground were fed to Nile tilapia, common carp and snakehead at 5% of fish biomass.	Highest weight gain obtained with Centrosema fed to tilapia and snakehead. Results are inconclusive.	ponds	Cruz & Laudencia, 1978.
Grasses			
Apparent digestibilities of carpet grass (Axonopus sp.) and napier grass (Pennisetum purpureum) by grass carp determined.	Poor digestibilities of grasses shown (20.92% for carpet grass and 16.45% for napier grass).	aquaria	Law et al. 1985.
Rice hull and straw			
Four diets with varying crude fibre (CF) content tested on T.nilotica fingerlings stocked at 10,000/ha.	Higher yield obtained using rice straw and rice hull (20% CF) as ingredients in the ration compared to the standard diet (10% CF).	ponds	Camacho, 1981.

Various leaf meal			
Four leaf meals (IILM, MLM, Hydrilla and Ipamoea reptans (or "Kangkong") given to common carp and tilapia in pellet form at 4% of fish biomass.	For tilapia, feeding with MLM gave the highest mean weight and yield. For common carp, Hydrilla and "Kangkong" gave the highest mean weight while IILM gave the highest yield. Fingerling production was lowest with IILM.	ponds	Cruz & Laudencia, 1978b.
Azolla			
A.pinnata fed to Nile tilapia fingerling in fresh, powder, and pellet form replacing the complete control diet mix from 10% to 90%. Control diet consisted of 40% fish meal, 40% rice bran 10% corn starch, 9% corn meal and 1% Afsillin.	Negative growth obtained in all Azolla feeding which lasted 28 days. A lowering of growth performance and FCRS observed with increasing Azolla incorporation.	aquaria	Almazan et al., 1986.
Three experiments were conducted on the supplemental feeding of fresh/whole A.pinnata to Nile tilapia in cages in Laguna Lake.	Higher weight gain of fish was observed over the unfed control.	cages	SEAFDEC Ann. Rept. 1984.

Table 4: Chemical analyses of some common leaf proteins and aquatic weeds presently being used as NCFR in the Philippines[1].

LEAF PROTEINS	CHEMICAL ANALYSIS Crude Protein (%)	Crude Fibre (%)	Ash (%)
Cassava (Manihot esculenta)	29.75	15.25	8.63
Camote (Ipomoea batatas)	29.1	11.0	9.4
Sesbania (Sesbania sesban)	29.2	10.7	10.5
Azolla (A. pinnata)[2]	24-30	9.1	10.5
Ipil-Ipil (L.leucocephala)	26.3	18.2	8.3
Papaya (Carica papaya)	25.3	14.9	11.1
Kangkong (Ipomoea reptans)	20.51	38.86	20.73
Acacia (Samanea saman)	20.49	20.94	4.71
Mulberry (Morus sp.)	19.6	12.21	17.75
Water hyacinth (Eichornia crassipes)	12.8	24.4	11.5
Para grass (Brachiara mutica)	9.7	31.2	12.4
Corn (Zea mays)	6.1	32.7	9.6
Napier grass (Pennisetum purpureum)	6.4	32.4	15.3
Rice (Oryza sativa) straw	3.8	33.7	24.3

[1] Source: Zamora and Baguio, 1984; [2] Source: Singh, 1979.

Conclusions

Based on the foregoing, there seems to be a growing interest among Asian scientists to conduct research on NCFR. However, most of the work done so far has been preliminary in nature. For example, experimental results on the use of ipil-ipil leaf meal and *Azolla* for rearing tilapia to marketable size are conflicting. This may be explained by the varying conditions under which the experiments were conducted. Moreover, data from laboratory and field experiments differ. Thus, unless sustained efforts are exerted towards conducting more research on NCFR, meaningful results cannot be disseminated to the end users.

In recent years, more rural farmers have been turning to fish farming for their livelihood. This is understandable considering that the very nature of aquaculture operations require close monitoring that is easily provided by the family unit. In the

Philippines alone, reports show that production from aquaculture reached 285,000 tons and employs 300,000 people (Smith, 1985). If properly directed by the government, benefits from aquaculture should lead to the socio-economic upliftment of the rural poor.

A comprehensive state of the art on NCFR availability and utilization related to animal production in Asia and the Pacific was recently conducted through the initiative of the Food Agriculture Organization (FAO) of the United Nations (Devendra, 1985). It was estimated that at least 40 per cent cost reduction in feeds was achieved with the use of non-traditional feeds. Therefore, it is envisioned that a coordinated programme on the utilization of NCFR would accelerate aquaculture development in the countryside.

Table 5: Amino Acid Composition (% of protein) of some Leaf Proteins and Azolla pinnata.

AMINO ACID	Leucaena[1]	Cassava[2]	Azolla[3]
Alanine	6.10	—	6.45
Arginine	5.70	1.64	6.62
Aspartic	13.2	—	9.39
Cystine	—	0.23	2,26
Glysine	5.65	1.92	5.72
Glutamic	11.05	—	12.72
Histidine	2.03	.73	2.31
Isoleucine	5.58	1.86	5.38
Leucine	5.70	3.02	9.05
Lysine	5.63	2.08	6.45
Methionine	1.32	0.40	1.88
Phenylalanine	6.03	1.02	5.64
Proline	7.34	—	4.48
Serine	5.28	1.87	4.10
Threonine	5.68	—	4.70
Tryptophan	—	0.27	2.01
Tyrosine	4.02	0.99	4.10
Valine	6.37	1.10	6.75

References: [1] Glude, J.B. 1975; [2] Zamora and Baguio, 1984; [3] Buckingham et al., 1978.

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Development of a Supplementary Feeding Programme for Milkfish (*Chanos chanos Forsskal*) Reared in Brackishwater Ponds in the Philippines

YVONNE N. CHIU

Milkfish (*Chanos chanos* Forsskal) is the major aquaculture product in some 480,000 hectares of brackishwater ponds in the Philippines, Taiwan and Indonesia, which jointly produce about 285,000 tons annually. Milkfish contributes 90 per cent to the total national brackishwater pond production in the Philippines, 46 per cent in Taiwan and 49 per cent in Indonesia, with annual average yields of 870, 2,509 and 515 $kgha^{-1}$ respectively (Smith and Chong, 1984). In the Philippines, some 196,000 hectares comprising more than 50 per cent of the total mangrove resources have been converted into fishponds; but now this practice has been curtailed. If fish production is to increase to meet the needs of the growing population, than fish culture techniques have to be intensified (Chiu et al., 1986).

Every fish-farmer measures his success by the profitability of his ventures. The cost of production per unit weight of fish generally increases with the intensity of culture. Consequently, there is a trend of favouring the lower intensity of culture when the market price of the fish is low and vice-versa.

In Taiwan, Chen (1981) reported considerably higher profits with the deep-water system of culturing milkfish. This technology which can result in yields of over 10 t ha^{-1}, involves the expensive deepening of ponds to 2-3 metres, the increase in stocking density to 20,000 per hectare, the feeding of dry pelleted diets containing 24-29 per cent protein and providing artificial aeration. However, based on Chen's data, deep-water milkfish producers would have experienced losses if prices dropped to less than $2/kg (Smith and Chong, 1984). In the Philippines, milkfish prices range from $0.70/kg to $1.00/kg even as prices of feed and grain are somewhat comparable to that in Taiwan. Moreover, the cost of poultry feeds of 18 per cent protein is about $0.30/kg. Therefore, increasing its protein content by up to 10 per cent would increase the feed cost by another $0.10/kg. Evidently, a less intensive culture system would be more suitable under the Philippines' economic setting, where land cost is lower and energy cost is higher than that in Taiwan.

The use of organic and inorganic fertilizers to increase pond productivity is widely practised in the Philippines. On the other hand, there is no clear-cut milkfish feed technology, and the few who practice supplementary feeding use single ingredients such as rice bran and bread crumbs (Tan et al., 1984). Supplementary feeding has been shown to increase the carrying capacity of ponds over that resulting from fertilizer inputs, in the culture of species such as tilapia and carp. The composition and cost of supplemental diets are dependent on the standing crop of fish relative to the quantity and quality of natural food available. Natural food generally contains quantities of protein, vitamins and other nutrient growth factors beyond that needed by the fish. This allows the use of high-energy feedstuffs such as low-cost grains in supporting an additional biomass of fish. Evidently, this additional yield could be obtained from a lower cost of input than when the standing crop is beyond the point that natural sources of protein and other nutrients can support maximum growth. At this point, diets needed to further increase production will have to supply the lacking components such as high protein levels, vitamins and other growth factors, thereby increasing the cost of production. For example, in Israeli carp culture, it has been observed that maximum growth can be attained with only cereal grains up to a standing crop of 800 $kgha^{-1}$, a mixture of grains and pellets containing 25 per cent protein between 800 $kgha^{-1}$ and 1,800 $kgha^{-1}$ and 25 per cent protein pellets beyond 1,800 $kgha^{-1}$. Beyond a standing crop of 2,400 $kgha^{-1}$, vitamin supplements are needed (Hepher and Pruginin, 1981).

It is not only nutrient inputs that limit the critical standing crop of fish, or the point wherein growth rate starts to be less than the potential maximum. Dissolved oxygen levels, usually of less than 2 ppm, can limit growth even when food is adequate. Toxic metabolic wastes such as ammonia and carbon dioxide can also adversely affect growth, but these are likely to happen only under anoxic conditions. Thus water quality problems can often be remedied by aeration.

In milkfish culture, the cost-benefit analysis of various levels of intensity of culture has not been assessed as a function of its market price. Such analysis would require information regarding the critical standing crop at different levels of providing nutrient inputs and aeration. When the increase in profit resulting from a higher critical standing crop is higher than the cost of the added input, the more intensive culture system is favoured. Information regarding the profitability of increasing intensity of culture at varying degrees and the availability of technology would allow fish-farmers to weigh this against culturing other potential species. The urgency of such research has likewise been emphasized by Smith and Chong (1984). Aspects relevant to the development of more intensive methods of culturing milkfish with considerations to local economic conditions include:

1. the determination of the critical standing crop with the use of:
   (a) conventional and unconventional sources of cheap feedstuffs, usually containing protein levels between 10 per cent and 17 per cent, as single ingredients;
   (b) supplementary feeds formulated to contain more than 20 per cent protein;
   (c) vitamin supplements;
   (d) mineral supplements;
   (e) diets formulated with more than 25 per cent protein with considerations for amino acid balance through the proper combination of ingredients or through amino acid supplementation; and
   (f) facilities to augment the oxygen supply provided naturally by photosynthesis and diffusion.
2. the rate of supplementary feeding with considerations for the availability of natural food in the ponds;
3. the digestibility, energy value and nutrient value of food taken in by milkfish, considering different natural food bases and combinations with artificial diets; and

4. the development of water management strategies that would provide adequate dissolved oxygen, maximize the use of nutrients in the pond, while preventing the build-up of excessive concentrations of toxic metabolites under different levels of intensity of culture.

In the Philippines, up to the present moment, research has lagged behind the production sector in introducing improvements aimed at coping with economic conditions. This factor and the price-cost squeeze tend to weed out smaller scale and less efficient farmers. Research aimed at intensifying and increasing the profitability of culture will, in the long run, benefit the small-scale farmer most, if adequate extension services are provided.

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Research on Fish Nutrition in China

LIAO XIANGHUA

This history of freshwater pisciculture in China dates back to 437 B.C. Yet it was only after the 70's that research began to be directed toward the nutrition and nutritional physiology of cyprinid fish: Fish-farmers claim that fish feed is the basic factor in promoting high yields in pond culture. In China, grass carp is a key component in polyculture and the increase of its production has an important effect on the total yield in pond culture. In South China, the importance of mud carp is also stressed since it constitutes about one-third of the total fish output. Research at the Ichthyology Laboratory of Zhongshan University focuses on the nutritional requirements of grass carp and mud carp on a physiological basis with the aim of developing a scientific formulation of pellet feeds that will promote fish production.

Fish Nutrition

Research on nutrition of grass and mud carps initiated in our laboratory in 1976 can be categorized as follows:

Protein and amino acids: Daily protein requirements of grass carp at temperatures of 23-29°C amount to 1.5-1.7 g $100g^{-1}$ of wet weight of fish; whereas, protein required daily by mud carp ranges from 0.7-0.8 g $100g^{-1}1$ wet weight. Utilization of diet varies with age and temperature; juvenile fish are given a higher protein ration than fish of age II — III. The maintenance nitrogen metabolism (MNM) at 23.6-29°C is 3.0-4.0 $mgN100g^{-1}$ wet weight for grass carp and 14 mgN for mud carp. To study the amino acid nutrition requirements in the diet of grass and mud carps, qualitative and quantitative analyses were conducted on eggs, on whole carcasses of juvenile fish and on muscles of adult fish. Results show that the amino acid composition of the muscles of herbivorous grass carp consists of 17 amino acids of different quantities. The total amount of amino acid in the whole carcasses of juvenile fish and in fish eggs is respectively 31 per cent and 26 per cent lower than that in the muscles of adult fish, while differences were not detected in the amino acid composition. The amino acid content in the muscles of mud carp were similar to those of grass carp.

Carbohydrate: Daily carbohydrate requirements of 100 g wet weight of grass carp and of mud carp are 0.95-1.28 and 0.5 g respectively, corresponding to 28 per cent and 24-26 per cent of carbohydrate, respectively, in the contents of their daily feed.

Lipid Nutrition: Daily lipid nutrition requirements amount to 0.4 g $100g^{-1}$ wet weight of grass carp, corresponding to 7-10 per cent of its daily diet and 0.10 g $100g^{-1}$ wet weight of mud carp, corresponding to 4-5 per cent in its daily diet. Experiments showed that the composition of body lipids is not significantly affected by dietary protein levels but carbohydrate and lipid levels have a distinct effect on the accumulation of body lipid and the lipid content in liver.

Energy Budget: The daily energy budget for grass carp runs into 3,100-3,400 $kcalkg^{-1}$ per feed when sufficient protein is provided in the diet. The ratio between calorie and protein (c/p ratio) is 75.85-100.2 $kcalkg^{-1}$. When expressed in the ratio of protein and energy (P/E ratio) it is 99.8-123.9 mg/kcal. In the case of mud carp the calorific value of food components is 3,000 $kcalkg^{-1}$ per feed, c/p being 76-81 $kcalkg^{-1}$ and P/E, 122.8-131.1 $mgkcal^{-1}$.

Vitamins: No reliable method has been established to determine the exact amount of vitamin in the diet of grass carp in the field. Five to 15 per cent of green manure was added to the daily diet of grass carp and results have proved satisfactory.

Inorganic Salt and Trace Elements: Daily requirements of mineral mix were found to be 8-12 per cent and 14 per cent for grass carp and mud carp respectively.

Nutritional Disease: Nutritional disease in grass carp is attributable to an imbalance in the major dietary components of pellet feed. The use of pellet feed for grass carp in recent years in China has led to lipoid liver degeneration, retarded growth and flesh of inferior quality. Our laboratory has conducted the following studies in nutritional pathology: 1) study of the lipid content of liver; 2) histological and electron microscopical studies of the structure of the hepetopancreas; 3) study of 18 levels of enzyme activities; 4) study of biochemistry indices in blood serum; and 5) investigation of three stages of lipoid liver degeneration.

Non-conventional Feed Resources

With reference to the situations in China and, more specifically, in Guangdong Province, two factors must be taken into consideration: 1) the consumption by the vast human population of most of the protein resources, leading little or none available for fish feed; 2) the concentration of 33,333 hectares of fish ponds in the Pearl River Delta in Guangdong. Large amounts of low-cost fish feed is needed to meet the daily requirements of the fishes. Research on the conversion of non-conventional feedstuff, such as waste products, into useful feed resources is of great significance. Our work on the use of non-conventional feed covers the following aspects; 1) the use of water hyacinth *Eichornis carassipes* Solm as a substitute for green manure to feed grass carp. The plant was harvested, chopped, blended with a small amount of corn flour and fermented overnight. Good results have been obtained in rearing grass carp beyond age II^+; 2) the use of pellet feeds prepared by mixing different portions of enzymatic fibre meal, which contained 10-12 per cent crude protein, with other ingredients, such as cereals and peanut cakes. The pellet feed, composed of 60 per cent enzymatic fibre and other ingredients and containing 19.15 per cent crude protein level, increased the production of grass carp fingerling by 61.8-116 per cent and saved 70 per cent cereal as compared with the results in the control ponds where fingerlings were fed solely with cereals; 3) utilization of waste precipitate of sugar manufacture and condensed waste fluid in fermentation in the feed of mud carp. The addition to the basic feed of 20-30 per cent waste precipitate of sugar manufacture or 13 per cent condensed waste fluid from the alcohol fermentation industry, saved 23-25 per cent cereal and yielded 21 per cent increase in production. However, the presence of trace heavy metals should not be overlooked.

Future Plans

Intensive studies will be focused on improving the formulation of pellet feed for grass carp. Although our formulation of grass carp pellet feed is recommended by the Guangdong Fishery Bureau and adopted by nine fish feed factories in Nan Hai, Si Hui, Shun De and Zhong Shan counties, the formulation is far from perfect. A large amount of research remains to be carried out in the coming years on the following topics:

(i) Quantitative amino acid requirements and graded doses of amino acids and protein in the diet;
(ii) the balance of essential amino acids and non-essential amino acids and its relation to growth;
(iii) the effect of total dietary lipid on linolenic acid requirement;
(iv) evaluation of digestibility of local conventional and non-conventional feed ingredients;
(v) improvement of the meat quality of grass carp through experiments on: (a) different compositions of protein, carbohydrate and lipid in the diet and their effect on lipid accumulation in the muscles, liver and intestinal mesentery; (b) enzymes or catalytic agents that reduce the accumulation of fat;
(vi) supplementation of mineral mix and trace elements.

An Overview of Carp Nutrition Research in India

H.P.C. SHETTY AND M.C. NANDEESHA

Introduction

Carps have been cultured in India since ancient times. However, the adoption of scientific management measures is only of recent origin. Based on research over the last three decades, a tentative package of practices has been developed for the composite culture of carps, as a result of which it has been possible to obtain productions ranging from about 4,000 to 10,000 $kgha^{-1}$ yr^{-1} in experimental and demonstration ponds. The system essentially involves, apart from other management measures, balanced stocking of six species of carps, viz. catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*); periodic manuring of ponds with organic and/or inorganic fertilizers; and regular feeding of fishes at 2-4 per cent of their body weight. The artificial feed traditionally given in India is a 1:1 mixture of rice bran and oil cake. Since this diet is not nutritionally balanced, there have been several studies in the country to understand the basic nutritional requirements of the cultivable fish and to formulate nutritionally balanced, but cheap diets. An attempt has been made in this paper to give an overview of the work done in India on carp nutrition and diet formulation.

Studies on Basic Nutritional Requirements

Studies to determine the qualitative and quantitative nutritional requirements of the cultivated carps were initiated only in the recent past.

Proteins, carbohydrates and fats

Few basic investigations have been carried out to understand the nutritional requirements of carps at different stages (Table 1). These studies indicate that carps in their early stages require about 45 per cent protein and 26 per cent carbohydrate (Sen et al., 1978). The protein requirement appears to decline to 30 per cent after the fingerling stage. The requirement of carbohydrate beyond the fingerling stage and the requirement of fat at different stages of life are not known.

Vitamins and minerals

Preliminary attempts have been made to ascertain the impact of vitamins and minerals on the growth and survival of carps. Vitamin B_{12} and cobalt nitrate, combined with goat stomach extract significantly increased the survival of major carp spawn (Das, 1959). The role of ascorbic acid on the growth and survival of mrigal hatchlings has been demonstrated by Mahajan and Agarwal (1980) who found that, in hatchlings, best growth and survival were obtained without any deformities with a diet containing 600 $mgkg^{-1}$ diet. Malnutrition diseases have been recorded in fry, fingerlings and adults of carps when diets were devoid of ascorbic acid (Anon., 1982). Based on hematological studies, Mahajan and John (1979) concluded that Vitamin B_{12} and folic acid were more essential than thiamine and inositol. Vitamin E is known to enhance fecundity and induce complete spawning in catla, rohu and common carp, when fed at 5 $mgkg^{-1}$ body weight day^{-1} (Gupta et al., 1979).

Table 1: Protein and Carbohydrate requirements of carps (a-Sen et al., 1978; b-Anon. 1983, c-Srinivas & Murthy, 1985; d-Renukaradhya & Varghese, 1986; e-sen & Chatterjee, 1979a).

Species	Prot. (%)	Carb. (%)	Development Stage
Common carp[a]	45	26	Spawn, fry and fingerling
Rohu[a]	45	26	Fry and fingerling
Mrigal[b]	45	28	Fry
Mahseer[c]	40	—	Fingerling
Catla[d]	30	—	Advanced fingerling
Rohu[d]	30	—	•
Indian major carps[e]	—	3.44mg/day/fish	Fry

Some minerals have been screened for their effect on carps. When iron was incorporated in a synthetic diet at 14.5 $mg100g^{-1}$ diet and fed to rohu, its food conversion efficiency, growth and survival were found to be optimal (Mahajan and Katta, 1979). Cobalt chloride, boron, manganese and molybdenum at 0.01 mg, 1 mg, 0.01 mg and 0.05 $mgday^{-1}fish^{-1}$ respectively have been found to enhance the growth and survival of Indian major carp fry and fingerlings by Sen and Chatterjee (1979a, b).

Natural Food Preferences of Carp Spawn and Fry

According to Hora (1943), microphytoplankton form the food of the fry of carps. The fry of catla, rohu and kalbasu (*Labeo calbasu*) in the size range of 5-10 mm are known to feed on unicellular algae and from 10-20 mm size on protozoans (Mookerjee, 1944, 1945). Based on the findings of a systematic investigation, Alikunhi (1952) inferred that microphytoplankton formed only an emergency food of catla and common carp fry and that the main food consisted of crustaceans and rotifers, while zooplankton induced best growth and survival of fry, and have been confirmed by Mitra and Mahapatra (1956).

Use of Artificial Feeds in Carp Culture

The survival of Indian major carps during their early stages under culture condition is generally low, being about 30 per cent from spawn to fry stage and about 50 per cent from fry to fingerling stage which is mainly due to the lack of a balanced diet. Therefore, in recent years, recourse is being taken to supplement the natural food with some artificial feed.

Artificial feeds for carp spawn and fry

Singh and Bhanot (1970) prepared diets using powdered algae (*Zygnema, Spirogonium or Mougeotia*) in combination with fish meal, potato starch, terramycin, yeast and salt. They recorded good growth of common carp when fed on the diet containing *Mougeotia*, but slightly inferior growth with the feeds containing *Spirogonium* or *Zygnema*. Other algae like *Oedogonium* (Singh, 1970), *Microcystis* (Ahmed, 1966; 1967), *Scenedesmus* (Gupta and Ahmed, 1966) and *Spirogyra* (Singh et al., 1979) have also been evaluated vis-a-vis growth and survival of carps. In most cases the algae were found to be useful as a component of fish diets.

Dried powder of *Nymphoides* and *Spirodela*, mixed with rice bran, has also been found to be useful (Patnaik and Das, 1979).

Mitra and Das (1965) evaluated various protein sources as feed for Indian major and minor carp fry. Among the several sources tried, higher survival and yield of carp spawn were obtained with til oil cake, rice powder and black gram, silkworm pupae and fish meal as compared to rice bran. Lakshmanan et al. (1967) also tried several feed sources and found that a mixture of notonectids, prawn and cowpea (5:3:2) yielded superior growth and better survival. Chakrabarthy et al. (1973) observed better performance of carp spawn when fed on zooplankton, silkworm pupae, soybean or wheat bran. Good results have also been obtained with fish-cum-prawn powder by Mahajan and Yadave (1974) and with petroleum protein and rice polish by Chakrabarthy and Kar (1975).

Artificial feeds for fingerlings and adults

A practical approach in evaluating a fish meal based artificial diet vis-a-vis a traditional feed mixture was made by Varghese et al. (1976). Their results conclusively proved that the 31 per cent protein diet containing 25 per cent fish meal is not only useful in enhancing fish growth but is also economical. Although it is now well accepted that fish meal based diets induce faster growth of carps, the uncertainty in availability and the escalation in cost of fish meal has forced investigators to look for alternative economical protein sources as a replacement for fish meal.

Jeyachandran and Paul Raj (1976) found that in common carp good growth was recorded with silkworm pupae powder and formulated feed. In subsequent trials, Jeyachandran and Paul Raj (1977) showed that silkworm pupae and prawn waste can be profitably utilized as feed for common carp.

Intensive investigations on the substitution of fish meal with cheaper protein sources were initiated in the University of Agricultural Sciences, Karnataka, a decade ago, the findings of which are summarised in Tables 2 to 6. The methodology followed in the formulation and processing of diets in almost all trials were as per the procedure described by Jayaram and Shetty (1981). The feeding rate was generally 5 per cent, a rate known to result in good conversion and growth and minimal wastage of food (Kumar, 1980; Sen et al., 1980; Ghosh et al., 1984). The temperature of water in the different trials ranged from 24°C to 32°C.

An analysis of the data presented in Tables 2 to 6 indicate the suitability of several plant and animal sources as feed ingredients for carps. The results obtained with sericulture wastes, shrimp waste, slaughter house waste and water hyacinth are highly significant in the Indian context. Interestingly, the newly developed diets had no adverse influence on organoleptic quality which is very important from the point of view of consumer acceptability. However, tissue composition was found to vary based on the type of feed and its nutrient level (Jayaram and Shetty, 1980b; Jayaram et al., 1980; Venugopal, 1980; Arul, 1981; Borthakur, 1983; Bhat, 1984). The base line data obtained from the experiments conducted so far can be fruitfully utilized for the development of balanced diets suitable for adoption in composite culture on a commercial scale.

Feed for grass carp

The exotic grass carp, *Ctenopharyngodon idella*, was introduced into India in 1959 for the purpose of biological control of aquatic weeds in fishery waters. However, its fast growth rate and good table quality have led to its inclusion in composite culture operations all over the country (Sinha and Gupta, 1975). According to Prabhavathy and Srinivasan (1977), grass carp is known to ignore all other aquatic vegetation in the presence of *Hydrilla*. A growth rate of 12.4 $gday^{-1}$ was recorded by Keshavanath and Basavaraju (1980) when grass carp was grown in a *Hydrilla* choked irrigation tank over a period of four months. A comparative evaluation of *Utricularia* and combination of *Lerna* and *Azolla* showed that the latter is better acceptable to the fish (Varghese et al., 1976). Among the other aquatic vegetation tried, *Spirodela* and *Cyanodon* have yielded good results, while *Ceratophyllum* has been found to be a poor inducer of growth (Anon., 1981); this is probably due to its poor digestibility (Venkatesh and Shetty, 1978b, d).

Table 7 shows the proximate composition of the plants screened as feed for grass carp, while Table 8 includes data on the growth performance. The results clearly indicate that the terrestrial plants are superior to aquatic plants. Use of ku-babul as feed for grass carp has limitations because of the free amino acid mimosine. Ramakrishna and Shetty (1982) recorded de-

Table 2: Percentage composition of ingredient and proximate composition of formulated feeds.

Source/ ingredients/ % composition	Prot.	Fat	Carbohy. (NFE)	Ash	Fibre	CR	Diet Code
Jayaram & Shetty (1980d)							
a + b (50:50)	23.73	6.10	37.20	11.75	12.48	1.68	CI
FM, a, b, c (33:22:31:14)	33.22	6.54	38.74	7.40	4.50	1.19	FMI
SWP, a, b, c	34.83	9.98	32.37	3.38	7.64	1.34	SWP
Devaraj & Keshavappa (1980)							
Pd, a, b,	17.10	5.30	—	22.40	—	1.99	Pd
FM, a, b, d, (25:25:40:10)	29.50	5.90	—	25.00	—	1.94	FMII
a + b (40:60)	18.00	9.00	—	19.36	—	2.10	CII
Venugopal (1980)							
a + b (50:50)	24.47	5.48	34.57	16.11	12.06	0.93	CIII
FM, a, b, c	34.58	5.62	27.27	16.61	8.71	0.94	FMIII
Co. FM, a, b, c (36:18:23:16:7)	33.38	6.07	33.06	13.39	8.51	0.94	Co.
Si., a, b, c (40:32:8:20)	34.70	6.68	31.90	12.15	4.54	0.81	Si.
Anil (1981)							
FM, a, b, c (20:10:60:10)	23.48	7.32	41.58	15.20	12.42	3.22	FMIV
Sw, a, b, c (35:18:37:10)	25.07	9.04	37.73	16.40	11.76	3.09	SW
Ei + SW, a, b, c (30:18:22:20:10) Ei a, b, c (60:20:5:15)	24.92	8.57	37.67	14.60	14.24	3.17	Ei

Table 2 (continued)

Devaraj et al. (1981)						
L, a, b, d (40:20:20:20)	21.33	4.33	42.59	15.28	12.35	3.09 L
Ca, a, b, d (40:20:20:20)	19.25	3.64	47.63	12.50	12.86	3.64 Ca.
a, b (40:60)	17.50	9.00	32.49	19.36	11.85	3.08 CN
Borthakur (1983)						
a, b (50:50)	25.35	5.90	30.25	15.58	14.24	1.31 CV
FM, a, b, c (45:20:20:15)	35.01	7.51	26.38	15.97	6.18	1.09 FMV
Swp, Sw, a, b, c (30:25:25:10:10)	34.96	14.98	29.01	8.63	5.07	1.30 PS
Swp, CM, a, b, c (25:20:20:15:20)	35.36	12.71	29.05	6.95	6.29	1.09 CM
Bhat (1986)						
FM, a, b, c (25:25:40:10)	31.50	4.96	27.30	15.82	11.54	1.23 FMVI
SR, a, b, c (23:25:42:10)	31.82	2.93	31.65	11.28	12.69	1.37 SB
SQ, a, b, c (30:30:30:10)	31.02	2.93	26.62	18.99	16.62	1.31 SQ
Devaraj & Keshavappa (1985)						
Pd	15.20	2.52	—	17.20	17.95	2.14 PdII
a, b	20.75	8.90	—	19.85	25.00	3.48 CVI
Nandeesha et al. (1986)						
FM, a, b, c (22.5:22.5:40:15)	35.80	11.80	19.45	18.85	7.90	1.93 FMVII
SWF, a, b; c (42.5:19.5:26:12.5)	32.66	7.00	26.14	18.40	11.60	2.03 SWF
SLH, a, b, c (22:20:43:15)	35.40	8.20	31.06	12.90	8.84	1.67 SLH

Numbers within parentheses indicate proportion of various ingredients in the diet; a — ground oil cake, b — rice bran, c — tapioca flour and d — ragi flour; FM — fish meal; Swp — Silkworm pupae; Pd — Poultry droppings; Co — Colocasia leaves; Si — Fish silage; Sw — Shrimpwaste power; Ei — Eichornia leaves powder; L — Lemna powder; Ca — Cabbage leaves powder; CM — Clam meal powder; SB — Soybean meal; SQ — Squilla meal; SWF — Silkworm faecal matter; SLH — Slaughter house waste; L — Lucernea; K — Ku-babul.

Table 3: Growth response of catla to different feeds (the dietary codes and composition are given in Table 2).

Source/Code	Weight (g) Initial	Final	Growth (g day^{-1})	Culture (days)
Jayaram & Shetty (1980d)				
CI	11.93	147.0	1.50	98
FMI	11.93	156.8	1.60	98
SWP	11.93	200.0	2.05	98
Venugopal (1980)				
CIII	2.60	177.7	1.41	126
FMIII	2.60	249.5	1.98	126
Co	2.60	197.8	1.57	126
Si	2.60	200.3	1.59	126
Anil (1981)				
FMIV	3.00	166.8	1.39	120
SW	3.00	159.6	1.33	120
SEi	3.00	141.6	1.18	120
EEi	3.00	164.4	1.37	120
Nandeesha et al. (1986)				
FMVII	20.00	123.2	1.10	112
SWF	20.00	110.9	0.99	112
SLH	20.00	159.0	1.42	112

Table 4: Growth response of rohu to different feeds.

Source/Code	Weight (g)		Growth	Culture	Digestibility (%)		
	Ini.	Fin.	(g day^{-1})	(days)	Prot.	Fat	Fibre
Jayaram & Shetty (1980c, d)							
CI	26.03	109.8	1.12	98	—	—	—
FMI	26.03	123.5	1.26	98	94.8	88.6	14.8
SWP	26.3	92.1	0.94	98	91.8	91.4	16.8
Anil (1981)							
FMIV	4.0	69.6	0.58	120	90.6	91.2	13.8
SW	4.0	62.4	0.52	120	87.7	85.0	10.9
SEi	4.0	79.2	0.66	120	94.2	91.0	20.9
Ei	4.0	85.2	0.71	120	94.8	90.5	22.2

Table 4 (continued)

Borthakur (1983)							
CV	5.3	109.2	0.91	120	—	—	—
FMV	5.3	148.8	1.24	120	—	—	—
PS	5.3	117.6	0.98	120	—	—	—
PC	5.3	111.6	0.93	120	—	—	—
Bhat (1984) & Bhat et al. (1986)							
FMVI	5.7	143.6	1.08	133	92.4	86.0	49.6
SB	5.7	134.3	1.01	133	92.7	85.7	50.4
SQ	5.7	138.3	1.04	133	92.1	82.1	56.4
Nandeesha et al. (1986)							
FMVII	10.0	60.5	0.54	112	—	—	—
SIF	10.0	72.8	0.65	112	—	—	—
SLH	10.0	61.6	0.55	112	—	—	—

Table 5: Growth response of mrigal silver carp to different feeds. (No. of culture days are given in parentheses).

Source/Code	Mrigal weight (g)		growth $gday^{-1}$	Silver carp weight (g)		growth $gday^{-1}$
	Ini.	Fin.		Ini.	Fin.	
Venugopal (1980)	(126)					
CIII	2.4	97.0	0.77			
FMIII	2.4	107.1	0.85			
Co	2.4	100.8	0.80			
Si	2.4	80.6	0.64			
Borthakur (1983)	(120)			(120)		
CV	4.8	51.6	0.43	4.8	105.6	0.88
FMV	4.8	87.6	0.73	4.8	189.6	1.58
PS	4.8	78.0	0.65	4.8	196.8	1.64
PC	4.8	91.2	0.76	4.8	148.8	1.24
Bhat et al. (1986)				(133)		
FMVI				6.0	264.7	1.99
SB				6.0	246.1	1.85
SQ				6.0	121.0	0.91

Table 5 (continued)

Nandeesha et al. (1986)	(112)		
FMVII	6.6	73.9	0.66
SWF	6.6	153.4	1.37
SLH	6.6	209.4	1.87

Table 6: Growth response of common carp to different feeds (culture period in days and initial weight in g are given in parentheses).

Source/Code	Final Wt. (g)	Growth ($gday^{-1}$)	CR	Digestibility (%)		
				Prot.	Fat	Fibre
Jayaram & Shetty (1980c, d) (98 days; 12.37g)						
CI	122.5	1.25	—	—	—	—
FMI	147.0	1.50	2.54	97.6	94.9	58.5
Devaraj & Kashavappa (1980) (120 days; 4.00g)						
PI	82.8	0.69	—	—	—	—
FMII	86.4	0.72	—	—	—	—
CII	94.8	0.79	—	—	—	—
Venugopal (1980) (126 days; 2.0g)						
CIII	262.1	2.08	—	—	—	—
FMIII	338.9	2.69	2.54	92.7	96.5	76.7
Co	331.4	2.63	2.83	86.3	78.3	33.7
Si	425.9	3.38	2.48	95.8	90.1	41.7
Anil (1981) (120 days; 5.00g)						
FMIV	250.8	2.09	3.92	93.0	92.3	59.1
SW	188.4	1.57	4.18	88.9	90.3	55.8
SEi	206.4	1.72	3.95	91.0	93.7	47.8
Ei	276.0	2.30	3.55	94.8	92.2	57.9
Devaraj et al. (1981) (140 days; 3.00g)						
L	71.14	0.51	—	—	—	—
Ca	72.8	0.52	—	—	—	—
CIV	88.2	0.63	—	—	—	—

Table 6 (continued)

Borthakur (1983) (120 days; 1.80g)						
CV	138.0	1.15	—	—	—	—
FMV	187.2	1.56	5.30	92.7	90.4	55.9
PS	168.0	1.40	3.94	93.7	89.7	70.6
PC	190.8	1.59	4.47	92.7	88.2	55.5
Bhat (1984): Bhat et al. (1986) (133 days; 3.60g)						
FMVI	356.4	2.68	2.47	97.6	96.6	81.2
SB	343.1	2.58	2.94	97.1	93.8	85.0
SQ	333.8	2.51	2.92	97.5	93.6	79.4
Devaraj & Keshavappa (1985) (154 days; 17.60g)						
PII	97.0	0.63	—	—	—	—
CVI	207.9	1.35	—	—	—	—
Nandeesha et al. (1986) (112 days; 1.54g)						
FMVII	92.9	0.83	—	—	—	—
SWF	103.0	0.92	—	—	—	—
SLH	134.4	1.20	—	—	—	—

velopment of black coloration of the body and cataract of the eye in grass carp raised on ku-babul. This source, being rich in protein, could possibly be used by reducing the mimosine content through partial drying or cooking. Venkatesh and Shetty (1978c) assessed the influence of grass carp on plankton production through the fertilizing effect of its excreta, while Sen et al., (1978) reported that the growth of other carps was influenced by grass carp excreta. These observations clearly demonstrate the positive role of grass carp in composite culture.

Use of Growth Promoters

It has been found that the growth and/or survival of various stages of fish can be appreciably enhanced through the addition of growth — promoting substances such as yeast, antibiotics, hormones, etc. into the diet.

Table 7: Proximate composition of plants used as feed for grass carp. SD is given in parenthesis.

Plant	Moisture	Protein	Fat	Carbohydrate (NFE)	Ash	Fibre
Hydrilla verticillata[a]	89.79 (0.12)	14.60 (2.46)	7.32 (3.20)	33.10-57.82	21.56 (2.09)	11.06 (4.61)
Ceratophyllum demersum[a]	93.16 (0.34)	13.68 (2.62)	3.07 (1.68)	36.32-54.20	30.49 (1.52)	7.50 (3.12)
Pennisetum purpureum x P. typheideum[a]	83.29 (1.16)	16.85 (2.36)	4.54 (2.11)	40.14-55.12	10.20 (1.22)	21.78 (4.80)
Brachiaria mutica (para grass)[b]	77.08 (1.75)	20.98 (1.66)	2.86 (0.44)	47.58 (2.65)	9.45 (0.65)	19.10 (1.33)
Pueraria phaseoloides (kudzu)[b]	65.47 (2.59)	20.33 (2.38)	6.03 (3.42)	43.96 (2.62)	6.58 (0.28)	20.90 (1.77)
Vigna sinensis (cowpea)[a]	78.48 (4.79)	41.15 (4.86)	8.12 (1.19)	29.24 (3.16)	9.45 (1.25)	12.40 (3.48)
Leucaena leucocephala (ku-babul)[a]	62.13 (1.77)	39.60 (7.60)	7.07 (0.86)	40.11 (2.67)	6.24 (1.48)	8.23 (0.94)
Panicum maximum (Green panic)[d]	78.89 (0.51)	16.01 (0.05)	3.80 (0.19)	47.19 (0.50)	8.09 (0.25)	25.37 (0.18)
Chloris gayana (Rhodes grass)[d]	80.20 (0.51)	17.30 (0.43)	3.72 (0.32)	44.99 (2.66)	7.43 (0.65)	26.65 (2.47)
Medicage sativa (Lucerne)[c]	74.60	18.25	3.97	—	—	—
Moringa pterigoperma (Drumstick leaves)[c]	75.20	27.02	6.85	—	—	—

([a] — Venkatesh & Shetty, 1978 [b] — Gowrishankar, 1979; [c] — Ramakrishna, 1980; [d] — Halinga, 1981; [e] — Devaraj et al. 1986).

Table 8: Growth response of grass carp to some aquatic and terrestrial plants. (The mean initial weight, culture period and the feeding rate are given in parentheses).

Plant used/source	Growth $g day^{-1}$	Final wt. (g)	CR	Digestibility of nutrients (%)		
				Protein	Fat	Fibre
Venkatesh & Shetty (1978a, b) — (11.97g; 182 days; 10%)						
Hydrilla	0.49	89.18	93.98	80.98	82.84	42.96
Ceratophyllum	0.30	54.60	128.43	58.96	68.95	38.97
Hybrid napier	1.72	313.04	26.99	85.70	76.69	32.07
Gowrishankar (1979) — (9.53g; 120 days; 10%)						
Hybrid napier	0.80	96.00	18.51	78.30	72.60	40.10
Para grass	0.89	106.80	25.40	88.70	64.50	27.40
Kudzu	0.93	111.60	20.10	75.90	66.10	40.80
Keshawantha & Basavaraju — (500.0g; 126 days; ad lib.)						
Hydrilla	12.40	1562.40	131.50	—	—	—

Ramakrishna (1980) — (11.25g; 154 days; 5%)						
Hybrid napier	0.43	66.22	24.54	87.17	88.21	16.03
Cowpea	0.73	112.42	17.84	83.21	86.78	46.32
Ku-babul	0.45	69.30	38.10	85.65	82.86	38.54
Halinge (1981) — (11.00g; 126 days; 5%)						
Hybrid napier	1.06	133.56	20.98	79.51	77.27	19.51
Green panic	1.99	250.74	13.72	80.13	71.43	30.25
Rhodes grass	1.43	180.18	16.34	81.87	71.93	19.67
Devaraj et al. (1985) — (3.00g; 120 days; ad lib.)						
Hydrilla	4.21	505.20	45.56	—	—	—
Lucernea	8.31	997.20	16.46	—	—	—
Devaraj et al. (1986) — (4.00g; 120 days; 30-50% and ** 10–15%)						
Lucernea*	1.42	170.40	13.90	—	—	—
Drumstick leaves**	0.93	111.60	10.20	—	—	—

Yeast and antibiotics

Tripathi et al. (1979) were able to achieve higher survival of carps in nursery ponds, using protein-rich diets fortified with yeast. According to Singh et al. (1980), diets containing yeast lead to better acceptability and conversion in the case of fry and fingerling rohu. Further, Das and Krishnamurthy (1959, 1961a, 1961b) and Das (1960) found yeast + B-Complex, yeast + B_{12} and some antibiotics to be useful in enhancing the growth and survival of carps. Mahajan and Sharma (1976) obtained good results with yeast, as with B-Complex, in regard to growth and survival of common carp and rohu spawn, but found higher doses of antibiotics to be detrimental. The effect of enterocycline, hoesteocycline and chloromycetin on the growth and survival of Indian major carp fry and fingerlings has been reported by Sen and Chatterjee (1979a).

Hormones

Accelerated growth was reported in common carp treated with 17 alpha methyltestosterone, at 200 ppm through feed (Rao and Rao, 1982). In a subsequent experiment, using the same dosage of the hormone for initial dipping of the eggs and subsequent feeding, both the growth rate and survival were found to be consistently better than those of the controls (Rao et al., 1984). Further, the hormone was successfully used for sex conversion and growth promotion of common carp (Ali, 1985). The hatchlings, which were administered with 300 and 400 ppm of the hormone in their feed over a period of 30 days and grown on hormone-free diet for one year, showed decidedly better growth to the extent of 40.64 per cent and 46.89 per cent respectively as compared to fish grown on control diets. At 5 ppm, 17 alpha methyltestosterone was found to enhance the growth and food conversion of rohu (Reddy, personal communication). Deb (personal communication) recently carried out a detailed investigation on the effect of this hormone as a growth promoter in catla, rohu, common carp and mrigal. Of the three dosages tried, viz. 1, 3 and 5 ppm, faster growth and better food conversion were observed at 1 ppm in catla, rohu and common carp and at 3 ppm in the case of mrigal. Diethylstilboesterol, an estrogen, has been found to promote growth of common carp at 5 ppm (Basavaraja, personal communication) and rohu (Reddy, personal communication).

Similar results have been obtained by Nandeesha (personal communication) in the case of catla, the hormone used being hCG at 25 ppm. In all the above experiments, it was seen that dosages beyond optimum resulted in poor growth as compared to untreated fish.

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PART III

Recommendations
Group Discussions
List of Participants

Recommendations

1.0

Six finfish species groups were identified as the main species on which further finfish nutrition research should be carried out and supported. These were:

(a) the carps	—	the Chinese and the Gangetic major carps and common carp
(b) tilapias	—	*Oreochromis niloticus* and *O. aureus*
(c) the milkfish	—	*Chanos chanos*
(d) air breathers	—	catfishes, snakeheads, etc.
(e) mullets	—	*Mugil* sp.
(f) groupers and seabass	—	*Epinephalus* sp. etc.

The main areas of research needed for each group are spelt out under each species group. Certain areas of research were recognized as important by all groups; in particular, the studies on the development of non-conventional feed resources, and digestibility studies of such resources.

2.0

It was recommended that all the information available on non-conventional feed resources hitherto utilized in finfish diets in the region and the "performance" of the species on each diet should be collected and made available to finfish nutrition researchers in the region. Information on the nutritive value and optimum level of the ingredients used in diets, the availability, method of preparation, digestibility, and costs should also be reported.

The above listing should be supplemented by other ingredients which have hitherto not been experimented on fish, but which have proved to be useful in animal diets.

3.0

It was agreed that a manual on methodology on finfish nutrition research in the region should be prepared early, perhaps within two years. It was suggested that selected individual researchers be assigned a single topic and that they meet as a group to finalize the manual. It was agreed that such a manual should also include the mass culture and the harvest of feed organisms such as *Spirulina, Brachionus, Artemia, Moina, Tubifex,* etc.

4.0

One representative per country was selected to act as a focus for information exchange within the region and to report on the ongoing finfish nutrition research to the group at large. The representatives are:

India	— Prof. T.J. Pandian
Malaysia	— Mr S. Pathmasothy
Philippines	— Dr Yvonne Chiu
Thailand	— Dr Mali Boonyaratpalin
Sri Lanka	— Prof. Sena S. De Silva

5.0

It was agreed that all endeavours should be made for the Finfish Nutritionists to hold workshops at least once every three years.

Research Priorities for Species Groups (Resumé of Group Discussions)

1.0 Tilapine Fish

It was generally agreed:

(a) that the basic requirements (gross nutrient class) for tilapia were now known. It would, therefore, appear that the research trend is moving away from basic fundamental nutrition studies to those that are more applied;

(b) that *Oreochromis niloticus* and the Red Tilapia are the most popular and important tilapia species to work on; and

(c) that the target group for whose benefits research should be directed at are the small-scale farmers. With this in mind, it was the consensus of the group that future research emphasis should be directed towards,
   (i) natural food production and
   (ii) development of supplementary feeds.

Natural food production

The need for emphasis in the following areas of research were emphasized:

Development of techniques,

(a) to increase the natural food production within ponds, and to enhance the quality of these food organisms.

(b) on digestibility studies on the various food organisms.

The group also expressed views that the supplementary feeding practices utilized need to be reassessed taking into account the natural feeding habits of tilapia. It also noted the need for well-planned basic experimentation to assess the proportion of naturally produced food that tilapias obtain in different culture systems.

Supplementary feeds
The group defined supplementary feeds as those prepared feeds (whether it is as a whole feed or as ingredients within a feed) presented for consumption to increase production.

It would appear that with intensification of culture methods, i.e. increased stocking density, there is a limit to which the natural food production can support a fish population with adequate growth, beyond which supplementary feeding becomes imperative for economical gains.

It was felt that supplementary feeds could be classified as (i) a protein source (ii) an energy source, and appropriate priority be assigned. In order to reduce the most expensive item in the operating cost, i.e. the feed cost, it has been the trend to conduct research on non-conventional feed resources (NCFR) with a view to replacing the more expensive traditional feedstuffs or ingredients. It should be noted that NCFR differ from country to country within the region. It was also deemed extremely important to study the feeding behaviour of tilapia to supplementary feeds as this would have implications for feeding practices.

Digestibility studies on supplementary feeds, be it NCFR or conventional ones, are limited. Efforts should be expended to determine, collate and publish such results whenever possible. To do this satisfactorily, it is essential that the methodology for those types of studies be standardized, in association with standardization of methods of analysis. This would create uniformity in the description of the feedstuffs being evaluated, and studies in the region comparable with those elsewhere.

Lastly, it was of the opinion of the group that two areas of research, which are extremely important, but lacking at the present time, are broodstock and larval nutrition. Greater efforts should be channelled into these two neglected areas.

(Members of the group: Kok Leong Wee, Roger Pullin, Sena S. De Silva, Celine D. De Silva, D.E.M. Weerakoon)

2.0 Air-breathing Fish
Since all air-breathing fish are carnivorous, there is a need to study and understand the basic protein and lipid requirements of these fish.

Air-breathing fish like the murrel do not readily accept pelleted feed. As such there is an urgent need to study the inclusion of suitable attractants in the feed, feed leaching and other wastage of the feed by observing the feeding behaviour of these fish.

Most air-breathing fish pass through remarkable changes in the structure, function and behaviour related to air-breathing. There is a need to follow the nutritional requirements of all the life stages.

Most air-breathing fish spawn at the age of 1^+ or 2^+ especially at the onset of the monsoons. Hence spawning is limited spatially and temporarily. However, they are able to spawn more frequently, when subjected to suitable food and feeding regimes. Hence there is a need to support studies on the dietary requirements of brood stock.

An exploratory survey may be undertaken to identify the non-conventional feed resources like silkworm pupae meal, soybean meal, etc.

There is a need to study the digestibility of non-conventional feed resources by air-breathing fish.

(Members of the group: T.J. Pandian, L. Landesman)

3.0 Seabass

The seabass (*Lates calcarifer*) grows well in both fresh and salt water and recently has been spawned (both artificially and naturally) in Thailand. This species, because of the relatively high market value is rapidly becoming one of the most popular candidates for culture in the region.

At present there is no practical diet available for the various culture conditions and little is known regarding the nutritional requirements of the species. "Trash fish" is the primary food presently used. This limits culture to coastal areas and certain seasons, and often leads to water quality or disease problems. Therefore, there is a need to develop practical diets for different age groups of seabass to allow expansion of culture in both freshwater and seawater areas in the region.

The recommended research programmes for seabass and grouper nutrition and diet development are as follows:

(a) to examine the nutritional requirements of seabass including protein, amino acid, fat, fatty acid, carbohydrate, vitamins (A, D, E, C, B complex) and minerals (Ca, P, Mg.) both with regard to quality and quantity required in the diet;

(b) to examine the optimum protein and energy ratio in diets;
(c) to examine the acceptability of different forms of feeds: floating, semibuoyant, pelleted, flaked, and moist;
(d) to examine the use of vegetable protein as a substitute for animal protein;
(e) to determine optimal feeding rate and frequency for various age groups of seabass;
(f) to develop least-cost feed formulations; and
(g) to develop diets for larval stages of seabass.

(Members of the group: Mali Boonyaratpalin, Wong Tat Meng, Shim Kim Fah)

4.0 Carps

A critical analysis of the work carried out so far highlights the following facts:

(a) Barring a few investigations, there has generally been no systematic approach to the study of basic nutritional requirements of carps at various stages of development.
(b) Eventhough a number of useful pelleted feeds have already been developed, complete artificial diets suitable for fry, fingerling and "grow-out" stages have yet to be developed, keeping in view the basic nutritional requirements.
(c) Fish meal being far too costly, studies conducted so far evaluating cheaper but nutritionally adequate and locally available animal and plant protein substitutes have yielded valuable results of economic significance, but such studies need to be continued and more coherence between groups of researchers engaged in these studies is needed.
(d) Studies on brood fish nutrition is lacking. The poor response of breeders to hypophysation and poor survival of the hatchlings in many of the Indian fish farms could be attributed to the lack of proper knowledge of nutritional requirements of brood fish. This aspect needs to be studied in detail on an urgent footing.
(e) There is a need for making a fuller study of the role and usefulness of various growth promoting substances, with a view eventually to reducing the cost of fish production.
(f) In the Asian region, information is lacking on the contribution of natural food in culture waters to fish production vis-a-vis the supplemental feeds. It is highly desirable to

ascertain the extent to which fish productivity can be sustained with the maximum possible natural productivity of the water body, so that the addition of supplemental feeds can be tailored to the exact needs. This will have substantial economic advantages.

Proper dissemination and exchange of research results of fish nutrition studies in the Asian region would go on a long way in speeding up the growth of successful fish culture in Asia.

(Members of the group: H.P.C. Shetty, M.C. Nandeesha, D.E.M. Weerakoon, T. Subramanium).

List of Participants

INDIA

Dr T. Subramanium
Department of Zoology
Madras University
Gunidy Campus
Madras 600025

Prof H.P.C. Shetty
College of Fisheries
University of Agricultural Sciences
Mangalore 575002

Mr M.C. Nandeesha
Dept. of Aquaculture
College of Fisheries
Mangalore 575002

Prof T.J. Pandian
School of Biological Sciences
Madurai Kamraj University
Madurai 625021

PHILIPPINES

Dr Julia B. Pantastico
SEAFDEC Aquaculture Dept.
P.O. Box 256
Iloilo City

Dr E.M. Cruz
PCARRD Housing
Los Banos
Laguna Pail

Dr Lita V. Benitez
SEAFDEC Aquaculture Dept.
P.O. Box 256
Iloilo City

Dr Felicitas B. Fascual
SEAFDEC Aquaculture Dept.
P.O. Box 256
Iloilo City

Dr Yvonne N. Chiu
College of Fisheries
U.P. in the Visayas
Iloilo City

Ms Oeronica R. Ava
Aquacultural Dept.
SEAFDEC
Tig Banan
Iloilo City

Dr Corazon B. Santiago
SEAFDEC Aquaculture Dept.
Binangonan Research Station
Rizal

Dr Lenor M. Santos
College of Fisheries
Uni. of the Philippines
Diliman
Quezon City

SINGAPORE

Dr K.F. Shim
Dept. of Zoology
National University of Singapore
Kent Ridge

SRI LANKA

Prof Sena S. De Silva
Dept. of Zoology
University of Ruhuna
Matara

Dr Celine De Silva
Dept. of Zoology
University of Ruhuna
Matra

Miss R. Gunasekera
Dept. of Zoology
University of Ruhuna
Matara

Mr P.P.G.N. Siriwardene
Ministry of Fisheries
Maligawatte Secretariat
Colombo 10

Mr D.E.M. Weerakoon
Ministry of Fisheries
Maligawatte Secretariat
Colombo 10

THAILAND

Dr Mali Boonyaratpalin
NIFI
Bangkhen
Bangkok 10900

Dr Kok Leong Wee
Asian Institute of Technology
P.O. Box 2754
Bangkok 10501

INTERNATIONAL ORGANIZATIONS

Dr Roger S.V. Pullin
ICLARM
MC P.O. Box 1501
Metro Manila
Philippines

Dr I. Csavas
FAO Regional Office
39 Phra Atit Road
Bangkok 2

Dr Brian Davy
IDRC
Tanglin P.O. Box 101
Singapore 9124

Dr C. Devendra
IDRC
Tanglin P.O. Box 101
Singapore 9124

OBSERVERS

Dr Wong Tat-Meng
School of Biological Sciences
University Sains Malaysia
11800 Penang
Malaysia

Dr Dean M. Akiyama
American Soybean Association
541 Orchard Rd., #11-03
Liat Towers, Singapore 0923

Ms Myrna N. Bautista
SEAFDEC Aquaculture Dept.
P.O. Box 256, Iloilo City
Philippines

Ms Neila S. Sumagaysay
College of Fisheries
U.P. in the Visayas
Iloilo City, Philippines

Mr Gopinath Nagaraj
Dept. of Fisheries
8th Floor, Wisma Tani
Jalan Mahameru
Kuala Lumpur, Malaysia

Ms Oseni M. Millamena
SEAFDEC Aquacultural
Dept.
P.O. Box 256
Iloilo City, Philippines

Ms Evelyn S. Tubongbanua
College of Fisheries
U.P. in the Visayas
Iloilo City, Philippines

Mr Hugh Thomforde
College of Fisheries
U.P. in the Visayas
Iloilo City, Philippines

Asia is the cradle of Aquaculture. There is currently an increasing emphasis on the intensification of existing aquaculture systems in most Asian countries. Nutritional research will play a central role in this evolving trend. This book deals with on-going practices and trends in fish nutrition research in Asia. It also highlights the urgent need for fish nutrition research in the region.

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