Feeds and Feeding for Inland Aquaculture in Mekong Region Countries

Feed for grass carp is often collected by children and transported by bicycle; the Red River (Dan Phuong District, Watay Province, 20 km west of Hanoi, Vietnam). Photographer: Geoff Allan.

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Editors: Peter Edwards and Geoff L. Allan

NACA

Network of Aquaculture Centres in Asia–Pacific

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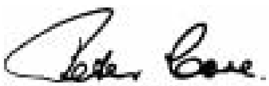
Foreword

Aquaculture of freshwater species in the Mekong regions of Cambodia, Vietnam, Lao PDR and Thailand is an important source of protein and income for small-scale land owners. However, the costs associated with nutrient inputs — as pond fertilisers to encourage growth of natural foods for fish, or as ingredients and feeds for fish — can make them hard to obtain and are constraining development of aquaculture. The limited availability of ingredients, and lack of information about the most cost-effective way to make and deliver feeds, often result in poor quality feed of low nutritional value and thence reduced production and profitability.

ACIAR has supported several projects to improve feeds and feeding practices for aquaculture species. The focus is on finding and evaluating locally available ingredients and understanding the nutritional requirements of target species. Capacity building among nutrition researchers working to develop improved diets, and extension workers transferring benefits to low-income farmers, are key priorities to ensure the impacts of the projects continue long after they have been finished.

This publication reports the results of a comprehensive study to describe the current situation with feeds and feeding for inland aquaculture in 'Mekong countries', and to identify the research and training needed to benefit small-scale aquaculture producers in these countries. It is number 56 in ACIAR's technical reports series. More information about ACIAR publications is available on our website at <www.aciar.gov.au>.



Peter Core
Director
Australian Centre for International Agricultural Research

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Abbreviations

AADCP	ASEAN Australia Development Cooperation Program
AGIFISH	Angiang Fisheries Import–Export Joint Stock Co.
AIMS	Aquaculture of Indigenous Mekong Species (project)
AIT	Asian Institute of Technology (Bangkok)
AIT–AARM	AIT–Aquaculture and Aquatic Resources Management
AIT SERD	AIT School of Environment, Resources and Development
APIP	Agriculture Productivity Improvement Project (Cambodia)
BAAC	Bank of Agriculture and Agricultural Cooperatives
CIRAD	Centre for International Cooperation in Agricultural Research for Development (France)
CP	Charoen Pokphand company (Thailand)
CTU	Can Tho University (Vietnam)
DLF	Department of Livestock and Fisheries (Laos)
DoF	Department of Fisheries
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCR	feed conversion ratio
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (German technical assistance agency)
HAKI	Fish Culture Research Institute, Szarvas, Hungary
IAAS	integrated agriculture/aquaculture systems
IFAS	integrated fisheries/aquaculture systems
IPAS	integrated peri-urban/aquaculture systems
JICA	Japan International Center for Cooperation in Agriculture
LLARReC	Lao Living Aquatic Resources Research Center
MRC	Mekong River Commission
NACA	Network of Aquaculture Centres in Asia–Pacific
NGO(s)	non-government organisation(s)
NIFI	National Inland Fisheries Institute
PADEK	Partnership for Aquaculture Development in Kampuchea
RDC	Regional Development Center (Laos)
RIA	Research Institute for Aquaculture (Vietnam)
RUA	Royal University of Agriculture (Cambodia)
SAO	Southeast Asian Aquaculture Outreach (NGO)
SAPL	Prek Leap College of Agriculture (Cambodia)
SUFA	Support to Freshwater Aquaculture
TSP	triple superphosphate
UAF	University of Agriculture and Fisheries (Vietnam)
UC	University of Cantho (Vietnam)
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WES	West–East–South project between HAKI, Hungary, The Netherlands funding and Vietnam (UC)
WTO	World Trade Organization

Executive Summary

The lack of availability and high cost of nutrients (including manures and inorganic fertilisers), feed ingredients and formulated feeds are restricting supply of aquatic protein for aquaculture in many developing countries. The specific problem with feeds and feeding varies greatly between different regions. A comprehensive field and desktop study was done to describe the current situation with feeds and feeding for inland aquaculture in 'Mekong countries' — Cambodia, Lao People's Democratic Republic, Vietnam and Thailand (northeastern part only) — and to identify how and where research, training and extension could be used to most benefit small-scale, low-income farmers.

This field study and desktop review were followed by a workshop held in Siem Reap, Cambodia on 24–26 June 2002. The workshop was attended by over 40 delegates, mainly from the four countries, with resource people from Australia and Thailand. The primary objective of the workshop was to discuss the review and agree on research, training and extension priorities to help improve feeds and feeding for inland aquaculture in the Mekong.

Two areas of traditional aquaculture in which small-scale farmers could benefit from improved feeding practice are integrated agriculture/aquaculture systems (IAAS) and integrated fisheries/aquaculture systems (IFAS). IAAS are constrained by limited nutrient inputs (manure, green fodder, agricultural by-products) and no tradition of on-farm feed formulation. If used, feed ingredients are currently fed singly and without processing in almost all cases. Pond fertilisation techniques are well understood scientifically, although research on the relative merits of using inorganic fertilisers either solely or in combination with manures is warranted in some areas, and there is a need for training and extension in semi-intensive culture using fertilisation techniques. IAAS could also be intensified through research into supplementary feeding of 'green water' ponds using different feed ingredients (or combinations of ingredients), possibly at different stages in the growth cycle. Availability of ingredients differs very widely, both regionally and seasonally, and an understanding of the best combinations of ingredients, for different species and culture methods is needed. The occasional use of manufactured feeds to augment other sources of nutrients also needs to be assessed.

In northern and central Vietnam, farming grass carp as the aquaculture component of integrated garden, aquaculture and livestock (VAC) systems is popular among poor households. However, women are spending increasing time and effort to collect and transport grass, which is itself highly sought-after. Development of practical, cost- and time-effective feeds for grass carp, based on available ingredients, is required.

The development of a denser, high-fibre feed for giant goramy, currently an expensive restaurant commodity, would possibly lower the cost of production and allow the species also to contribute to poverty alleviation. There is also a limited number of other high-value species currently being cultured or considered for culture, e.g. climbing perch and a carp indigenous to northern Vietnam (*Spinibarbus denticulatus*), for which nutritional requirements are unknown. Researchable issues for these species also include identifying suitable formulations for both farm-made and manufactured feeds.

For all species, identification of the merits of different methods of preparing feeds, e.g. chopping, grinding, cooking and binding, and delivering feeds, e.g. feeding frequency and application method such as feeding trays or broadcasting, require investigation.

Integrated fisheries/aquaculture systems use low-value fish species (trash fish) harvested from freshwater or marine systems to feed higher-value aquaculture species. This practice is unsustainable in many areas, and in some cases has led to conflict between the use of low-value fish for human consumption and for use as a feed ingredient. Formulation and evaluation of alternative ingredients and feeds are researchable issues for species in many areas. Understanding the supply and demand characteristics of trash fish used 'fresh' or as a low-quality dried fish or meal, and how demand for use in aquafeeds influences its direct use for human food, are related priorities.

A major researchable issue is the high cost of manufactured pelleted feed, which is due, in part, to conventional use of largely imported fish meal and, increasingly, soybean meal. Defatted rice bran containing up to 18% protein is one of the most widely available feed ingredients and has potential for used in increasing amounts for several species. It could reduce the need for imported protein sources, e.g. fish meal and soybean meal, in diets of omnivorous species such as river catfish (*Pangasius*) and tilapia that have increasing importance as a staple as well as an export commodity. The variability in rice bran quality needs to be reduced and more research on rice-bran-based formulations for selected species is warranted. The tropical rice-growing countries of the region have a comparative advantage over other parts of the world in terms of production of both feeds and fish.

It was clear that understanding of feeds and feeding was very variable both between and within the countries surveyed. A few farmers had a high level of understanding of nutritional requirements of the species they were culturing, and often had quite sophisticated methods of making feeds on their farms. Most farmers, however, sometimes located nearby, had poor understanding of how to feed their fish. There was a clear need for training and better farmer extension. The best methods of achieving these goals in different regions are researchable issues.

Similarly, the capacity to evaluate nutritional requirements and the best way to utilise available ingredients (including inorganic and organic fertilisers, feed ingredients and manufactured feeds) differed within and between countries. There was a perceived need to improve nutritional research capacity in many areas, and the initiation of a feed and feeding network, with a focused program of training and information exchange, is recommended.

Summary of Researchable Issues

1. Optimal combinations of fertilisers, feed ingredients and manufactured feeds to maximise production of different species and life stages for different regions
2. Development of time- and cost-effective feeds for grass carp

3. Development of cost-effective diets for high-value species like giant goramy, climbing perch and the northern Vietnamese carp, *Spinibarbus denticulatus*
4. Determination of optimal methods of preparing — e.g. grinding, cooking, binding — and delivering feeds
5. Understanding the supply and demand characteristics of trash fish, both freshwater and marine, in order to reduce dependence on this resource where necessary
6. Understanding the variability in supply and composition of rice bran and evaluation of the potential to increase use of this ingredient in feeds
7. Improving farmer extension on feeds and feeding
8. Improving nutritional research capacity through networking and training.

Feed ingredients, especially protein sources, are expensive and hard to obtain in many regions. This farmer is broadcasting rice bran in a small family-owned pond in Cambodia. Photographer: Peter Edwards.

1 Review of Feeds and Feeding in Mekong Countries[1]

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1.1 Introduction

The expansion of aquaculture in Asia over the last decade has been faster than anywhere else in the world (FAO 2000). Figure 1 presents production data for freshwater fishes and crustaceans in 'Mekong countries' (Cambodia, Lao People's Democratic Republic (PDR), Vietnam and Thailand) over the last decade. One of the drivers for this expansion has been the shift to more-intensive farming practices, in particular the use of increasingly sophisticated formulated feeds. There is a voluminous knowledge base on fish nutrition: in the primary literature, in textbooks, in proceedings, and in training manuals. An important Regional Expert Consultation on Farm-made Aquafeeds was held in Bangkok almost a decade ago in 1992 (New et al. 1993) in which emphasis in fish nutrition was placed on the needs of small-scale farmers already using, or with the potential to use, farm-made feeds. Furthermore, increasing emphasis has been given over the past decade by donors, including ACIAR, to poorer members of developing country societies.

Thus, it was timely to reassess the current situation regarding feeds and feeding in Southeast Asian inland aquaculture to better inform ACIAR (and other donors) on how to best direct research funds to benefit lower-income fish farmers. Important questions to be answered were:

- what is the extent of the 'middle ground' between traditional and industrial feeding practices?
- what are the feed and feeding issues constraining sustainable farming practices and more 'profitable' farming for lower-income fish farmers?

There was a need to supplement an academic framework of the subject and its key issues with up-to-date, field-level information of what farmers and related practitioners are actually doing (as opposed to what researchers might think they are, or should be).

1.2 Back-to-basics

The fundamental issues regarding fish feed are the size, nature and economics of the nutrient flows. A major characteristic of small-scale farms in the region is their

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limited nutrient flows. Small-scale farms are traditionally crop dominated (usually rice), with buffalo and/or cattle for draught, and scavenging poultry and pigs (where religion permits). Pigs are housed in sties except in the least-developed societies. Aquaculture is a relatively new farming practice in most areas of the region (as is feedlot livestock).

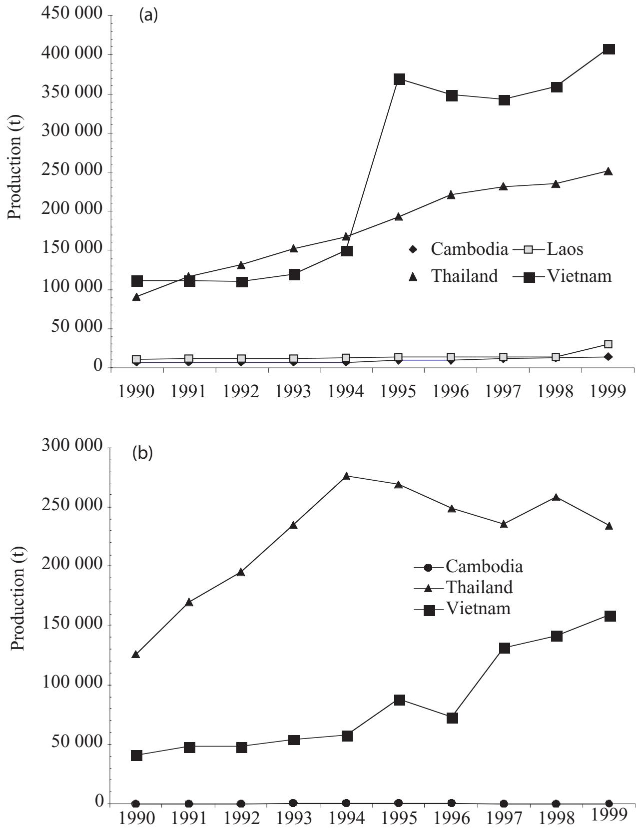

Figure 1. Aquaculture production in Mekong River countries: (a) freshwater fishes; (b) crustaceans.

As fish are relatively high-value produce, farmers are increasingly interested in their culture for increased income as well as food. Possible reasons why more small-scale farmers do not produce fish at present are:

- they do not know how to, as aquaculture is relatively new farming practice for them, i.e. there is an 'extension gap'.
- they do not have feed inputs, as they are resource-poor farmers
- they do not have access to markets for input supply and/or marketing produce.

Key questions to be answered are:

- how can aquaculture fit into existing farming systems (agroecosystems) and ecosystems such as rivers and lakes/reservoirs in the region through cage culture?

- how can the existing flow of nutrients on farms be improved with the introduction of aquaculture, or improved aquaculture practice on farms, using currently available on-farm or locally available nutrient sources?
- how can the nutrient flow to the farm be significantly increased to improve farm productivity and profitability through aquaculture?

1.3 The 1992 regional expert consultation

It is instructive to summarise the findings of the 1992 FAO/AADCP Regional Expert Consultation on Farm-made Aquaculture Feeds (New et al. 1993), the first to deal with the topic and thereby providing a baseline to inform this review. The Expert Consultation recognised that the bulk of Asian finfish aquaculture occurs in semi-intensive pond farming systems (depends on fertilisers and farm-made feeds) and intensive culture of catfish and snakehead in ponds and cages (using freshwater or inland small or 'trash' fish). This is still mainly the case today. The expert consultation defined farm-made feeds as 'feeds in pellet or other forms, consisting of one or more artificial and/or natural feedstuffs, produced for the exclusive use of a particular farming activity, not for commercial sale or profit'.

Although the consultation recognised that there is an increasing tendency for farmers to utilise commercial feeds formulated as nutritional complete diets in semi-intensive pond farming systems, and that farmers initially successful with use of farm-made feeds often shift to use of commercial feeds, the following points, which are still valid today, were made:

- Nutrition and feeding of finfish and crustaceans in semi-intensive pond farming systems are complex and poorly understood. There is little to no knowledge of dietary nutrient requirements for many of the cultured species in such systems due to the difficulty in quantifying the contribution of naturally available food organisms.
- Farm-made feeds facilitate the use of locally available agricultural products and agro-industrial processing wastes that would otherwise have limited use within the community, thus also providing environmental advantages.
- There is a need to identify and utilise alternative protein sources that are both inexpensive and sustainable.
- Farm-made feeds are potentially cheaper than commercial feeds.
- There is scope for improving not only farm-made feeds but also formulated feed by commercial feedstuff manufacturers.

The expert consultation recommended the organisation of further meetings to assess R&D progress at 3-year intervals, but none appears to have been held. This increases the value of the current investigation.

A change in terminology to that used in the 1992 consultation is used; from 'farm-made feeds' and 'commercial feeds' to 'traditional feeding practice', 'improved feeding practice' and 'manufactured feed'. The consultation stated that 'commercial feeds' are produced by feedstuff manufacturers but 'farm-made feeds' may be:

- natural feed production within a pond culture facility by fertilisation, as outlined by Yakupitiyage (1993) in a paper presented at the consultation
- single ingredients such as trash fish or rice bran which are fed directly to fish without processing
- may be purchased or commercial.

Even if farmers do not purchase inputs there is an opportunity cost involved in time and labour to collect them.

1.4 Review outline

The terms of reference for the review are given in Appendix 2. The review comprised two main activities: a field survey in Cambodia, Lao PDR, Thailand and Vietnam; and an academic framework based on the literature of fish nutritional requirements, fish feeding habits, nutritional characteristics of feed ingredients and feeds, and feeding practice (feed preparation and storage, feeding strategies). From the results of these two activities, researchable issues have been identified and a tabular summary made of: species of overall current importance; feeding practices (traditional, improved, and manufactured feed) by culture facility (ponds, cages); and potential for increased production and/or profitability through improved feeding practices.

1.5 Current practices and potential

The diversity and rate of change of aquaculture practice in the region almost defies generalisation. Assessment of the need for improved feeds and feeding practices is best viewed initially in the context of the evolution or developmental chronology of pond and cage aquaculture in the region. Traditional aquaculture developed by farmers themselves has a long history in relatively few areas of the region, so that in most areas it is limited in occurrence and underdeveloped with considerable potential for both expansion and intensification. Furthermore, the introduction of manufactured formulated feed by agro-industry has a relatively recent history of less than a decade, even in areas where it being promoted. Aquaculture in both ponds and cages needs to be assessed as integrated with agriculture or fisheries, or as a stand-alone activity. Improvements to traditional practice in particular may come from farmers themselves as well as from scientifically based or industrially derived knowledge or inputs. Farmer-based knowledge is likely to also influence the future development of manufactured feed. The current importance of cultured inland species with feeding practice in pond and cage culture, and potential for research to yield benefits, are assessed for Cambodia (Table 1), Lao PDR (Table 2), northeastern and central Thailand (Table 3), northern Vietnam (Table 4) and southern Vietnam (Table 5).

1.6 Demand and marketing

Demand for fish is high throughout most of the countries of the region, as fish is a traditional as well as a preferred source of food. However, market and farm-gate prices vary widely depending on supply and demand.

Table 1. Current importance, culture facility, feeding practice and potential of inland species in Cambodia. 0, +, +, ++ in increasing importance; * = indigenous to region.

Species	Current import-ance	Pond culture Feeding practice			Cage culture Feeding practice			Potential	
		Traditional	Improved	Manu-factured feed	Traditional	Improved	Manu-factured feed	Pond culture	Cage culture
Anabantids									
**Anabas testudineus* (Climbing perch)	+	+						++	
**Osphronemus p gourami* (Giant goramy)	0							++	
**Trichogaster pectoralis* (Snakeskin goramy)	+	+						++	
Carps									
Aristichthys nobilis (Bighead carp)	+	+							++
**Barbodes altus* (Tin foil barb)	+				+			+++	++
**B. gonionotus* (Silver barb)	++	++			+			+	
**Cirrhinus microlepis*	0							+++	
C. mrigala (Mrigal)	++	++						++	++
**Ctenopharyngodon idella* (Grass carp)	+	+						++	
**Cyprinus carpio* (Common carp)	++	++	+					+	
**Hypophthalmichthys molitrix* (Silver carp)	+	+						++	
Labeo rohita (Rohu)	++	++						+	+
**Leptobarbus hoeveni* (Hoeven's barb)	+				+			+	
**Morulius chrysophekadion*	0							+	
**Osteochilus melanopleurus*	0								
Catfish									
Clarias macrocephalus × *C. gariepinus* (Hybrid walking catfish)	+	+	+					+	
**Pangasius bocourti*	+				+				+
**P. hypophthalmus* (Silver striped catfish)	+++	++	++		+++	+		++	+++
Cichlids									
Oreochromis niloticus (Nile tilapia)	+	+			+			+++	++
O. spp. (Red tilapia)	0							+	++

Table 1. (cont'd) Current importance, culture facility, feeding practice and potential of inland species in Cambodia. 0, +, +, ++ in increasing importance; * = indigenous to region.

Species	Current import-ance	Pond culture			Cage culture			Potential	
		Feeding practice			Feeding practice			Pond culture	Cage culture
		Traditional	Improved	Manu-factured feed	Traditional	Improved	Manu-factured feed		
Featherbacks									
**Notopterus notopterus* (Spotted featherback)	0							+	
Gobies									
**Oxyeleotris mormoratus* (Sand goby)	+				+				+
Prawns									
**Macrobrachium rosenbergii* (Giant river prawn)	+	+						++	
Snakehead									
**Channa micropeltes* (Red snakehead)	+++				+++				+++
**C. striata*	+	+						+	

Table 2. Current importance, culture facility, feeding practice and potential of inland species in Lao PDR. 0, +, +, ++ in increasing importance *Indigenous to region.

Species	Current import-ance	Pond culture			Cage culture			Potential	
		Feeding practice			Feeding practice			Pond culture	Cage culture
		Traditional	Improved	Manufac-tured feed	Traditional	Improved	Manu-factured feed		
Anabantids									
**Anabas testudineus* (Climbing perch)	+	+						++	
**Osphronemus exodon*	+				+			+	++
**O. gourami* (Giant goramy)	+				+			+	++
**Trichogaster pectoralis* (Snakeskin goramy)	+	+						++	

Table 2. (cont'd) Current importance, culture facility, feeding practice and potential of inland species in Lao PDR. 0, +, +, ++ in increasing importance *Indigenous to region.

Species	Current importance	Pond culture			Cage culture			Potential	
		Feeding practice			Feeding practice			Pond culture	Cage culture
		Traditional	Improved	Manufactured feed	Traditional	Improved	Manufactured feed		
Carps									
Aristichthys nobilis (Bighead carp)	+	+			+			+	+
**B. gonionotus* (Silver barb)	++				++			+++	
**Cirrhinus microlepis*	0							+	
**C. molitorella* (Mud carp)	0							+	
C. mrigala (Mrigal)	++	++						+++	
**Ctenopharyngodon idella* (Grass carp)	+	+			+			++	++
**Cyprinus carpio* (Common carp)	++	++						+++	
**Hypophthalmichthys molitrix* (Silver carp)	+	+						+	
Labeo rohita (Rohu)	++	++						+++	
**Morulius chrysophekadion*	0							+	
**Osteochilus melanopleurus*	0							+	
**Puntioplites falcifer*	0							+	
Catfish									
Clarias macrocephalus × *C. gariepinus* (Hybrid walking catfish)	+	+						+	
C. gariepinus (African walking catfish)	+	+						+	
**Pangasius hypophthalmus* (Silver striped catfish)	+	+						++	++
Cichlids									
Oreochromis niloticus (Nile tilapia)	++	++						+++	
O. spp. (Red tilapia)	+						+	+	++
Featherbacks									
**Notopterus notopterus* (Spotted featherback)	+	+						++	
Prawns									
**Macrobrachium rosenbergii* (Giant river prawn)	0							+	

Table 2. (cont'd) Current importance, culture facility, feeding practice and potential of inland species in Lao PDR. 0, +, +, ++ in increasing importance *Indigenous to region.

Species	Current importance	Pond culture – Feeding practice: Traditional	Pond culture – Feeding practice: Improved	Pond culture – Feeding practice: Manufactured feed	Cage culture – Feeding practice: Traditional	Cage culture – Feeding practice: Improved	Cage culture – Feeding practice: Manufactured feed	Potential: Pond culture	Potential: Cage culture
Snakehead									
**Channa micropeltes* (Red snakehead)	+				+				++
**C. striata*	+	+						+	

Table 3. Current importance, culture facility, feeding practice and potential of inland species in northeastern and central Thailand. 0, +, +, ++ in increasing importance. *Indigenous to region.

Species	Current importance	Pond culture – Feeding practice: Traditional	Pond culture – Feeding practice: Improved	Pond culture – Feeding practice: Manufactured feed	Cage culture – Feeding practice: Traditional	Cage culture – Feeding practice: Improved	Cage culture – Feeding practice: Manufactured feed	Potential: Pond culture	Potential: Cage culture
Anabantids									
**Anabas testudineus* (Climbing perch)	+	+			+	+		++	
**Osphronemus gourami* (Giant goramy)	+	+						+++	+++
**Trichogaster pectoralis* (Snakeskin goramy)	+	+		+				+	
Carps									
Aristichthys nobilis (Bighead carp)	+	+							
**B. gonionotus* (Silver barb)	+++	++	+					++	
**Cirrhinus microlepis*	+	+						+	
C. mrigala (Mrigal)	+++	++	+					++	
**Ctenopharyngodon idella* (Grass carp)	+	+						+	
**Cyprinus carpio* (Common carp)	+++	++	+					++	
**Hypophthalmichthys molitrix* (Silver carp)	+	+	+					+	
Labeo rohita (Rohu)	+++	++	+					+++	
**Leptobarbus hoeveni* (Hoeven's barb)	0							+	
**Morulius chrysophekadion*	0							+	
**Osteochilus melanopleurus*	0							+	

Table 3. (cont'd) Current importance, culture facility, feeding practice and potential of inland species in northeastern and central Thailand. 0, +, +, ++ in increasing importance. *Indigenous to region.

Species	Current importance	Pond culture – Feeding practice: Traditional	Pond culture – Feeding practice: Improved	Pond culture – Feeding practice: Manufactured feed	Cage culture – Feeding practice: Traditional	Cage culture – Feeding practice: Improved	Cage culture – Feeding practice: Manufactured feed	Potential: Pond culture	Potential: Cage culture
Catfish									
Clarias macrocephalus × *C. gariepinus* (Hybrid walking catfish)	+++	+		+				++	
C. gariepinus (African walking catfish)	+	+		+				++	
**Clupisoma sinensis*	+				+				+
**Mystus wyckoides*	+				+				++
**Pangasius bocourti*	+				+				+
**P. conchophilus*	+				+				+
**P. hypophthalmus* (Silver striped catfish)	++	++			+				++
**P. larnaudii*	+				+			++	+
**P.sanitwongsei*	+				+				+
Characins									
Colossoma brachypomum (Freshwater pompano)	+						+		++
Cichlids									
Oreochromis niloticus (Nile tilapia)	+++	++	+	+			+	+++	++
O. spp. (Red tilapia)	++	+		+			++	++	+++
Featherbacks									
**Notopterus notopterus* (Spotted featherback)	+	+						++	
Gobies	+								
**Oxyeleotris mormoratus* (Sand goby)					+				+
Prawns									
**Macrobrachium rosenbergii* (Giant river prawn)	++		+	+				+++	
Snakehead									
**Channa gachua*	+	+							
**C. micropeltes* (Red snakehead)	+	+			+			+	+
**C. striata*	+++	+++							

Table 4. Current importance, culture facility, feeding practice and potential of inland species in northern Vietnam. 0, +, +, ++ in increasing importance. *Indigenous to region.

Species	Current importance	Pond culture: Feeding practice: Traditional	Pond culture: Feeding practice: Improved	Pond culture: Feeding practice: Manufactured feed	Cage culture: Feeding practice: Traditional	Cage culture: Feeding practice: Improved	Cage culture: Feeding practice: Manufactured feed	Potential: Pond culture	Potential: Cage culture
Carps									
Aristichthys nobilis (Bighead carp)	+	+						+	
**C. molitorella* (Mud carp)	+	+						+	
C. mrigala (Mrigal)	+++	+++						+++	
**Ctenopharyngodon idella* (Grass carp)	+++	+++			+++			+++	+++
**Cyprinus carpio* (Common carp)	+++	+++						+++	
**Hypophthalmichthys molitrix* (Silver carp)	+++	+++						+	
Labeo rohita (Rohu)	+++	+++						+++	
Mylopharyngodon piceus (Black carp)	+	+						++	
**Semilabeo obscorum*	0							++	++
**Spinibarbus denticulatus*	+	+			+			++	++
Catfish									
**Bagrus yarrelli*	+				+				++
Clarias macrocephalus × *C. gariepinus* (Hybrid walking catfish)	+	+						+	
**Hemibagrus gutattus*	+				+				++
**Pangasius bocourti*	+						+		+
**P. hypophthalmus* (Silver striped catfish)	+						+	++	++
Characins									
Colossoma brachypomum (Freshwater pompano)	+	+		+				++	
Cichlids									
Oreochromis niloticus (Nile tilapia)	++	++		+				+++	++
O. spp. (Red tilapia)	+			+				++	+++
Prawns									
**Macrobrachium rosenbergii* (Giant river prawn)	+			+				++	
Snakehead									
**Channa fuscus*	+	+							+

Table 5. Current importance, culture facility, feeding practice and potential of inland species in southern Vietnam. 0, +, +, ++ in increasing importance. *Indigenous to region.

Species	Current importance	Pond culture: Feeding practice – Traditional	Pond culture: Feeding practice – Improved	Pond culture: Feeding practice – Manufactured feed	Cage culture: Feeding practice – Traditional	Cage culture: Feeding practice – Improved	Cage culture: Feeding practice – Manufactured feed	Potential: Pond culture	Potential: Cage culture
Anabantids									
**Anabas testudineus* (Climbing perch)	+	+		+				+++	
**Helostoma temmincki* (Kissing goramy)	++	++				+		+	
Osphronemus gourami (Giant goramy)	++	++		+				+++	++
**Trichogaster pectoralis* (Snakeskin goramy)	+	+						++	
Carps									
Aristichthys nobilis (Bighead carp)	+	+						+	
**Barbodes altus* (Tin foil barb)	+				+				+
**B. gonionotus* (Silver barb)	+++	+++			+			+++	
**B. schwanfeldii*	+				+			+	+
**Cirrhinus microlepis*	0							+++	
C. mrigala(Mrigal)	++	++	+					+	
**Ctenopharyngodon idella* (Grass carp)	+	+						+++	
**Cyprinus carpio* (Common carp)	++	++	+					+	
**Hypophthalmichthys molitrix* (Silver carp)	+	+						+++	
Labeo rohita (Rohu)	++	++	+						
**Leptobarbus hoeveni* (Hoeven's barb)	+				+				+
**Morulius chrysophekadion*	0							+	
**Osteochilus melanopleurus*	+	+						+	

Table 5. (cont'd) Current importance, culture facility, feeding practice and potential of inland species in southern Vietnam. 0, +, +, ++ in increasing importance. *Indigenous to region.

Species	Current import-ance	Pond culture – Feeding practice			Cage culture – Feeding practice			Potential	
		Traditional	Improved	Manufac-tured feed	Traditional	Improved	Manu-factured feed	Pond culture	Cage culture
Catfish									
Clarias macrocephalus × *gariepinus* (Hybrid walking catfish)	+	+						+	
**Pangasius bocourti*	+					+	+		+
**P. conchophilus*	+				+				
**P. hypophthalmus* (Silver striped catfish)	+++	+++			++	++	+	++	+++
* *P. hunyit*	+				+				
**P. larnaudii*	+				+				+
Colossoma brachypomum (Freshwater pompano)	+			+				++	
Cichlids									
Oreochromis niloticus (Nile tilapia)	++	++	+	+	+	+	+	+++	+++
O. spp. (Red tilapia)	+			+	+	+	+	++	+++
Featherbacks									
**Notopterus notopterus* (Spotted featherback)	+	+						++	
Gobies									
**Oxyeleotris mormoratus* (Sand goby)	+	+							+
Prawns									
**Macrobrachium rosenbergii* (Giant river prawn)	+	+		+				+++	
Snakehead									
**Channa gachua*	+	+						+	+++
**C. micropeltes* (Red snakehead)	++				++			++	++
**C. striata*	+	+			+				

A farm-gate fish to paddy (F:P) ratio is introduced to indicate relative demand for fish, based on an index with attributes of purchasing price parity. This enables comparison of the relative prices of fish between countries with different social and economic conditions. The highest F:P ratios for staple food fish occur in Laos where neither locally captured and cultured nor imported fish from Thailand can currently satisfy demand. In contrast, the lowest F:P ratios occur in southern Vietnam where an abundance of wild fish from the Mekong Delta lowers prices year round rather than in the rainy season in most areas.

The situation with fish in northeastern Thailand is the reverse of the usual situation with agricultural products, as the price is higher in rural than urban areas because of unsatisfied rural demand for fish. In northeastern Thailand, the same relatively high price is obtained by farmers for fish irrespective of species, size and season. However, in one area of Sakorn Nakorn the farm-gate price of fish has fallen recently. The farmer thought that this might be due to the rapid increase in volume of tilapia from cage culture. In China, the prices of fish have fallen drastically recently, due to overproduction, especially of high-value species but also of staple fish. Furthermore, staple fish usually do not suffer from marked fluctuations in market price like livestock, particularly pigs, but this may be because there is still a relatively high and unsatisfied demand for fish.

In both Cambodia and northeastern Thailand, farmers were observed to get higher farm-gate prices for fish sold in relatively small amounts locally compared with the sale of large amounts of fish destined for urban markets, indicating a degree of urban market saturation in some areas. In contrast, there was little difference between the farm-gate price of locally marketed fish and fish destined for urban markets in Laos, due to huge unsatisfied demand for fish in urban as well as rural areas.

Although there are no feed mills for manufactured fish feed in Laos and Cambodia, highly competitive sectors in Thailand and Vietnam should serve to keep prices relatively low. Prices should decline further for feed with a fairly low protein content of 15–18% comprised mainly of defatted rice bran rather than soybean meal and trash fish, to be used as feed for herbivorous and omnivorous species.

Fish have higher market value when destined for local luxury markets, restaurants and export. *Pangasius* and tilapia of appropriate quality are the fish exported in the largest amounts, especially the former, with about 60,000 tonnes exported as fillets from Vietnam. Recently, however, the farm-gate price of cage-raised *Pangasius* has fallen drastically due to competition from processing plants to export fillets at low prices. The sustainability of the *Pangasius* export market to the USA is further threatened by protectionism despite recent World Trade Organization (WTO) declarations concerning global free trade.

1.7 Pond culture

Some types of pond aquaculture have several hundred years of tradition in the region, including the VAC (an acronym from the first letter of the Vietnamese words for garden, pond and livestock quarters) integrated system in the Red River Delta formerly based on collection of wild carp seed from rivers, overhung latrine ponds in the Mekong Delta formerly based on collection of wild *Pangasius* seed from rivers, and overhung latrine ponds in West Java formerly based on common carp bred at household level. A second wave of development of pond aquaculture in Southeast Asia followed the introduction of Chinese carps from China. Seed was transported by sea each year at the end of the 19th and the start of the 20th century. While there have been considerable increases in both the area and the production from pond-based aquaculture, especially over the last 2–3 decades in response to declining supplies of wild fish, there is a huge 'extension gap' between traditional and improved practices in most countries of the region.

Vietnam went through a cooperative period like China, but traditional pond culture in the Red River Delta, although similar to that in China, was left as a relatively neglected, household-level activity rather than being consolidated, expanded and intensified by being reorganised into communes, as was agriculture. There are useful lessons to be learned about small-scale, relatively well integrated, 'Chinese style' crop, livestock and fish-farming systems that also have a role for the more-resource-poor farms in Cambodia, Laos and northeastern Thailand. Features of traditional Chinese pond culture all have relevance for at least some areas of the countries of the region, depending on social attitudes and resources: grass and other vegetation for macrophagous fish; nightsoil, livestock manure and green manure as fertilisers; supplementary feeds from brans, oil cakes and distillery wastes; and village-level as opposed to private ponds. Traditional practice depends on a polyculture of mainly herbivorous and omnivorous species, the composition of which varies depending on species availability and preference. Supplementary feed is traditionally fed as single ingredients, unprocessed and uncooked. There is a tradition of cooking for only pig feed. Rice bran, in particular, is fed inefficiently as a broadcast powder.

Small-scale, pond aquaculture in these countries is usually constrained by limited nutrient inputs. Small-scale pig rearing at household level, which is still widespread in Vietnam and to some extent in Cambodia and Laos, was a traditional activity in northeastern Thailand but is now much less common with the concentration of pig farming in the hands of larger, richer and usually peri-urban farmers. This appears to have taken place largely before the introduction of aquaculture and the widespread availability of fish seed in Thailand. This process of consolidation has also begun in southern Vietnam. The availability of other forms of manure is limited. There is a cultural aversion to use of nightsoil in aquaculture, except in Vietnam. Most poultry scavenge for their food and thus their manure is difficult to collect. Large ruminant manure can be collected, but it has a low nutrient content. Aquaculture is also constrained by limited feed, despite the widespread availability of grass and other types of vegetation as grass carp is not popular except in northern and central Vietnam. Millers retain rice bran in most countries and oil cakes are not readily available. However, farmers who have now mastered the principles of pond fertilisation are experimenting with intensification of aquaculture through use of supplementary feed in green-water ponds.

More recent is the development of stand-alone ponds with aquaculture as the sole farming activity. Although stand-alone ponds may be fertilised with wastewater, as in the Thanh Tri district of Hanoi, most are intensively fed by refuse of various kinds, such as waste food from restaurants and canteens, food-processing factory waste, slaughterhouse waste and trash fish. Some species, e.g. *Clarias, Macrobrachium* and tilapia, may be fed with commercial pelleted feed.

Pelleted feed is readily available but profit margins are low and many small-scale farmers have lost money through investing in this route, especially through attempting to culture *Clarias*, an activity which rapidly rose in popularity but declined with production-driven price falls in all countries in the region. Farmers continue to culture this fish in central and northeastern Thailand.

A traditional aquaculture activity in China is private lease of ponds from the local community, with rentals based on the degree of incidental pollution from run-off and intentional pollution from public overhung latrines. Such ponds also occur in the Red River Delta in Vietnam. In northeastern Thailand there are natural swamps that have been recently excavated by the Department of Fisheries (DoF) to form 'village fish ponds', but these usually are devoid of significant amounts of fish as they may be unable to receive nutrient-rich run-off because of large surrounding dikes. Their primary function is as water reservoirs, although DoF has asked the Asian Institute of Technology (AIT) to help to increase fish production. A comparison of the green water in a typical southern China village pond, fertilised from run-off from pig sties and overhung latrines, with the silty infertile water of one new village pond observed recently in Roi-Et in northeastern Thailand illustrated the problem with nutrient deficiency.

Considerable research has been carried out by AIT and other agencies on fertilisation of ponds with livestock manure and inorganic fertilisers. AIT attempted to introduce feedlot duck/fish integrated farming as an initial strategy for promoting small-scale aquaculture. While it succeeded technically in terms of duck and fish production, it failed spectacularly due to socioeconomic constraints, in particular input supply and marketing (duck feed and duck eggs, respectively). It should be noted that feedlot livestock farming depends on manufactured feeds and is therefore equivalent to intensive aquaculture using manufactured pelleted feed. Similar results were subsequently obtained by a Canadian/DoF project. More recently, a Belgian/BAAC (Bank of Agriculture and Agricultural Cooperatives) project has promoted the feedlot/livestock route with some success, but this may be due to considerable institutional support. Use of formulated feed for livestock and/or fish may not be the most appropriate way for small-scale farmers to culture fish because of high feed costs and often low prices for livestock and their produce. However, a mixture of fine rice-bran and livestock feed concentrate has been successfully promoted by AIT for small-scale farmers to nurse fingerlings in hapa nets in ponds because the relatively small amounts are used only for a short time.

The cheapest form of nutrients that farmers can purchase in terms of nitrogen and phosphorus content is undoubtedly inorganic fertilisers. Farmers commonly use them in the region on crops, including rice (and elsewhere as pasture for ruminants). They can be used to produce plankton-rich green-water for fish. (Theoretically at least, they can also be used to produce green fodder for fish, although AIT research showed this to be uneconomic because of the large amount of fertiliser required for grass to attain a relatively high nutritional value, with a minimum of 15% protein content on a dry matter basis). AIT has successfully used them at two levels: a low-level input of urea to supplement buffalo manure as pond fertilisers (with DFID support) and a high-level input of urea and triple superphosphate (TSP) (with CRSP (Collaborative Research Support Program), USA support). Farmers are now experimenting with supplementary feed in fertilised ponds, so this study is timely as there is farmer demand for the technology.

AIT Outreach farmers in northeastern Thailand are now progressing to intensification of their fertilised ponds with supplementary feeding. One farmer visited uses high-input urea/TSP, but two others who now have sufficient resources through profit from aquaculture, raise livestock to produce green water. Even though they make little money on livestock, there is no need to purchase fertilisers for greening ponds. One farmer was enterprising enough to produce his own diet modified from a recipe found in a book. He cooks broken rice to a paste, mixes in rice bran, soybean meal, fish meal and pig oil, and feeds as moist balls in a feeding tray. He sometimes cooks and grinds golden snail to reduce fish meal requirement.

The Department of Agriculture in Thailand has been promoting use of cherry snails as an ingredient in fertilisers for crops but farmers are increasingly using them to feed ducks and fish. A small-scale farmer visited was feeding tilapia, silver barb and rohu in ponds with a recipe that includes cherry snails and EM as he received training in the latter. (EM is a mixture of bacteria used to ferment vegetable matter, molasses and manure. It is used as a fertiliser and is promoted for its probiotic properties.) Rather than purchasing EM, he makes it himself from fermenting cherry snails, pineapple and sugar. A moist feed in balls is made from ground snails, ground vegetation and rice bran with EM and a little salt. Cherry snails are collected, 200 kg/day, from his own and neighbours' fields in the rainy season. As cherry snails now occur throughout the region, their abundance and use as an alternative protein source in fish feeds warrants research.

The central species in the Chinese carp polyculture system is the herbivorous grass carp which is also native to the Red River and forms part of the traditional carp polyculture of the delta. A species that can feed on green fodder, especially grass, is especially relevant for poor farming households as wild grass can be collected on and around the farm and be supplemented with leaves of cassava, sweet potato, sugarcane and banana as well as duckweed and chopped banana stems. Unfortunately, due to the voracious and inefficient feeding of grass carp, collecting green fodder is very time-consuming. Women in northern and central Vietnam reported spending up to several hours each day collecting 10–100 kg fodder for ponds of around 0.06 ha that produce about 700 kg grass carp/year in two crops. As more households take up aquaculture, the demand on the limited resource is increasing drastically, necessitating travelling increasing distances and spending more time collecting it. There is a need to research alternative high-fibre diets for grass carp. Research is also justified on *Spinibarbus denticulatus*, a high-value carp indigenous to northern Vietnam with a similar feeding niche to grass carp. There is limited information available on nutritional requirements for this species.

Another herbivore widely cultured in the region is the giant goramy, which takes up to 18–24 months to reach a marketable size of at least 1 kg when fed only tender aquatic or terrestrial vegetation. It is mainly destined for the restaurant trade because it is expensive due to its long culture period. Research is required to develop denser, high-fibre diets to reduce both growth period and market price, so that the fish may contribute to poverty alleviation. Fish fed commercial pellets have unacceptably soft flesh, but a farmer in central Thailand produces large fish of acceptable quality in 1 year with a predominantly rice-bran-based diet. As for *S. denticulatus*, there is a need for information on the nutritional requirements for giant goramy.

1.8 Cage culture

Traditional cage culture probably first developed as an activity integrated with fisheries rather than agriculture in Cambodia, possibly more than a century ago. It subsequently spread to Thailand, Vietnam and, more recently, Laos. Older literature sometimes states that it is indigenous to Thailand but mentions Siem Riep Province, previously in Siam but now in Cambodia. The traditional and intensive cage culture of the region developed in association with the 'live boats' of fishers which have water-filled holds used to hold and transport the catch. The classic French account by Chevey and Le Poulain (1940) of the freshwater fisheries of Cambodia refers to them as a 'jonque vivier' or 'fishpond junk'. Initially, it was entirely dependent on wild fish both as seed and feed, and a major researchable issue is how to reduce dependence on wild fisheries. The term 'farm-made' feed is particularly inappropriate for capture fisheries dependent cage culture, as fish are commonly fed whole, chopped or minced as a sole ingredient without cooking. Integration may also be at the livelihood level, as cage farmers, especially small-scale ones, may also be fishers and collect their own seed and feed. Cage farmers in Dong Nai in Vietnam collect small clams and tubifex worms to feed common carp.

Pangasius hypophthalmus is cultured in cages (and ponds of large-scale farmers) using either cooked rice bran or uncooked, small, wild fish depending on supply, i.e. on price and season, without knowledge of fish nutritional requirements. Cooking rice bran is apparently recent in Cambodia, having been introduced by a non-government organisation (NGO). At Chau Doc in Vietnam, the most common feed for *P. hypophthalmus* is a cooked mixture of rice bran and marine trash fish at a 2:1 ratio. Until recently, fish were fed manually, but now are fed through a mincer with various sizes of die plate depending on stage of culture.

Cage culture of *Channa micropeltes*, another major species in the region cultured mainly in Cambodia, is fed entirely on small, wild, freshwater fish. Small-scale farmers feed slowly by hand but large-scale farmers use mincers in Cambodia and Vietnam or feeding trays in Cambodia.

The seasonal availability and difficulty in storing fresh or dried fish and rice bran constrain meaningful research on better diet formulation.

Modern cage culture using drums as floats, wood or steel frames, nylon mesh for the cages and manufactured pelleted feed originated in Japan in the 1960s but has developed rapidly over the last 5–6 years in the region. The Charoen Pokphand (CP) company has had a major direct influence on culture of red tilapia, the major species grown with pelleted feed, in Thailand and indirectly in Laos. The main researchable issue is the cost of feed, but in Vietnam cage design is also important. Large volume cages are being used to culture dissolved oxygen breathing tilapia. High FCRs suggest that high-density, low-volume (HDLV) cages, as used in Thailand, may be more appropriate.

Culture of grass carp in cages, integrated with agriculture, has developed rapidly in northern and central Vietnam; and more recently by fishers in Nam Ngum reservoir in Laos. Grass carp cage culture in Vietnam faces the same problem as for pond culture but in Laos it is based primarily on submersed aquatic macrophytes from the reservoir, the supply of which is seasonal. Fishers in Nam Ngum have limited land to grow cassava and the dry season limits grass growth.

Extensive cage culture in eutrophic ‘green water’ lakes and reservoirs was introduced from Nepal into Nam Houm reservoir in Laos. In Nepal, it has considerably improved the livelihoods of a group of fishers in the Pokhara Valley. However, suitable sites are rare in the region and Nam Houm is already suffering from hyper-eutrophication due in part to rapid increase in the number of cages and associated feeding of fish.

1.9 Feed and feeding strategies

The main aim of the research proposed is to bridge the gap in feeding practice between ‘traditional feeding practice’ and use of ‘manufactured feed’ through ‘improved feeding practice’. Traditional feeding practice is based on three types of integration with:

- agriculture in integrated agriculture/aquaculture systems (IAAS) with usually limited on- or near-farm sources of fertilisers, green fodders and agricultural by-products
- fisheries in integrated fisheries/aquaculture systems (IFAS) using small freshwater or marine fish or ‘trash fish’
- peri-urban areas in integrated peri-urban/aquaculture systems (IPAS) using wastes of cities and industry such as wastewater or sewage, waste vegetables from markets, waste food from canteens and restaurants, and factory processing wastes including those from slaughterhouses and fish-processing factories. IPAS may also conceptually include fertilisers; i.e. manure from intensive feedlot livestock and effluents from intensive aquaculture as both depend on manufactured feed.

As pointed out by the 1992 expert consultation, there is scope for research to improve not only so-called ‘farm-made feeds’, but also commercially manufactured feed, so that it can be better integrated into the local economy with less international or global trade of ingredients, and be marketed at a lower price.

As extension must be linked for the fruits of research to improve livelihoods, another major challenge is to extend knowledge on appropriate practice to farmers. The success of any project to introduce new knowledge or technology to farmers throughout the region will depend on the development of appropriate technical messages, appropriate media in which to communicate them, and appropriate channels of extension or communication. The development of national and regional R&D (extension) networks is required if there is to be any appreciable impact on the livelihoods of poor, small-scale farmers and consumers.

When farmers purchase commercially manufactured, formulated feed, it is the major item in the cost of production. Use of formulated feed is usually feasible for larger farmers who have the ability to manage cash flow from investment in feed before harvest of produce. They also benefit from large-scale operation, with economies of scale to compensate for relatively low profit margins due to high unit feed costs. However, small-scale livestock and/or fish farmers experience considerable financial difficulties with the use of commercially manufactured feed. The relatively high unit cost of commercially manufactured feed may be offset initially by the high profit margins of high-value fish but small-scale farmers are seldom early adopters of new technology and so are less likely than richer farmers to benefit from the early phase of expansion of an aquaculture technology. If small-scale farmers do take up aquaculture, it is usually later, when markets become saturated and demand falls.

Farmers interviewed during the survey recognised that commercially manufactured feed is the most effective way to culture fish, but the cost of production currently exceeds the market value of staple food fish. There is therefore a need to improve traditional methods of feeding practice as well as to lower the cost of production of manufactured feed by using cheaper, locally available ingredients. It may be feasible in the future to culture staple food fish on manufactured feed, but considerations such as economies of scale for purchasing feeds or ingredients and in influencing market price will be important considerations. The comparison with mass production of chickens on commercially manufactured feeds in some developing as well as developed countries indicates that this approach is possible. The vertical integration in the poultry industry, where one company also controls seed supply (chicks), feed production, grow-out and processing, is rarely practised in aquaculture in Southeast Asia. This approach has worked with channel catfish in the USA, with Atlantic salmon in Europe and South America, and with tilapia in Thailand.

The single largest issue emerging from the survey was how to reduce feed costs. Small-scale farmers rarely used manufactured feed, but some larger-scale farmers involved in cage culture or pond culture of higher-value species reported they had to use manufactured feed at least some of the time to maintain growth of fish or prawns. In northern Vietnam, the need to attain marketable size in a shorter growing season is an additional factor.

Farmers using manufactured feed had various strategies to lower feed costs:

- use of a cheaper brand of an equivalent pellet; several farmers, while recognising that CP pellets were of better quality than those of other manufacturers, had broken a contract farming agreement to enable them to purchase cheaper manufactured feed to culture tilapia in cages
- use of a cheaper type of fish pellet, such as those for herbivorous fish rather than pellets specifically formulated for tilapia
- use of livestock feed e.g. duck pellets for *Macrobrachium*
- reduction in the amount of manufactured feed used, by mixing it with formulated pig feed, rice bran, cassava root, and cassava and *Leucaena* leaves.

Another strategy followed by some farmers is to manufacture their own feed. While most farmers said they lacked the knowledge, time or labour to formulate their own feed, examples were found, e.g. in Nakon Sakorn, northeastern Thailand. A major problem expressed by several farmers is the difficulty in obtaining the ingredients, but a farmer in northeastern Thailand ordered ingredients by phone from a provincial town feed merchant who arranged for them to be delivered by the local bus service. A large-scale Kalasin *Macrobrachium* farmer who purchased ingredients was mixing feed for several farmer clients in the area. The BAAC project, also in northeastern Thailand, was establishing farmer cooperatives, with a lead farmer in each province mixing, for subsequent distribution to cooperating farmers, ingredients delivered by a feed company. However, there is a question of whether it is economically feasible and sustainable to obtain and process ingredients, and distribute the 'farm-made feed'. Furthermore, feeds with a water content above about 10% will spoil rapidly, presenting potential problems with transport and storage.

There is no tradition of on-farm feed formulation in Asian aquaculture, and some of the farmers' recipes were at worst bizarre and at best inefficient. Even so, the cost of production was lower than the purchase price of commercially manufactured feed. Besides, rational formulation of feed for different phases of growth of various fish species raised in 'green water' and intensive 'clear water' systems in cages, feed processing would also benefit from research. Feed preparation is largely limited to cooking in a wok material derived from rearing pigs, chopping either manually or by machine, and maceration of ingredients through a motor driven meat mincer fitted with a die to produce strands of feed which are subsequently sun dried. Grinding of ingredients is rare.

The feasibility of farmers obtaining or producing ingredients from on-farm activities, particularly from cultivation of crops, was explored during the survey, but very few farmers were growing crops or producing animals to provide ingredients for farm-made feed. However, there does seem to be some potential to produce at least some food for fish on small-scale farms, as indicated by research on-farm feed production and integration with livestock being carried out by Reg Preston at the University of Tropical Agriculture in Phnom Penh. During the survey, farmers were asked in particular about growing soybean to feed fish but none were doing so or appeared even to consider it worth while or feasible. Most said they had no experience with soybean but a farmer in northeastern Thailand who was preparing farm-made feed, had grown the crop previously in a contract farming scheme but had given up over health concerns because of the requirement for a high pesticide input. A constraint of soybean is a relatively low yield which is exacerbated by the generally small size of farm in the region. One farmer replied it is more profitable to grow watermelon. In general, significant on-farm production of feed ingredients for use in formulating diets on the same farm does not appear to be feasible. The practice probably has relevance only for poorer farming households engaged in traditional small-scale aquaculture and in the earlier stages of development of aquaculture as part of their livelihood strategy, and not for intensification of production through improved feeding practice.

A recommendation of the 1992 expert consultation was a need to identify and use alternative protein sources for fish feed. Considerable quantities of feed ingredients are imported; e.g. Vietnam imports about 70,000 tonnes each of soybean meal and fish meal annually as local production cannot meet domestic demand. Vietnam produces about 130,000 tonnes of soybeans annually, but this is insufficient to meet the demand for human food. The American Soybean Association has recently opened an office in Hanoi so import of more soybean from the USA is to be expected as the WTO facilitates global trade. Similarly, peanuts are grown for human consumption. Importation of beans into the countries of the region is inevitable due to their dense populations and limited per capita availability of arable land.

According to Philippe Serène (formerly managing director of the feed-manufacturing company Proconco), defatted rice bran with a protein content of 18% is the best prospect for a locally available source of protein for herbivorous and omnivorous fish species, including *Pangasius* and tilapia which have a bright future for both domestic and export markets. Such fish can digest up to 60% rice bran in the diet, the amino acid profile of which can be balanced by addition of a few percent (4%) fish meal. The tropical rice-growing countries of the region would therefore have a comparative advantage in production of both feeds and fish.

However, quality of rice bran varies widely because of milling practices. There is a need to quantify the amount and quality of rice bran available in key areas and carry out feeding trials on the best way to maximise the effectiveness of this ingredient. Research is also warranted on high-fibre diets for the grass carp *Spinibarbus denticulatus* indigenous to northern Vietnam, and the giant goramy.

Research on reducing dependence on 'trash fish', both freshwater species from rivers, lakes and reservoirs, and marine species, is a priority related to vegetable-based protein research. Research is required to understand both supply and demand for traditional 'fresh' use or as a low-quality meal. How demand for use of 'trash fish' for aquafeeds is affecting its direct use as human food requires study also.

Research on slaughterhouse waste (chicken offal, bones) is probably not warranted, as these are appropriated by better-off farmers in large quantities through contracts, but other alternative protein sources with potential benefit for poor farmers are golden or cherry snails and distillery waste from local liquor production, e.g. in Vientiane province in Laos. Brewery waste, e.g. in suburban Hanoi, probably falls in the former category.

Quality of ingredients is of concern in feed manufacture because improper or lengthy storage can lead to rancidity of rice bran, ammoniacal trash fish and maize containing aflatoxin. There is a view in Laos that manufactured feed for culture of tilapia in cages, currently imported, could be produced locally, as 80–85% of ingredients are available locally; rice bran, broken rice, maize and cassava are plentiful locally so that there should only be a need to import soybean and fish meal in future. However, a major constraint is the poor and inconsistent quality of local ingredients.

1.10 Research needs according to stakeholders

The following account is based on replies received from persons responding to questioning about what they thought are 'researchable issues in fish feeds and feeding'.

1.10.1 Cambodia

- Cage farmers replied that price is the only feed research issue.
- As trash fish are abundant in Cambodia, there is high potential for intensive aquaculture, but source of ingredients is a major problem for small-scale farmers. For this reason, the Prek Leap College of Agriculture (SAPL) uses fertilisers in pond culture. The production is low but culture is economic. It is recognised that intensification also requires feed.
- Although farmers use separate ingredients to feed fish in Cambodia, Bati Station formulates feed using three to four ingredients for use on-station. They propose to formulate pelleted feed to see if it is an economic strategy to

improve feeding efficiency. There is a need to produce a cheaper pellet as all pelleted feed is currently imported. The local Charoen Pokphand Company feed mill produces pig and poultry feed in powdered form only.

- Royal University of Agriculture (RUA) is carrying out a feeding trial with *Channa striata* in which golden snail is being compared with trash fish as a feed.
- Southeast Asian Aquaculture Outreach (SAO), a NGO promoting aquaculture, is also trying to lower feed costs and explore alternative ingredients. Growth of marble goby slows when pelleted feed is mixed with chopped trash fish; live feed (fingerlings of mrigal, silver barb and tilapia) is similar to trash fish; but trash fish is better than rice-field crab. *Barbodes altus* grows better on pellets than on duckweed and water spinach, which produce similar growth. Broodstock and fingerling nutrition of *Clarias macrocephalus* is better with cooked rice bran and dried fish than with rice bran and pelleted feed. Trash fish is the best feed for *Anabas*, but its use is not economic as the farm-gate price is only R4000/kg so diets also include duckweed and pelleted feed. Attempts are being made to reduce use of trash fish for *Wallago attu*, a carnivore, by using 30% rice bran with 70% trash fish.

1.10.2 Lao PDR

- There is great concern that the rapidly increasing culture of exotic tilapia is based on imported pelleted feed.
- Cage culture in Nam Ngum reservoir is largely based on *pa keo* (a small clupeid, *Clupeichthys aesarnensis*), so there is a need to reduce the dependency on this wild fish by developing feed formulations.
- Growth performance of indigenous fish species once they can be bred.
- Feeds and feeding for different culture systems for poverty alleviation.
- Integration of intensive and more-extensive systems to reuse resources and to benefit both rich and poor.
- Use of pa keo as a source of fish meal.

1.10.3 Thailand

- Diet formulation of supplementary feeds for fertilised green-water ponds.
- The main problem expressed repeatedly was how to reduce feed costs, as commercially formulated feed was said to be expensive and constantly increasing in price.

1.10.4 Vietnam

- According to Research Institute for Aquaculture (RIA) No. 2, only applied nutritional research has been carried out in Vietnam, using existing and mainly western scientific knowledge applied to Vietnamese species. The weakest link is the lack of basic knowledge on the nutrition of species cultured in Vietnam.
- There is little information on broodstock nutrition.

- RIA No. 2 is about to complete a project on the use of local resources and local infrastructure to produce 100 kg formulated feed/day for farmers. The approach should also be applied to inland aquaculture.
- According to RIA No. 1, there is a definite need for nutrition research to cover the middle ground between traditional and industrial feeding practices, through intensified VAC (an acronym from *vuon*, *ao* and *chuong*, Vietnamese for garden, pond and livestock quarters, a small-scale integrated system) and cage culture, and high-value new species (both indigenous and introduced exotic species such as *Colossoma* and larger sized tilapia).
- A farming-systems research approach is required for farm-made feeds, so that research is relevant for specific local conditions.
- Animal protein is available, e.g. small shrimp at D1,000–1,500/kg in Tac Ba and many other reservoirs, that can be used for feed but also as food directly for poor people, especially in mountainous and remote areas; crops such as sweetpotato leaf and cassava leaves and roots have potential.
- Feeding costs can be lowered by more economical use of ingredients, and by using different feeding strategies for fish of different ages. For most fish it is not economic to feed fish throughout the whole culture cycle, but is economic for two periods — nursing and fattening fish from 100 g to marketable size.

1.11 References

Chevey, P. and Le Poulain, F. 1940. La pêche dans les eaux douces du Cambodge. Saigon, Vietnam, Gouvernement Général De L'Indochine, 193p.

FAO (Food and Agriculture Organization of the United Nations) 2000. The state of world fisheries and aquaculture 2000. Rome, FAO. [FAO Fishstat was used to produce statistics on freshwater fisheries and crustaceans in Mekong countries<www.fao.org>.]

New, M.B., Tacon, A.G.J. and Csavas, I., ed. 1993. Farm-made aquafeeds. Proceedings of the regional expert consultation on farm-made aquafeeds, 14–18 December 1992, Bangkok, Thailand. Bangkok, FAO Regional Office for Asia and the Pacific, 434p.

Yakupitiyage, A. 1993. On-farm feed preparation and feeding strategies for carps and tilapias. In: M.B. New, Tacon, A.G.J. and Csavas, I., ed. Farm-made aquafeeds. Proceedings of the regional expert consultation on farm-made aquafeeds, 14–18 December 1992, Bangkok, Thailand. Bangkok, FAO Regional Office for Asia and the Pacific, pp. 87–100.


Cambodian farmer prepares feed for Basa catfish by mixing fishmeal and pelletted pig feed. Photographer: Peter Edwards.

2 Review of Fish Nutrition and Feeding[2]

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2.1 Introduction

Improvements in feeds and feeding strategies for aquaculture species need to be underpinned by a sound understanding of the basic principles of fish nutrition. Even in aquaculture systems where the cultured species derive all their nutrition from natural food, an understanding of nutritional requirements and how various supplementary feedstuffs (ingredients) might be utilised can help improve the productivity of the system. For intensive systems, where animals rely totally on feed inputs, it is essential that feeds are formulated to meet but not exceed the target species energy and nutritional requirements.

As many aquaculture farmers in Asia also farm other livestock (e.g. chickens and pigs), it is worth briefly considering the major differences between feeds for terrestrial and aquatic species. The major difference is that aquatic animals have much lower requirements for energy than terrestrial animals; because they are cold-blooded and live in an aquatic environment, their energy needs for thermoregulation and locomotion are much lower. There are two obvious implications of this: firstly, aquaculture diets are usually higher in protein; and secondly, the food conversion efficiency for aquaculture species is usually much better (i.e. the food conversion ratio (FCR) is lower).

Published values for protein requirements for aquatic animals range from about 20–60%. Why is this such a big range? The overall protein contents of the tissues of different aquaculture species are actually remarkably similar at 60–70% of dry weight (Anon. 1992) and 16–18% of wet weight. The large difference reflects differences in the ability of different species to utilise non-protein sources, lipid and carbohydrate, for energy. This is called 'protein-sparing'. For herbivorous and omnivorous species, dietary protein contents are much lower than for carnivorous species because the animals can use carbohydrate for energy. Although not a nutrient per se, dietary energy is just as important in fish nutrition as in nutrition for other species.

In the following parts of this section on fish nutrition, some of the key published literature is summarised or listed. The focus is on tropical, freshwater species.

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2 Citation: Allan, G.L. 2004. Review of fish nutrition and feeding. In: Edwards, P. and Allan, G.L., ed., Feeds and feeding for inland aquaculture in Mekong region countries. Canberra, ACIAR Technical Reports No. 56, 37–48.

2.2 Nutritional requirements

Regardless of whether fish feed predominantly on natural food (including phytoplankton, macroalgae, zooplankton, meiofauna, benthos and other pond organisms, including other fish) or on supplementary or complete feeds, they require energy and the same suite of nutrients. Research on nutrition of carps, tilapias and catfish is carried out in Europe and America in addition to Asia. Recent reviews of this information for common carp have been completed by Jauncey (1982), Satoh (1991) and Takeuchi et al. (2002), for Indian major carps by Murthy (2002), for tilapia by Luquet (1991) and Shiau (2002), and for channel catfish by Robinson and Li (2002). Far less information is available for the air-breathing catfish of the genus *Clarias*, although Jantrarotai (1996) has published information for hybrids (*Clarias macrocephalus* × *C. gariepinus*) on requirements for protein, energy, fatty acids and carbohydrates, and on evaluation of ingredients and practical diet formulation (for a summary and list of publications see Allan et al. 2000). The very limited nutritional information for *Pangasius* catfish and snakehead (*Channa* spp.) was summarised by Paripatananont (2002), but although other freshwater species such as goramy (family Anabantidae), sand goby (*Oxyeleotris marmoratus*) and featherback (*Notopterus notopterus*) are cultured in many areas, nutritional information for these species is almost completely lacking.

The most expensive nutrient to supply is usually protein. Carnivorous species tend to have a higher protein requirement than omnivores or herbivores, and are more expensive to feed. Earlier life stages such as fry and fingerlings also require relatively more protein than juveniles and immature adults. Published requirements for protein for several species are summarised in Table 6. Fish do not require protein as such, but rather a well balanced mix of essential and non-essential amino acids. The published requirements for essential amino acids are presented in Table 7.

One of the nutritional features that separates herbivorous and omnivorous fish from carnivorous fish is the ability to utilise carbohydrates, especially starch, for energy. Most of the carps, tilapias and many of the catfish are able to efficiently utilise carbohydrates, a feature that is closely linked with their success in traditional and extensive and semi-intensive aquaculture where fish are fed on natural food items, or low-cost, available ingredients that typically contain a high content of carbohydrates. This is evident by comparing the recommended nutrient specifications for carnivorous and omnivorous fish species given in Tables 8 and 9, respectively.

In addition to its role as an energy source, starch also plays a very important role in pellet manufacture. It is very difficult to process pelleted diets without some carbohydrate (starch), and the matrix formed by starch is responsible for most of the binding properties of manufactured pellets. The role of starch in extruded diets is especially critical and largely responsible for buoyancy control.

Lipids or fats are required nutrients for fish and supply energy and essential fatty acids. They can also be an important consideration in the manufacture of pellets, especially where extrusion technology is used. Excess dietary lipid can lead to unwanted accumulation of visceral and muscle fat in harvested fish. Summaries of lipid biochemistry of relevance in fish nutrition have been published by NRC (1993) and Tacon (1990). In general, carps seem to have gross requirements for lipid of less than 10% (7–8% for Indian major carps, according to Murthy (2002)) and require both n-3 and n-6 fatty acids at 1% of each in the diet (Murthy 2002; Takeuchi et al.

2002). Although lipid has a protein-sparing effect for tilapia, contents above 12% depressed growth (reported in Shiau (2002)). Requirements for both n-3 and n-6 fatty acids have been reported but as there have been some contradictory results, this may be a future research area for tilapia nutrition (Shiau 2002).

Table 6. Dietary protein requirement of carps, tilapias and Asian catfish.[a]

Species	Requirements (%)	Size
Carps:		
Cyprinus carpio	30–38	Fingerling/juveniles
Ctenopharyngodon idella	28–35	Fingerling
Hypophthalmichthys molitrix	37–42	Fry/fingerling
Aristichthys nobilis	30	Fry
Catla catla	35–47	Fry
	40	Fingerlings
	30	Adults
Labeo rohita and *Cirrhinus mrigala*	40	Fry
	35	Fingerlings
	30	Adults
Barbodes gonionotus	35	Fingerling
Tilapias:		
Oreochromis niloticus	45	Fry
	30–36	Fingerlings
	28–35	Juveniles
Oreochromis mossambicus	50	Fry
	30–40	Fingerlings
	29–35	Juveniles
Asian catfish:		
Clarias batrachus	40	
Clarias macrocephalus/gariepinus	35	
Pangasius hypophthalmus	27–29	Fingerlings
	>18	Juveniles?
Pangasius larnaudii	35	Fingerlings
	20	Juveniles
Snakehead:	43	Fry
Channa sp.	36	Fingerlings

[a] From information summarised by Jantrarotai (1996), Takeuchi et al. (2002), Murthy (2002), Shiau (2002) and Paripatananont (2002).

Practical diets for channel catfish typically contain 5–6% lipid, with about 3–5% coming from dietary ingredients and the rest sprayed onto pellets after manufacture, to control dust (Robinson and Li 2002). Channel catfish seem to require n-3 fatty acids (1–2% of diet) but not n-6 fatty acids (Robinson and Li 2002). For hybrid *Clarias* catfish, Jantrarotai and Somsueb (1995) and Jantrarotai et al. (1995) reported an optimal content of 4–10% for dietary lipid, 0.8–0.9 for n-3 fatty acids and 1.0–1.5% for n-6 fatty acids.

Fish also require vitamins and minerals. In extensive and semi-intensive culture, these requirements are met through natural food and, in general, supplementary diets require less attention to specific requirements for vitamins and minerals. Tables 10 and 11 present summaries of published requirements for vitamins and minerals.

Table 7. Quantitative essential amino acid requirements (per cent of dietary protein) of carps, tilapias and channel catfish.[a]

Amino acid	*Cyprinus carpio*	*Catla catla*	*Labeo rohita*	*Oreochromis niloticus*	*Ictalurus punctatus*
Arginine	4.2	4.8	5.8	4.2	4.3
Histidine	2.1	2.5	2.3	1.7	1.5
Isoleucine	2.3	2.4	3.0	3.1	2.6
Leucine	3.4	3.7	4.6	3.4	3.5
Lysine	5.7	6.2	5.6	5.1	5.1
Methionine	3.1	3.6	2.9	2.7	2.3
Phenylalanine	6.5	3.7	4.0	3.8	5.0
Threonine	3.9	5.0	4.3	3.8	2.0
Tryptophan	0.8	1.0	1.1	1.0	0.5
Valine	3.6	3.6	3.8	2.8	3.0

[a] From information summarised by NRC (1993), Jantrarotai (1996), Murthy (2002) and Shiau (2002).

Table 8. Recommended dietary nutrient levels for carnivorous fish species.[a]

Nutrient level	Fish size class				
	Fry	Fingerling	Juvenile	Grower	Brood fish
Crude lipid, % minimum	16	14	14	12	10
Fish:plant lipid	7:1	7:1	7:1	7:1	7:1
Crude protein, % minimum	52	49	47	45	47
Amino acids, % minimum					
Lysine	3.08	2.90	2.78	2.66	2.78
Methionine	1.00	0.94	0.90	0.87	0.90
Cystine	0.36	0.34	0.33	0.31	0.33
Carbohydrate, % maximum	15	20	25	25	25
Major minerals, %					
Calcium, % maximum	2.5	2.5	2	2	2
Available phosphorus, % minimum	1.0	0.8	0.8	0.7	0.8
Magnesium, % minimum	0.08	0.07	0.07	0.06	0.07

[a] Data from Tacon (1990).

Table 9. Recommended dietary nutrient levels for omnivorous fish species.[a]

Nutrient level	Fish size class				
	Fry	Fingerling	Juvenile	Grower	Brood fish
Crude lipid, % minimum	8	7	7	6	5
Fish:plant lipid	1:1	1:1	1:1	1:1	1:1
Crude protein, % minimum	42	39	37	35	37
Amino acids, % minimum					
Lysine	2.48	2.31	2.19	2.07	2.19
Methionine	0.81	0.75	0.71	0.67	0.71
Cystine	0.29	0.27	0.26	0.24	0.26
Carbohydrate, % maximum	30	35	40	40	40
Major minerals, %					
Calcium, % maximum	2.5	2.5	2	2	2
Available P, % minimum	1.0	0.8	0.8	0.7	0.8
Magnesium, % minimum	0.08	0.07	0.07	0.06	0.07

[a] Data from Tacon (1990).

Table 10. Vitamin requirements of carps, tilapias and Asian catfish (mg or IU/kg).[a]

Vitamin	*Cyprinus carpio*	*Oreochromis niloticus*	*Clarias batrachus*
Vitamin A (IU)	4,000–20,000		
Vitamin D_3	Not required		
Vitamin E	100–300	50–100	
Vitamin K	Not required		
Thiamine	Required		Not required
Riboflavin	4–10		Required
Pyridoxine	5.4		Required
Pantothenate	30–50		Required
Nicotinic acid	28		Required
Biotin	1		
Folic acid	Not required		Required
Cyanocobalamin	Not required	Not required	
Inositol	440		
Choline	4000		
Ascorbic acid	Not required	1250	Required

[a] From information summarised by Tacon (1990).

Table 11. Mineral requirements of carps and tilapias.[a]

Mineral	Carps	Tilapias
Calcium	0.028%	0.65%
Phosphorus	0.6–0.7%	0.5–0.9%
Magnesium	0.04–0.05%	0.06–0.08%
Zinc	15–30 mg/kg	10 mg/kg
Copper	3 mg/kg	3–4 mg/kg
Manganese	12–13 mg/kg	12 mg/kg

[a] From information summarised by Tacon (1990) and Jantrarotai (1996).

2.3 Ingredients

Protein, carbohydrate and lipid all supply energy fish need for maintenance and growth. Energy is released by the oxidation of amino acids, carbohydrates and lipids, with mean values of 23.6, 17.2 and 39.5 MJ/kg, respectively. However, as there are major differences between how well different species of fish digest the energy from different ingredients, as well as major differences between ingredients, it is very important to understand the bioavailability of energy from different feed ingredients before formulating diets.

Comprehensive descriptions of the pathways of energy flow in fish can be found in NRC (1993) and Tacon (1990). The major losses from ingested energy occur in faeces (excretory loss). The remainder is called digestible energy. From digestible energy, losses occur in gill and urine excretions (the remainder is metabolisable energy). From metabolisable energy, losses occur in energy needed for waste formation and digestion and adsorption (the remainder is net energy). From net energy, any energy not used for maintenance (basal metabolism, voluntary activity and any thermal regulation), becomes recovered energy and is that energy contained in the fish carcass (NRC 1993).

In contrast to warm-blooded terrestrial animals, fish are cold blooded, and once excretory losses of energy are accounted for, the other losses are minimal, and differences between different ingredients and fish species relatively minor. For this reason, determination of digestible energy is usually the focus of ingredient evaluation in fish nutrition. However, the difficulty of collecting fish faeces to measure excretory losses still presents a major hurdle to the fish nutritionist. Different techniques include collecting faeces after settlement (problems with overestimating digestibility because of leaching) or collecting faeces by stripping fish or after dissection (problems with underestimating digestibility because digestion is incomplete when faeces are collected).

When evaluating the potential for any ingredient to be used in fish feeds the following factors need to be considered:

1. The nutrient composition of the ingredient. In general, the higher the protein content the more valuable the ingredient (provided there is no contamination or anti-nutritional factors present). Tacon (1990) has published information about the composition of a large number of ingredients available in Southeast Asia. A summary of some of the key nutrients for some of these ingredients is included in Appendix 6.2. Other tables are also available (e.g. Hertrampf and Pascual 2000; Anon. 1992). Consistency of composition is very important as well. Many animal waste products, like slaughterhouse wastes, can vary widely in composition and this can present considerable difficulties to diet formulators.
2. Availability and price. Clearly, ingredients that are easily available and relatively cheap are preferable.
3. Presence and concentration of anti-nutrients. Anti-nutrients are usually found in plant ingredients and can cause serious problems, ranging from reduced feed intake, food efficiency and growth, as well as pancreatic hypertrophy, hypoglycaemia, liver damage and other pathologies (De Silva and Anderson 1995). Fortunately, most anti-nutrients are heat labile and are easily deactivated by cooking. Some of the major anti-nutrients are described in Table 12.
4. Presence of contamination (e.g. from pesticides, hydrocarbons from fuel or oil or toxins from fungal contamination [a common problem with peanut meal]) (Table 12).
5. Digestibility and how well energy and nutrients are utilised.
6. Effects on attractiveness and palatability of feeds. In general, aquatic products like fish meals, and animal meals, tend to make feeds more attractive (i.e. bring animals to the feeds) and palatable (i.e. make fish want to keep eating the feeds).

Table 12. Major anti-nutrients and contaminants in feed ingredients.[a]

Anti-nutrient	Description	Example of ingredients	Treatment
Trypsin inhibitors	Substances that inhibit protein metabolism. Many different kinds but most bind trypsin and/or chrysotrypsin	Most cereals, most oilseeds (soybean, peanut, rapeseed, cottonseed etc.), most legumes	Most protease inhibitors are heat labile and are deactivated by cooking.

Table 12. (cont'd) Major anti-nutrients and contaminants in feed ingredients.[a]

Anti-nutrient	Description	Example of ingredients	Treatment
Haem-agglutinising agents (lectins)	Proteins with a specific affinity for sugar molecules. Causes agglutination of red blood cells. Can reduce absorption of nutrients and can cause internal hemorrhage.	Barley, potato, rice bran, lentils, many legumes, peanut, soybean	Heat labile
Gossypol	Polyphenolic reactive pigments that exhibit acid properties. Reduce protein quality, especially lysine. Symptoms include reduced feed intake and growth.	Cottonseed	Not heat labile and not deactivated by soaking. Dietary iron and other minerals sometimes reduce undesirable effects.
Mimosine	Unusual amino acid thought to affect production of thyroxin and fish growth	Ipil-ipil (*Leucaena* sp.)	Mimosine content can be reduced by soaking in water.
Glucosinolates	When hydrolysed, glucosinolates release thiocynate ion, isothiocynates, goitrin and nitrates all of which function as anti-thyroid agents.	Rapeseed (canola is a name given to rapeseed cultures with low glucosinolate content)	Heating and soaking in water can reduce but not deactivate anti-nutrient properties.
Phytic acid	Approximately 70% of the phosphorus in soybean meal and many other plant-based ingredients is in the form of phytate which is largely unavailable to fish. Phytates form strong protein–phytic acid complexes that reduce the availability of protein and several minerals including zinc, manganese, copper, copper and iron.	Soybean meal and many plant ingredients	No effective treatment. Should increase mineral supplementation in soy and plant-based diets
Cyclopropenoic fatty acids (CFAs)	Can cause lesions, increased glycogen deposition and elevated saturated fatty acid content in liver. Powerful carcinogens when fed in combination with aflatoxins.	Cottonseed	No treatment
Erucic acid	Monounsaturated fatty acid that can cause lipid accumulation and necrosis in the heart and problems with skin, gills and kidneys.	Rapeseed	No treatment
Mycotoxins	Fungi grow well on many ingredients especially when stored in warm and damp or humid conditions. Can produce mycotoxins that are carcinogenic, cytoxic or neurotoxic.	Peanut (groundnut) meal is particularly susceptible but can affect many ingredients.	Proper storage in cool, dry conditions. Do not use mouldy feeds or feed ingredients.
Oxidative rancidity	Oxidation of unsaturated lipids produces free radicals, peroxides, hydroperoxides, aldehydes and ketone which can be toxic.	Marine and some plant oils and ingredients or diets with unsaturated lipids	Add antioxidants to feed. Don't use rancid oils.

Table 12. (cont'd) Major anti-nutrients and contaminants in feed ingredients.[a]

Anti-nutrient	Description	Example of ingredients	Treatment
Heavy metals	Metals may be both nutrients and toxins. Major toxic metals are mercury, cadmium, arsenic, copper, lead, aluminum, zinc.	Sometimes a problem in fishmeals	Metal chelators such as EDTA can reduce toxicity when added to the diet.

[a]Adapted from De Silva and Anderson (1995) and NRC (1993).

2.4 Feed preparation and feeding

Types of feed preparation are (see also Figure 2):

1. extensive – no inputs of fertiliser or feeds, animals are totally dependent on natural food
2. semi-intensive – fertilisers and/or feeds are added to enhance and complement natural food respectively
3. intensive – animals are totally dependent on nutritionally complete diets.

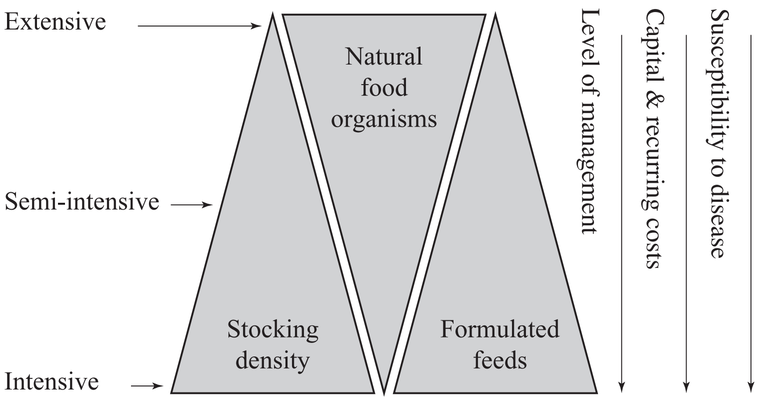

Figure 2. Schematic representation of the range of aquaculture practices in relation to inputs. Modified from De Silva (1993).

Practices that involved flooding fields with water containing larval or juvenile fish, or netting off sections of natural waterways, and then harvesting fish some time later, are examples of extensive aquaculture. Adding nutrients is usually done to increase productivity, and over 70% of the total production of finfish in Asia was semi-intensive (Tacon et al. 1995). The simplest method is to add fertilisers. Tacon (1990), Lin et al. (1997), Knud-Hansen (1998) and Edwards et al. (2000) discuss how and when to fertilise ponds. The basic goal of fertilisation is to increase the amount of natural food available for fish. Either organic fertilisers (manures), inorganic fertilisers (sometimes called chemical fertilisers [e.g. urea, superphosphate]) or a combination of both are used. The basic nutrients added are nitrogen (N), phosphorus (P) and carbon (C). Other nutrients may also be required to stimulate phytoplankton growth, including potassium (K), silicon (Si), calcium (Ca), magnesium (Mg) and chloride (Cl), depending on the nutrient status of pond soil and water (Lin et al. 1997).

Considerations in choosing the type of fertiliser include availability and cost, fertility of water and soil, and type, availability and value of the fish to be farmed. For detailed accounts of when liming is required, how much and what types to add see Boyd (1990), Tacon (1990) or Lin et al. (1997). Many inorganic fertilisers, particularly P, have low solubility in water. For P, for example, the amount of it that dissolved after the fertiliser was allowed to settle through a 2 m water column at 29°C was only 4.6, 5.1, 7.1 and 16.8% for superphosphate, triple superphosphate, monoammonium phosphate (MAP) and diammonium phosphate (DAP), respectively. Nitrogen is more soluble and 5.1, 11.7, 61.7, 85.9 and 98.8% N dissolved from MAP, DAP, sodium nitrate, ammonium sulfate and ammonium nitrate, respectively (Lin et al. 1997). The undissolved portion ends up in the sediment and can be released over time or remain bound to sediments. The amount of nutrients in different types of fertilisers is presented in Table 13 (after Lin et al. 1997).

On many farms in Southeast Asia, manure is in short supply and often used on other crops. The relative benefits of using manure in fish ponds compared with the benefits of using the manure on rice or other crops need to be considered in the context of whole-farm income and profit.

For semi-intensive farming systems where supplementary feed is added, farmers may just add feeds towards the end of the culture cycle as natural food resources become overgrazed, or combine fertiliser and feed inputs throughout the culture cycle. Edwards et al. (2000) emphasised that supplementary feeds should complement the limiting nutrients in natural foods. They presented unpublished data demonstrating the sequential improvements to tilapia production when fish in ponds received fertiliser only, fertiliser plus an energy supplement, fertiliser plus an energy and a protein supplement, fertiliser plus an energy, protein and a P supplement, and fertiliser plus an energy, protein, P and vitamin supplement. The relative merits of different approaches will be determined by the type of species (or mix of species) being farmed and the availability and cost of fertilisers and supplementary feed ingredients and feeds.

Table 13. Total amount of nutrients in different types of fertilisers.

Fertiliser	Nutrient content [a]	
	Nitrogen	Phosphorus
Urea	45	0
Ammonium nitrate	35	0
Superphosphate	0	10
Triple superphosphate	0	22
Diammonium phosphate	18	24
Cattle faeces	1.9	0.6
Cattle urine	9.7	0.1
Pig faeces	2.8	1.4
Pig urine	13.2	0.02
Buffalo faeces	1.2	0.6
Buffalo urine	2.1	0.01
Human faeces	3.8	1.9
Human urine	17.1	1.6

[a] Percentage of dry weight for inorganic fertilisers and faeces, urine as liquid.

In some turbid ponds, fertilisers alone may not be effective in stimulating natural food (Edwards et al. 2000), and supplementary or complete diets may be needed. Fish size at harvest in ponds where only fertilisers have been used is often smaller than in ponds where supplementary feeds or complete diets have been used. Presumably, this is because larger fish have difficulty obtaining sufficient nutrition from plankton and other natural food items (Edwards et al. 2000).

In general, fish productivity is greatest when they are fed nutritionally complete diets. However, although excellent diets are widely available, their price is often prohibitive. Farmers have the option of using complete diets for part of the culture cycle only (e.g. just after stocking or in the month before harvest) or blending the complete diet with other feed ingredient(s) (e.g. rice bran or diets for other animals like pigs or poultry).

There are many methods of preparing feeds, ranging from none (unprocessed feed ingredients) to factory-based, sophisticated manufacture of extruded pellets. Supplementary feeds may just be single ingredients, e.g. rice bran, or quite sophisticated blends of several ingredients. Complete diets are also sometimes used as supplementary feeds and fed in addition to other ingredients or only at certain stages of the culture cycle. Some species are not very efficient at consuming feed ingredients delivered as powder and feed delivered in this form may simply act as an expensive fertiliser. Moulding the feed into moist balls usually improves the feeding efficiency.

Another common practice is to process feed ingredient(s) through manual or motorised mincers that force the mixture through a die to give long strands of feed. These strands may then be sun-dried and broken up and delivered to fish. Where several ingredients are used, they should be thoroughly mixed before being put through the mincer. The process of mixing and mincing can increase the feed efficiency by ensuring that individual food particles are of a suitable size for effective intake and digestion, and that all ingredients are well distributed within the mixture.

Feed ingredients and mixtures are often cooked before being fed to fish. Cooking has several potential benefits. Firstly, it is very effective at destroying bacteria that may be contaminating the feed or ingredients. It also helps preserve the feed if it is to be stored. Cooking also helps to increase the digestibility of carbohydrate-rich ingredients (e.g. broken rice and rice bran) by gelatinising the starch. Finally, because of the gelatinisation of starch, cooking can help to bind the feed together.

Other options for delivering feeds include feeding trays or hanging bags. These have the added advantage of helping farmers to monitor feed consumption. The optimum number and position of feeding trays or bags will depend on fish species and pond size and dynamics. In general, feeding trays or bags should be positioned in areas where water quality is best and more trays or bags are better than fewer trays or bags.

If feeds are to be broadcast, it is best to spread them over as large an area as possible and to avoid the possibility of uneaten feeds building up and decomposing on the pond bottom. Feeding rates and timing of delivery are very species dependent. Tacon (1990) presents a number of feeding schedules for different species.

Even where ingredients are unprocessed, the storage of feeds can be a critical issue. Feeds or ingredients that are stored incorrectly can become mouldy, fats in the feeds can become rancid and unpalatable (or even toxic) and any heat-labile vitamins can be damaged or destroyed. It is preferable to store feeds or ingredients for as short a time as possible. The most important considerations when storing feeds are temperature and moisture (humidity). Feed in bags should always be kept on pallets off the floor and not in contact with walls or the ceiling. Feed sheds should be well ventilated and every effort should be made to make them vermin proof. Care should be taken not to store feed or ingredients in plastic bags as these can exacerbate problems with condensation. Insects can also cause considerable damage to feeds and ingredients and should be excluded.

Mouldy feeds and ingredients should not be fed. Mould growth can reduce the nutritional value of feeds and ingredients (through enzymatic destruction of lipids, amino acids and vitamins), negatively affect flavour and appearance and, for some moulds, produce metabolites (called mycotoxins) that can be very toxic to fish (Tacon 1990).

The most-effective feeding strategy will not only depend on the species being cultured but also on the cost and availability of nutritional inputs (fertilisers, supplementary feed ingredients and feeds and complete diets) and on the market price of the species cultured. Understanding the best strategy or mix of strategies for different species, farming systems and in different regions is an important priority to optimise production. Of equal importance is the need to develop effective methods to empower farmers, especially low-income farmers, to be able to make these decisions for themselves.

2.5 References

Anon. 1992. Raw material compendium: a compilation of worldwide data sources (1st ed.). St Louis, MO, USA, Anon International Inc., 511p.

Allan, G.L., Jantrarotai, W., Rowland, S., Kosuturak, P. and Booth, M. 2000. Replacing fishmeal in aquaculture diets. Final report to ACIAR, Project No. 9207. NSW Fisheries Final Report Series No. 25, 13p.

Boyd, E. 1990. Water quality in ponds for aquaculture. Shrimp Mart (Thai) Co. Ltd, 482p.

De Silva, S.S. 1993. Supplementary feeding in semi-intensive aquaculture systems. In: New, M.B., Tacon, A.G.J. and Csavas, I., ed., Farm-made aquafeeds. Proceedings of the regional expert consultation on farm-made aquafeeds, 14–18 December 1992, Bangkok, Thailand. Bangkok, FAO Regional Office for Asia and the Pacific, pp. 24–60.

De Silva, S.S. and Anderson, T.A. 1995. Fish nutrition in aquaculture. London, Chapman and Hall, 319p.

Edwards, P. 1993. Environmental issues in integrated agriculture–aquaculture and wastewater-fed fish culture systems. In: Pullin, R.S.V., Rosenthal, H. and Maclean, J.L., ed., Environment and aquaculture in developing countries. ICLARM Conference Proceedings 31, 139–170.

Edwards, P., Lin, C.K. and Yakupitiyage, A. 2000. Semi-intensive pond aquaculture. In: Beveridge, M.C.M. and McAndrew, B.J., ed., Tilapias: biology and exploitation. Kluwer Academic Publishers, 377–403.

Hertrampf, J.W. and Pascual, F.P. 2000. Handbook on ingredients for aquaculture feeds. London, Kluwer Academic Publishers, 573p.

Jantrarotai, W., 1996. Recent developments in freshwater finfish nutrition in Asia. In: Feed production on the threshold of the next age. In: Proceedings of a VICTAM conference, November 14–15, 1996, Bangkok, Thailand, 99–104.

Jantrarotai, W. and Somsueb, P., 1995. Optimum levels of essential fatty acids for growth and feed conversion of hybrid *Clarias* catfish. Kasetsart Journal (Natural Sciences), 29, 479–485.

Jantrorotai, W., Somsueb, P. and Sitasit, P. 1995. Nutritional studies in hybrid *Clarias* catfish for developing of complete catfish feed. Proceedings of the 33rd Kasetsart University Annual Conference. Abstract only.

Jauncey, K. 1982. Carp (*Cyprinus carpio* L.) nutrition – a review. In: Muir, J.F. and Roberts, R.J., ed., Recent advances in aquaculture. Boulder, CO, USA, Westview Press, 16–263.

Knud-Hansen, C.F., 1998. Pond fertilization: ecological approach and practical applications. Oregon State University, Corvallis, USA, Pond Dynamics/Aquaculture CRSP.

Lin, C.K., Teichert-Coddington, D.R., Green, B.W. and Veverica, K.L. 1997. Fertilization regimes. In: Egna, H.S. and Boyd, C.E., ed., Dynamics of pond aquaculture. Boca Raton, FL, USA, CRC Press, 73–107.

Luquet, P. 1991. Tilapia, *Oreochromis* spp. In: Wilson, R.P., ed., Handbook of nutrient requirements of finfish. Boca Raton, FL, USA, CRC Press, 169–179.

Murthy, H.S. 2002. Indian major carps. In: Webster, C.D. and Lim, C.E., ed., Nutrient requirements and feeding of finfish for aquaculture. Wallingford, UK, CABI Publishing, 262–272.

NRC (National Research Council), 1993. Nutrient requirements of fish. Washington, DC, USA, National Academy Press, 114p.

Paripatananont, T. 2002. Snakehead and *Pangasius* catfish. In: Webster, C.D. and Lim, C.E., ed., Nutrient requirements and feeding of finfish for aquaculture. Wallingford, UK, CABI Publishing, 396–412.

Robinson, E.H. and Li, M.H. 2002. Channel catfish, *Ictalurus punctatus*. In: Webster, C.D. and Lim, C.E., ed., Nutrient requirements and feeding of finfish for aquaculture. Wallingford, UK, CABI Publishing,293–318.

Satoh, S. 1991. Common carp, *Cyprinus carpio*. In: Wilson, R.P., ed., Handbook of nutrient requirements of finfish. Boca Raton, FL, USA, CRC Press, 55–67.

Shiau, S.-Y. 2002. Tilapia, *Oreochromis* spp. In: Webster, C.D. and Lim, C.E., ed., Nutrient requirements and feeding of finfish for aquaculture. Wallingford, UK, CABI Publishing, 273–292.

Tacon, A.G.J. 1990. Standard methods for the nutrition and feeding of farmed fish and shrimp. Volume 1: The essential nutrients. Redmond, WA, USA, Argent Laboratories Press, 208p.

Tacon, A.G.J., Phillips, M.J. and Barg, U.C., 1995. Aquaculture feeds and the environment: the Asian experience. Water Science Technology, 31(10), 41–59.

Takeuchi, T., Satoh, S. and Kiron, V., 2002. Common carp, *Cyprinus carpio*. In: Webster, C.D. and Lim, C.E., ed., Nutrient requirements and feeding of finfish for aquaculture. Wallingford, UK, CABI Publishing 245–261.

3 Contributed Country Papers

3.1 Feed and Feeding Constraints in Inland Aquaculture in Cambodia[3]

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3.1.1 Introduction

Rice and fish are the most common components of the diet in Cambodia. Although the national average consumption is around 30 to 35 kg per capita (DoF 2001), the amount of fish consumed by Cambodians living around the Great Lake area appears to be one of the highest in the world. The consumption of fish depends on the proximity of the population to the water, and the fish productivity of such water bodies. Hence, the fish consumption level is influenced by the productivity of the environment in which people are living. Cambodia has a coastline of 435 km and marine capture fisheries contribute approximately 10% of the total capture fish production. Freshwater fish production is around 441,000 metric tones (DoF 2001). This highlights the fact that fisheries are contributing substantially to Cambodia's gross domestic product.

Fish are playing a major role not only in the diet, but also in the economy of people. As there is little or no opportunity to enhance production from capture fisheries, aquaculture is widely seen as the principal avenue to fill the supply–demand gap. Because of this, the Department of Fisheries (DoF) has been taking steps to promote aquaculture in all the potential areas, in partnership with various NGOs, international organisations and other development agencies involved with rural-development projects. Most of the production from the aquaculture sector currently comes from cage culture, but pond culture has increased over the last decade. The greater opportunity to use aquaculture and aquatic resources for poverty alleviation in the country has been realised, and the focus is now on developing aquaculture systems that suit the needs of farmers. Poverty is rampant in rural areas and diversification in the farming systems is essential to increase farm incomes. Recognising this potential, DoF and many NGOs have been actively engaged in promoting small-scale aquaculture in the country.

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[3] Citation: Heng, N., Song, L.S., Borin, C., Viseth, H. and Vibol, O. 2004. Feed and feeding constraints in inland aquaculture in Cambodia. In: Edwards, P. and Allan, G.L., ed., Feeds and feeding for inland aquaculture in Mekong region countries. Canberra, ACIAR Technical Reports No. 56, 49–52.

Currently, feeding practice is one of the most important issues that should be taken into account in aquaculture development and management in Cambodia. However, some aquaculturists are not fully aware of proper feeding technologies. This applies particularly to small-scale aquaculture farmers, but many of commercial scale farmers also need information and training.

The objective of this paper is to review fish feeds and feeding practice, and identify constraints to Cambodian aquaculture development.

3.1.2 Fish feed and feeding practice in Cambodia

Currently, fish feeding practice in Cambodia varies according to the level of the culture system.

Small-scale feed and feeding

There are a number of projects implemented in collaboration with DoF, such as: the Agriculture Productivity Improvement Project (APIP); the Aquaculture of Indigenous Mekong Fish Species (AIMS/MRC); AIT–ARRM; and NGO activities that are dealing with small-scale aquaculture developments in different parts of the country. The fish species that are commonly used for pond culture are native species. *Pangasius hypophthalmus* is the major species; other species cultured are *Barbodes gonionotus, Barbodes altus, Leptobarbus hoeveni*, and *Trichogaster pectoralis*.

Small-scale farmers have limited on-farm feed resources for their farming operation. However, pond fertiliser techniques are well understood by farmers through aquaculture extension workers in some provinces, especially in project site areas. Green water is commonly used to feed fish by applying organic fertilisers. Small-scale farmers also apply inorganic fertiliser in order to improve pond productivity.

Rice bran, broken rice and waste vegetables are the most common feed ingredients used in Cambodia. These ingredients are sometimes fed directly without processing. Some additional feeds that most small-scale aquaculture farmers can afford are duckweed, termites, cassava leaves, kitchen wastes and rice wine waste. A few farmers are able to cook the fish diet, depending on the availability of labour and firewood.

Integrated fish-farming is also practised in some areas, such as pig-fish, duck-fish, chicken-fish, rice-fish and garden-fish etc. These practices are able to effectively reduce feed cost and increase fish production.

Commercial-scale feed and feeding

Cage culture is the most prevalent aquaculture practice in Cambodia. It is usually intensive, but it is done manually with no automatic feeding. Cage culture is commonly practised in rivers and streams in a number of provinces bordering the Great Lake.

The major fish species for cage culture are river catfish (*Pangasius hypophthalmus, P. bocourti* and *P. larnaudii*) and snakehead (*Channa micropeltes*). The river catfish, *P. hypophthalmus* is the dominant species for cage and pond culture. Fish production from cage culture systems is much higher than from pond culture. Commercial-scale cage culture in Cambodia contributed about 70% of the total aquaculture production (DoF 2001).

The main feed for pangasid catfish and snakehead is low-value fish, which are available during peak period of fish catch, particularly from November to January. Small cyprinids are caught by 'dai lot' (bag net fishing) along the Tonle Sap River. Availability of feed ingredients varies both regionally and seasonally. During the peak of the fish catch, cultured fish are overfed, due to an abundance of low-value fish. After the peak period fish are fed with cooked rice bran mixed with 10–20% of dry fish, depending on availability.

Aquaculturists rarely used industrial pellets to feed fish because this feed has not yet been produced in Cambodia. Pellet feeds are imported at a higher price than other feed types and are not produced locally because of high cost and low market demand. However, Cambodia produces feed pellets for animal husbandry which some rich farmers use to feed fish, but it is not profitable at present.

The following results have been recorded during studies on food conversion for pangasid catfish around Phnom Penh municipality during 1994–95:

- fed with only rice bran, FCR = 1:4 to 1:4.5
- fed with rice bran mixed with low value fish and dried fish, FCR = 1:3 to 1:3.5

Research on feed diet and feeding

A number of studies have been conducted during projects at Bati and Chrang Chamres Stations to compare fish growth and the efficiency of ingredients in different fish diets, particularly for brood-stock management.

Research is needed to identify the most suitable diets for local fish species. It is hoped that the efforts initiated by DoF and some national, international and non-government organisations on native species will help to develop aquaculture in Cambodia. The selected species in two key projects are:

- Aquaculture of Indigenous Mekong Fish Species (AIMS) Project at Chrang Chamres Station and Bati Station: *P. hypophthalmus, Osteochilus melanopleurus, Trichogaster pectoralis, Barbodes gonionotus, B. altus* and *Leptobarbus hoeveni*.
- Agriculture Productivity Improvement Project (APIP) has at Bati Station: *P. hypophthalmus, Cirrhinus microlepis, Osphronemus exodon* and *Channa micropeltes*.

Considerable effort has been placed on breeding the above species and developing suitable brood-stock diets. Table 1 gives the diet developed for *P. hypophthalmus* broodfish and Table 2 the diet for fingerlings and juveniles.

Table 1. Diet developed for *Pangasius hypophthalmus* broodfish.

Ingredients	Protein (%)	Composition (%)
Fish meal	50	55
Rice bran	12	25
Soya bean	38	10
Mungbean (geminated bean)	24	6
Vegetable oil		3
Vitamin E		1
Total	36	

Source: Bati Fish Seed Production and Research Center (BFSPRC).

In 2001, 50–60% of *P. hypophthalmus* were successfully matured at Bati Fish Seed Production and Research Center using the diet described in Table 1.

The trial was conducted over one month, with oxygen supplied during the first week. The survival rate of *P. hypophthalmus* seed ranged from 25% to 45% and the length growth from 4 to 6 cm.

Table 2. Diets used for fingerling and juvenile *Pangasius hypophthalmus*.

Period	Ingredient	Quantity (kg/100,000 seeds/day)	Subsequent feeding (time)
First week	Soya bean powder	01	08
	Eggs yolk	40 eggs	
	Vitamin premix	0.02	
Second week	Soya bean powder	02	06
	Eggs yolk	30 eggs	
	Vitamin premix	0.02	
Third week	Soya bean powder	1.5	04
	Fine rice bran	1.5	
	Vitamin premix	0.02	
Fourth week	Soya bean powder	01	03
	Fine rice bran	03	
	Vitamin premix	0.02	

Source: Bati Fish Seed Production and Research Center (BFSPRC).

Table 3. Diet for cyprinid broodfish.

Ingredient	Protein (%)	Composition (%)
Fish meal	50	10
Rice bran	12	50
Soya bean	38	28
Sprouted rice	8	10
Vitamin premix	–	01
Total	26	

Source: Chrang Chamres Fisheries Station, AIMS project.

Experiments were also carried out with cyprinid broodfish, including *L. hoeveni*, *O. melanopleurus, T. pectoralis, B. gonionotus* and *B. altus* (Table 3). Some 60–70% of broodfish matured.

3.1.3 Constraints of feed and feeding

Fresh fish feeds are available seasonally and regionally, which has led to problems of over-feeding in times of plenty and underfeeding when feeds are scarce. There is plenty every year in a short time during the peak fishing season period, particularly from November until January. For the rest of the year, some farmers able to use dried fish but others cannot afford this resource. During the peak fishing season, a large bulk of trash fish is sun-dried. The simple process used sometimes leads to contamination with sand or dust, which reduces the quality of the dry fish produced.

Manufactured pellet feeds are expensive and imported. Only a very few people can afford such high cost feeds and they are mainly used for ornamental fish and not for commercial-scale aquaculture.

Financial problems are a major constraint for poor aquaculture farmers. A large number of farmers using cage culture cannot afford to purchase feeds to feed their fish. There is no official credit system available in their localities although there are some private loan systems with high interest rates. The interest rate is 5–7% per month, which can effectively eliminate the profit margin for poor fish farmers.

Very few studies have been conducted on fish feed and feeding in Cambodia. There is no tradition of on-farm feed formulation that can be widely used in aquaculture systems. Pond fertiliser techniques are well understood by the farmers but organic manures are scarce in some cases since they are also needed for crops.

The market price for farmed fish, especially in relation to the cost of feeds, is also a major problem. Prices are very low when fish are plentiful from capture fisheries. Most consumers prefer to eat caught fish rather than cultured ones. This is partly because of the practice of building latrines on top of fish ponds by some farmers, especially for pangasid catfish culture.

Research grants are available for aquaculture research but this is not well-known among Cambodian researchers.

3.1.4 Conclusions

Suitable feed and feeding strategies are necessary to sustain aquaculture development.

There is no tradition of on-farm feed formulation than can be widely used in small-scale aquaculture systems. Manufactured pellet feeds are very expensive compared with other local feed ingredients. Fresh fish feeds are available seasonally and regionally over a short period.

Prices of cultured fish are usually low compared with wild fish, especially exotic species.

The experience of government employees is considered to be limited for planning and conducting feed and fish nutrition research; thus research priorities on feed and fish nutrition are not easily defined.

There is a lack of appropriate technology for low-value fish-feed processing from large amount of cyprinids during the peak of the wild catch.

3.1.5 Recommendations

1. Cooperation on feeds and feeding technologies through research and experimentation at provincial, national, regional and inter-regional levels should be established.
2. Capacity building of fisheries staff in aquaculture technology and management, with a focus on feeds and feeding technology, is needed.
3. The extension network and research collaboration between institutions dealing with inland aquaculture development and education, including feed and feeding technology, should be improved.
4. The market demand for domestic consumption and processed fish for export needs to be determined.

5. Sustainable aquaculture development is needed, and aquaculture-industry investment should be encouraged.

3.1.6 Bibliography

DoF (Department of Fisheries) 1995. Fisheries rehabilitation and development plan (1996–2000). Phnom Penh, Cambodia, DoF.

— 1997. Fisheries data collection 1980–96. Phnom Penh, Cambodia, DoF.

— 2001. Annual report on fisheries sector – 2001. DoF, Phnom Penh, Cambodia.

Edwards, P. and Allan, G.L. 2004. Review on feeds and feeding for inland aquaculture in Mekong region countries. ACIAR Technical Reports No. 56.

Mekong Committee 1992. Review of the fisheries sector in the lower Mekong basin. Bangkok, Thailand, Mekong River Commission.

Nandeesha, M.C. 1991. Aquaculture in Cambodia (Status, constraints and opportunities). Phnom Penh, Cambodia, CISE and PADEK.

Tana, T.S., 1993. Fish supply and demand in rural Svay Rieng Province. Thesis for the partial fulfillment of the degree of master of science. Bangkok, Thailand, Asian Institute of Technology.

Thuok, N. and Sina, L. 1997. Review of the fisheries and aquaculture sector in Cambodia. In: Workshop on Option for the Tonle Sap Lake management strategy. The natural resources based development strategy for the Tonle Sap Area Project, Phnom Penh, Cambodia.

Van Zalinge, N.P. 1997. Fishery research need in the lower Mekong Basin from a Cambodia perspective. Contribution to the National Fisheries Workshop, Vientiane, Lao PDR, 19–21 March 1997.

Some farmers spend a lot of time making their own feeds. In Sakon Nakorn, northeastern Thailand, this couple mix cooked rice, bran, soybean meal and powdered fish meal with pig oil to form ‘feed balls’ which they place in fish ponds. Photographer: Peter Edwards.

3.2 Feeds and Feeding Constraints in Inland Aquaculture in Lao PDR[4]

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3.2.1 Introduction

The aim of this paper is to provide an overview of aquaculture feed requirements in the Lao PDR and identify future directions of research and farmer extension. The review papers by Edwards (2004) and Allan (2004) provide a background for this overview.

This paper is divided into three parts. The first gives a background to aquaculture and aquaculture feed development in the Lao PDR, the second considers future research directions and the final section presents some recommendations for farmer extension activities.

3.2.2 Background

Aquaculture as a project activity for rural development in Laos has had a relatively recent history, beginning in the 1950s through USAID and Japanese foreign aid development of government hatcheries across the country (Ministere-de-l'Economie-Nationale 1972; USAID 1973). Later intervention in the country included three phases of a UNDP/FAO project from 1980 to 2000. The first phase introduced techniques for raising various species at provincial fishery stations. The second followed up this work with the extension of fish-culture techniques to selected farmers, and the third phase concentrated on building farmer extension networks in various provinces. All three phases were concerned with the development of technical expertise at provincial fish stations and at the household level (see Singh 1994; Funge-Smith 2000).

The UNDP/FAO and other projects have tended to focus on the poorer northern provinces and not the relatively fish-abundant southern provinces of the country. Despite this, there has been increasing attention on the southern provinces over the last decade through the Asian Institute of Technology's Aqua Outreach Programme and the Provincial Aquaculture Development project (the third and final phase of UNDP/FAO involvement).

Some of the main constraints to the adoption or further development of aquaculture that have been identified include (FAO/UNDP 1996; Haitook 1997; Funge-Smith 1999; Bush 2002a):

- shortage of fingerlings

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- poor roads and access to markets
- subsistence economy
- high seasonality of water supply
- low levels of technical knowledge
- cost of digging ponds.

Constraints directly related to feed include (Funge-Smith 1999):

- competition for rice bran with other agricultural activities
- competition for manure
- high price of imported formulated feed and feed ingredients.

Constraints to aquaculture are also influenced by a range of social and environmental factors, including the distribution of ponds in upland or lowland, rural or urban areas, as well as their proximity to major roads, irrigation and natural aquatic resources.

3.2.3 Pond culture

Most aquaculture in the Lao PDR is conducted in small, seasonal ponds to support household subsistence needs. The main species grown include the Chinese and Indian major carps, tilapia, silver barb (*Barbodes gonionotus*) and hybrid walking catfish (*Clarias gariepinus*. Average production in upland areas has been estimated as 30 kg/household (±38) and 49 kg/household in lowland areas (±106 kg) (Funge-Smith 1999).

The price of farmed fish in Vientiane markets ranges from 7000–30,000 kip, and 35–40% of all fish sold in Vientiane markets is farmed fish from Thailand. The high range of these prices is biased by the proximity to Vientiane. These figures for Vientiane are not representative of the price of farmed fish in other parts of the country. For example, in Savannakhet Province, the average monthly price for farmed fish during the 2001 wet season was 9900 to 10,600 kip/kg (Bush 2002b). The influence of the relatively static price in Savannakhet could provide a basis for further research. However, the low price may also provide constraints to further extension of commercially focused aquaculture.

A recent survey of 2468 ponds in three districts of Savannakhet Province showed that rice bran is by far the most commonly used feed, present in 58.3% of the samples (S.R. Bush, unpublished data). Termites are the second most used feed, present in 12.1% of all ponds. Although 36.6% of all ponds were recorded as having no feed input, several of these fertilised with manure. A high number of ponds are not used for aquaculture but as trap ponds for wild fish.

After no feed (36.6%) and rice bran (39.6%), the most common feeding strategy was a combination of rice bran and termites (7.5%) followed by rice bran and buffalo manure (5.3%). The combinations are based more on available local resources rather than a set feeding formula (S.R. Bush, unpublished data).

This study also showed considerable spatial variation in the use of various feeds. Commercial feeds appear to be used closer to the Thai border and urban areas of Khantabouli district in Savannakhet. Local-resource-based feeds such as termites also appear to be clustered. These patterns could provide a basis for further research.

Closer to Vientiane and other major urban centres, formulated feed is generally more available (Funge-Smith 1999). One fish farm near Vientiane, Seng Savang, reportedly produces their own pelleted feed for pond culture at half the price of equivalent imported CP feed from Thailand (Edwards 2004).

3.2.4 Cage culture

Cage culture activities are restricted to Nam Ngum reservoir, the smaller Nam Souan and Nam Houm reservoirs, the mainstream Mekong and some major tributaries. The main species cultured in the smaller reservoirs are Chinese and Indian major carps, while in Nam Ngum the main species cultured are carnivorous snakehead (*Channa micropeltes* and *C. striata*).

The feed conversion ratio (FCR) for snakehead culture in Nam Ngum reservoir is reported to range between 3:1 (Niklas Mattson, pers. comm.) to 5:1 (Edwards 2004) using wild caught *pa keo* (a clupeid). It is noted that herbivorous species would be easier to feed but are more difficult to sell (Edwards and Allan 2001). Further research is needed into the use of local and improved varieties of grass to supply these herbivorous species.

Cage culture along the Mekong is presently found near most of the major urban centres, Vientiane, Thakhek, Savannakhet and Pakse. Due to the easy access from Thailand most of these cages support CP-produced mono sex tilapia.

3.2.5 Research and development

There are a number of activities for aquaculture development currently under way or planned for the future. These are listed as follows:

- **HAKI collaboration** – discussion is ongoing with HAKI for the potential development of a business lease contract with the Department of Livestock and Fisheries.
- **Cage culture assessment –** the Network of Aquaculture Centers in Asia–Pacific (NACA) has been an active partner with the Living Aquatic Resource Center (LARReC) in assessing cage culture in seven provinces throughout the country.
- **Aquaculture Improvement Project (AQIP)** – a Japan International Center for Cooperation in Agriculture (JICA)-funded project for improving aquaculture. One of the immediate objectives of the project is to develop an aquaculture reference center at Nam Souang.
- **Asian Institute of Technology (AIT) Outreach seed supply** – ongoing work in the extension of fish nursing and spawning networks in southern Laos
- **Aquaculture of Indigenous Mekong Species (AIMS) –** a Mekong River Commission (MRC) research project for technical capacity to spawn and raise native Mekong species.

As each of these projects is working on different aspects of aquaculture, future research and development on feeding and feeds should be done in consideration of varying environmental, social and economic contexts found throughout the country.

3.2.6 Research priorities

Research into the development of feeds and feeding for both pond and cage culture is the responsibility of the LARReC in Vientiane. However, research activities should be encouraged within various parts of the country.

The main research priorities for the Lao PDR are identified as follows:

- **Rice bran potential** – due to the reliance on rice bran for feed, further investigation into optimal use of rice-bran-based feeds.
- **Optimal combinations of naturally existing feeds** – farm-based research investigating the nutritional benefits of various combinations of locally available materials.
- **Integrated farming systems research for upland aquaculture –** investigation into integrated systems of feed for upland production of herbivorous carp.
- **Development of alternative low-cost feeds** – to lower the cost of cage culture by developing cheap, locally produced, feed alternatives.
- **Alternatives to imported commercial feeds** – development of alternative high protein content feeds to substitute for 'trash fish'-based feeds.

3.2.7 Extension priorities

The main extension priorities recommended for Lao PDR are identified as follows:

- **District and provincial level government capacity building –** to enable local staff to carry out feed and feeding trials and extension.
- **Develop better alternatives for small-scale credit schemes –** to address the lack of available credit for farming communities.
- **Assistance to develop a fish-feed enterprise in Vientiane –** to encourage development of a fish-feed center in Vientiane ensuring local ownership and operation.
- **Farmer networks –** research into effective ways to develop farmer-to-farmer feed extension networks, similar to other networks developed by AIT and UNDP/FAO.

3.2.8 Acknowledgements

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3.2.9 References

Allan, G.L. 2004. Review of fish nutrition and feeding. This report.

Bush, S.R. 2002a. Aquatic resources utilisation in three districts of Savannakhet Province, Lao PDR. RDC Production 521. RDC, Savannakhet. 44 pp.

— 2002b. Wet season fish marketing summary. RDC Production. RDC and Provincial Livestock and Fisheries Office, Savannakhet, Lao PDR. 35 pp.

Edwards, P. 2004. Review on feeds and feeding for inland aquaculture in Mekong region countries. This report.

FAO (Food an Agriculture Organization of the United Nations)/United Nations Development Programme (UNDP) 1996. Development of fish culture extension. LAO/89/003 Terminal Report. Rome, FAO, 21p.

Funge-Smith, S. 1999. Small scale rural aquaculture in Lao PDR. Lao/97/007. Vientiane, FAO, 16p.

— 2000. Provincial aquaculture development project: end of assignment report. Provincial Aquaculture Development Project LAO/97/007. Vientiane, FAO, 48p.

Haitook, T. 1997. Fish seed supply network and its effect on aquaculture development in Savannakhet Province, Lao PDR. Bangkok, Thailand, School of Environment, Resources and Development, Asian Institute of Technology**,** 171p.

Ministere-de-L'Economie-Nationale 1972. Etude sur l'Economie Lao 1967–1972. Vientiane, Lao PDR, Ministere de l'Economie Nationale, Bureau des Etudes Techniques, Royame du Laos, 178p.

Singh, S.B. 1994. Fish culture in land-locked Lao PDR. FAO Aquaculture Newsletter, 7, 16–18.

USAID (United States Agency for International Development) 1973. Facts of foreign aid to Laos (2nd ed.). Embassy of the United States of America, USAID Mission to Laos, Vientiane.

Basa catfish are farmed intensively in ponds and in cages. Farm workers feed a cooked mixture of trash fish and rice bran to fish in a floating cage on the Mekong Delta near That Not. Each cage can produce 60 t of fish every eight months. Photographer: Brett Glencross.

3.3 Feed and Feeding Constraints in Inland Aquaculture in Thailand[5]

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3.3.1 Introduction

Aquaculture in Thailand has been practised for more than 70 years, starting with the pond culture of sepat siam (*Trichogaste*r *pectoralis*) in freshwater ponds. The Department of Fisheries has been attempting to increase fish production by restocking natural waters as well as by promoting and developing aquaculture. As shown in Table 1 and Figure 1, the total production obtained from both captured and cultured fish has increased markedly. Today, aquaculture production surpasses the natural catch and the captured production from inland aquaculture has levelled off. Rapid development of aquaculture in Thailand was also observed in the last decade. Culture technology has developed quickly and the area devoted to aquaculture-farms continues to expand. For some species, culture systems have changed from extensive to semi-intensive and intensive, to increase production per unit area. Because of this, the total production from aquaculture has continued to increase (Table 2).

Thailand has a total land area of 513,115 km^2 with 2614 km of coastline and approximately 45,450 km^2 of inland water area. The available area for inland aquaculture comprises 47 major rivers and 11,900 natural lakes and man-made reservoirs. In the central region is the alluvial flood plain of the Chao Phraya River which is 365 km long. The northern region comprises four major rivers: Ping, Wang, Yom and Nan with lengths of 335, 555, 590 and 637 km, respectively. There are three major rivers in the northeastern region: Chi, Moon and Mae Kong, with lengths of 442, 673 and 4335 km, respectively. Mae-Klong (140 km) and Phetchaburi (170 km) are the two major river in the west. Pattani (165 km) and Tapi (214 km) are the main rivers in the south.

At present more than 20 species of freshwater fish are being cultured in various systems ranging from super-intensive farming for commercial production to extensive culture mainly for home consumption. There are four different culture types: pond, paddy, ditch and cage, as described in Table 3. The most popular culture species are tilapia (*Oreochromis niloticus*), hybrid catfish (*Clarias macrocephalus* × *C. gariepinus*), silver barb (*Barbodes gonionotus*), sepat siam (*Trichogaster pectoralis*), striped catfish (*Pangasius hypophthalmus*), prawn (*Macrobrachium rosenbergii*) and common carp (*Cyprinus carpio*). The highest production is obtained from pond culture, followed by paddy field and ditch culture type. The lowest is obtained from cage culture (Table 4). However, at present there is an increasing trend for cage culture, especially of

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Table 3. Inland aquaculture systems in Thailand.

System	Culture species	Size of pond (rai)[a]	Culture area	Stocking density (fish/rai)	Feed and feeding	Rearing period (months)	Harvested size (g)	Production (kg./rai)
Extensive								
1. Paddy-field culture	– silver carp – common carp – tilapia – rohu – Chinese carps	5 (rice field, with 30 m^2 fish pond used for nursing and harvesting)	North and northeast	500 (5–7 cm)	Inorganic fertiliser Manure integrated with poultry and/or pigs	3	300–1,000	100–200
2. Integrated with poultry and/or pigs in rain-fed area	– silver barb – common carp – tilapia – rohu – Chinese carps	0.5–2	North and northeast	3,000 (2–3 cm.)	Poultry or pig manure	6–8	300–800	300–500
3. Back yard pond	– silver barb – common carp – tilapia – rohu – Chinese carps	0.25–1	North and northeast	3,000 (2–3 cm.)	Inorganic fertiliser, manure integrated with poultry and/or pig-farm-made feed	6–12	400–1,000	500
Semi-intensive								
1. Poly culture pond	– silver barb – common carp – tilapia, rohu – Chinese carp	10–30	Central	8,000–10,000 (2–3 cm)	fertiliser and industrial by-product supplement with maize, rice bran, soybean meal – farm-made feed	8–10	500–1,500	500–1,200
2. Integrated with poultry or pigs in irrigated area	tilapia	5–10	Central	5,000–8,000 (2–3 cm.)	poultry or pig manure – supplement with maize, rice bran, soybean meal – farm-made feed	6–8	600–1,200	500–1,200

Table 3. (cont'd) Inland aquaculture systems in Thailand.

System	Culture species	Size of pond (rai)[a]	Culture area	Stocking density (fish/rai)	Feed and feeding	Rearing period (months)	Harvested size (g)	Production (kg./rai)
	Hybrid catfish	2–10	Central	15,000–20,000 (2–3 cm.)	poultry and/or pig manure – supplement with chicken by-product – farm-made feed	4–6	300–500	800–2,000
Intensive								
pond	hybrid catfish	1–5	Central	30,000–50,000 (2–3 cm)	Floating pellet and chicken by-product	4–6	300–800	1,500–8,000
pond	tilapia	3–5	Central	2,500–3,500 (150–250 g)	Sinking and floating pellet	3–6	600–1,500	1,000–2,000
cage	Nile tilapia Red tilapia	25 m^2 (5 × 5 × 2 m)	Central, north, south & northeast	50 fish/m^2 (25–50 g)	Floating pellet	3–4	600–1,500	80–120 kg/m^2
cage	Nile tilapia	25 m^2 (5 × 5 × 2 m)	Northeast	20 fish/ m^2 (10–15 cm)	Farm-made feed	4–6	400–1,000	50–80 kg/m^2

[a] 1 rai = 1600 m^2; 6.25 rai = 1 ha.

monosex tilapia. Some fish species are farmed in monoculture or polyculture and some are integrated with livestock such as poultry and pigs.

The culture area is expanding every year, as shown in Table 5. In 1999, the total area of freshwater fish farming was 715,951 rai, which was divided into pond culture (78.75%) and paddy field (18.36%). Ditch and cage culture were 2.85 and 0.04%, respectively. However, only 79.47% of the total area, or 568,975 rai, was recorded as productive area in 1999. The total area for farming increased by 6.4% over that recorded in 1998. The rate of increase was highest for pond culture.

Table 1. Production (tonnes) of freshwater fish species in Thailand during 1995–1999.

Species	1995	1996	1997	1998	1999
Total	191,643.78	208,446.19	205,023.45	202,276.37	206,840.00
Nile tilapia	55,745.58	29,253.65	28,726.62	40,173.07	49,770.00
Common carp	10,144.23	7,420.06	7,418.18	11,507.01	13,720.00
Walking catfish	8,080.14	5,827.49	3,410.88	10,933.74	12,080.00
Silver carp	22,468.35	25,750.09	25,295.86	44,348.51	45,490.00
Sepat siam	186.35	384.26	353.12	1,485.95	450.00
Snake-head fish	21,809.52	25,508.31	24,098.78	16,663.75	17,950.00
Giant freshwater prawn	308.05	1,615.40	1,540.14	35.82	100.00
Striped catfish	5,692.53	541.98	521.99	917.19	1,100.00

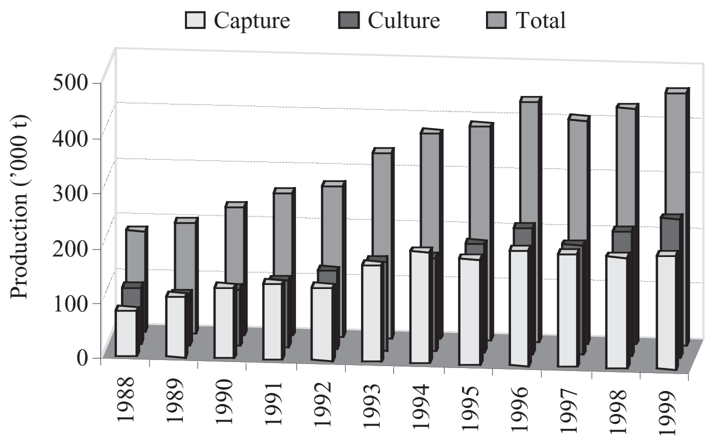

Figure 1. Total capture and cultured production of freshwater fish in Thailand during 1988–99.

In 1999, the total yield from freshwater aquaculture was 252,612 tonnes. Just over 90% of total production was obtained from the pond culture system (Table 6), while the outputs obtained from paddy field, ditch and cage culture were 6.58, 2.02 and 0.57%, respectively. The province obtaining the highest production was Samutprakarn. Chachoengsao and Samutsakorn were the second and the third, respectively. The total productive fish farm area in Samutprakarn was 123,386 rai, or 21.69% of the total productive area (Table 7). Of this area, 83.03% was for pond culture, 16.96% for paddy field culture and 0.01% for cage culture. The main species cultured was sepat siam, which occupied more than 70% of the total productive area. In Chachoengsao province, 18.81% (or 6,153 rai) of the productive area was for pond culture, while 77.82% (or 25,464 rai) was for paddy field culture and the remaining was for ditch culture.

Table 2. Production (tonne) of cultured species over the last 5 years (1995–1999).

Cultured species	1995	1996	1997	1998	1999
Tilapia (*Oreochromis niloticus*)	76,054	81,546	67,773	73,427	76,461
Carp *(Cyprinus carpio*)	3,556	4,178	12,182	7,093	5,811
Silver barb (*Barbodes gonionotus*)	27,432	33,150	33,504	38,952	41,289
Sepat siam (*Trichogaster pectoralis*)	16,714	13,816	12,947	17,214	21,988
Chinese carp	654	1,032	768	565	481
Hybrid catfish (*Clarias macrocephalus* × *C. gariepinus*)	44,120	64,373	51,289	57,466	72,289
Snakehead (*Channa striatus*)	5,790	6,292	4,001	5,336	4,005
Striped catfish (*Pangasius hypophthalmus*)	7,307	9,758	7,678	11,183	11,340
Prawn (*Macrobrachium rosenbergii*)	7,792	5,585	2,160	4,764	8,494
Mozambique tilapia (*O. mossambica*)	2	185	110	115	30
Sand goby (*Oxyeleotris marmoratus*)	67	142	53	45	1
Giant goramy (*Osphronemus gorami*)	349	1,160	1,266	1,475	1,709
Rohu (*Labeo rohita*)	1,481	2,850	1,661	1,877	1,703
Feather back (*Notopterus notopterus*)	50	48	0.6	6	25
Swamp eel (*Fluta alba*)	1	12	13	15.8	539
Moon light goramy (*Trichogaster microlepis*)	259	350	54	93	98
Climbing perch (*Anabas testudineus*)	949	695	846	763	760
Frog (*Rana* sp.)	178	440	588	1,132	1,010
Giant snakehead (*C. micropeltes*)	639	594	469	1,398	118
Soft-shelled turtle (*Trionyx cartilageneus*)	7	117	261	324	342
Small scale mud carp (*Cirrhina microlepis*)	478	670	454	1,620	1,283
Others	2,178	1,661	2,100	2,059	2,832
Total production of cultured species	196,056	228,654	200,177	226,923	252,612

The main species in 1999 was tilapia, obtaining 76,460 tonnes (or 30.27% of the total production) followed by hybrid catfish, 72,289 tonnes (or 28.62% of the total), silver barb 41,289 tonnes (or 16.34%, of the total), sepat siam 21,988 tonnes (or 8.7% of the total) and striped catfish 11,340 tonnes (or 4.49% of the total) as shown in Table 8.

The main production of freshwater aquaculture comes from semi-intensive farming systems, followed by intensive and extensive systems. However, the culture system differed depending on the cultured species, as shown in Tables 3 and 9.

3.3.2 Feed and feeding practice in inland aquaculture

Formerly, most aquafeeds were farm-made and kitchen wastes. Since 1986, aquaculture has been booming and this has increased the demand for aquafeeds.

At present in Thailand there are 40 feed mills producing aquafeeds. Of those, 20 produce floating fish feed. However, farm-made feed is still practised for freshwater fish and shrimp farming, especially for snakehead, catfish and prawn in Suphanburi Province. The quality and quantity of farm-made feeds cannot be controlled properly, resulting in unpredictable fish production. Moreover, farm-made feed is less stable in water than manufactured feed, causing problems to the aquatic environment.

Feeds and feeding constraints for freshwater fish species vary depending upon the cultured species and cultured system as described in Table 3.

Table 4. Production (tonnes) of fish cultured in Thailand in 1999 by species and method of culture.

Species	Pond culture	Paddy-field	Ditch culture	Cage culture
Tilapia (*Oreochromis niloticus)*	71,377	3,038	1,770	275
Carp *(Cyprinus carpio)*	5,166	637	8	–
Silver barb (*Barbodes gonionotus)*	37,301	2,126	1,815	47
Sepat siam (*Trichogaster pectoralis*)	12,792	9,126	67	4
Chinese carps	475	3	3	–
Hybrid catfish (Clarias *macrocephalus* × *C. gariepinus)*	71,345	149	574	221
Snake head (*Channa striata)*	3,831	128	46	–
Striped catfish (*Pangasius hypophthalmus)*	11,123	30	66	120
Prawn (*Macrobrachium rosenbergii)*	8,494	–	0.11	–
Java tilapia (*O. mossambicus)*	24	–	6	–
Sand goby (*Oxyeleotris marmoratus)*	1	0.04	–	–
Giant goramy (*Osphronemus gorami)*	529	–	573	607
Rohu (*Labeo rohita)*	1,626	16	62	0.03
Feather back (*Notopterus notopterus)*	24	0.54	–	–
Swamp eel (*Fluta alba)*	539	–	–	–
Moonlight goramy (*Trichogaster microlepis)*	94	2.24	1	–
Climbing perch (*Anabas testudineus)*	688	33	39	0.09
Frog *(Rana* sp.*)*	907	0.23	–	103
Soft-shelled turtle (*Trionyx cartilageneus)*	330	12	–	–
Giant snake head (*Channa micropeltes)*	46	–	2	71
Small scale mud carp (*Cirrhina microlepis)*	1,233	4	48	–
Others	1,482	1,311	40	0.3
Total production (252, 612 tonnes)	229,428	16,618	5,118	1,448

Table 5. Total area (rai)[a] of fish farms and productive areas in Thailand during 1995–1999.

Type of culture	1995		1996		1997		1998		1999	
	Total area	Productive area	Total area	Productive area	Total area	Productive area	Total area	Productive area	Total area	Productive area
Total	565,258	364,992	488,893	393,783	555,685	422,550	670,117	518,680	715,951	568,975
Pond	340,003	274,291	385,628	306,787	430,718	315,691	531,684	404,850	563,790	442,631
Paddy-field	217,246	112,258	91,104	80,693	111,503	98,980	119,442	104,394	131,474	113,595
Ditch	7,951	5,421	11,968	6,158	13,313	7,774	18,768	9,262	20,410	12,506
Cage	58	22	193	145	151	105	223	174	277	243

[a] 1 Rai = 1600 m^2; 6.25 rai = 1 ha.

Table 6. Quantity (tonnes) of total production by type of fish culture in Thailand during 1995–1999.

Type of culture	1995	1996	1997	1998	1999
Total	196,056	228,654	200,177	226,923	252,612
Pond	167,983	208,226	182,911	206,738	229,428
Paddy-field	25,857	16,229	10,553	13,151	16,618
Ditch	1,603	1,732	4,601	5,406	5,118
Cage	839	613	2,467	1,629	1,448

Table 7. Total area (rai) of productive fish farms in the main provinces of Thailand, 1995–1999.

Province	1995	1996	1997	1998	1999
Samutprakarn	72,996	111,008	72,121	123,573	123,386
Chachoengsao	30,386	19,287	29,427	32,714	32,720
Samutsakorn	40,462	8,196	18,271	26,187	30,906
Udornthanee	14,391	13,478	13,478	24,679	24,873
Supanburi	16,295	10,510	15,647	18,862	20,499
Petchaboon	9,803	7,317	8,849	15,658	15,528
Khonkaen	11,485	11,362	16,594	16,518	16,307
Nakornpanom	5,449	8,498	14,708	14,709	14,708
Nakornpatom	18,363	19,268	14,453	14,615	14,615
Chaiyapoom	5,801	12,527	10,289	11,846	14,265
Mahasarakarm	6,034	10,775	15,377	14,205	14,255
Nongkai	9,802	8,432	12,652	13,104	13,947

Table 8. Quantity (tonnes) and value ('000 Baht) of aquaculture production by species in Thailand in 1999.

Species	Quantity	Value
Tilapia (*Oreochromis niloticus*)	76,460	1,997,561
Common carp (*Cyprinus carpio)*	5,811	185,126
Hybrid catfish (*Clarias macrocephalus x C. gariepinus*)	72,289	1,986,980
Silver barb (*Barbodes gonionotus)*	41,289	1,148,208
Sepat siam (*Trichogaster pectoralis*)	21,988	695,859
Striped catfish (*Pangasius hypophthalmus)*	11,340	187,370
Giant freshwater prawn (*Macrobrachium rosenbergii)*	8,494	1,105,320
Snakehead *(Channa striata)*	4,005	208,914
Rohu (*Labeo rohita)*	1,704	39,496
Others	2,832	51,190

Cultured species: carnivorous/omnivorous species

The cultured species are hybrid catfish, snakehead and sand goby. They are fed mainly on home-made feed, which consists of trash fish, cooked broken rice and rice bran. However, sometimes hybrid catfish are fed a single diet such as chicken by-product and kitchen waste until satiation, once a day. Minced trash fish is the sole feed for the fry. The inclusion of trash fish is reduced to 80% by the addition of 20% rice bran when the fish reach the fingerling size. The feed conversion rates of such trash fish based feeds range from 3:1 to 5:1. Commercial feed is often used for intensive culture systems. They are fed three times a day from fry to fingerling stage. The feeding rate is 4–8%, while it is reduced as the fish grow.

Cultured species: herbivorous species

Most farmers of herbivorous fish in Thailand still practise extensive culture with a low stocking density, although fish fry are available from both private and government hatcheries. The most important herbivorous fish in Thailand are tilapia (*Oreochromis niloticus*), sepat siam (*Trichogaster pectoralis*) and silver barb (*Barbodes gonionotus*).

Feed and feeding practice for herbivorous fish in Thailand may be classified into four levels as follows:

1. Natural feed: They are produced by fertilisation with organic manure and inorganic fertiliser or a combination of both.
2. Supplementary feed: They consist of aquatic plants, rice bran, broken rice and trash fish. Farm-made feed: A simple mixture is usually made. The mixtures may be further processed into a wet dough, moist feed, or extruded through a mincer die and sun dried to minimise dispersion losses.
3. Commercial feed: They are usually expensive.
4. The price of herbivorous fish is relatively low. They are usually produced for domestic consumption rather than export. Thus, these factors influence the feed type suitable for each cultured species.

Table 9. Proportion (%) of total production of each species obtained in 1999 from each culture system, calculated based on the total production.

Species	Extensive system	Semi-intensive system	Intensive system
Tilapia (*Oreochromis niloticus*)	6.29	93.35	0.36
Carp *(Cyprinus carpio)*	11.09	88.72	–
Silver carp (*Barbodes gonionotus)*	9.54	90.34	0.11
Sepat siam (*Trichogaster pectoralis*)	100.00	–	–
Hybrid catfish (*Clarias macrocephalus* × *C. gariepinus*)	1.00	99.00	
Snakehead *(Channa striata)*	4.35	95.65	
Striped catfish (*Pangasius hypophthalmus)*	0.85	98.09	–
Giant freshwater prawn (*Macrobrachium rosenbergii)*	–	100.00	
Sand goby (*Oxyeleotris marmorata*)	3.67	97.25	–
Rohu (*Labeo rohita)*	4.58	95.42	–

Culture systems

For extensive culture systems, manure is loaded into the pond before stocking with seed. The stocking density of seed for this system is very low, at 500 fish/rai. Usually, the pond size is about 5 rai. Sometimes farmers culture fish in rice fields and backyard ponds. Some farms integrate fish with poultry and/or pigs. The culture species are tilapia, silver carp, common carp, rohu and Chinese carps. The production varies between 100 and 500 kg/rai, depending on the type of culture (Table 3). The production may be increased when farm-made feed is supplemented with commercial pelleted feed.

For semi-intensive culture, farmers operate traditional ponds and usually rely on both natural food and kitchen wastes, by-products from slaughterhouse or they prepare simple feed by mixing rice bran, soybean cake and trash fish. The culture types are polyculture integrated with poultry or pigs. The important cultured species for this system are tilapia and hybrid catfish. The stocking density is high, between 8,000 and 10,000 fingerling/rai. The pond size varies between 5 and 30 rai. The production obtained varies between 500 and 1000 kg/rai. Intensive culture systems occur for pond and cage culture. The pond size varies between 1 and 5 rai, normally smaller than extensive and semi-intensive culture systems. The cultured species are hybrid catfish, Nile tilapia, red tilapia, snakehead and prawn. The types of feeds given are raw materials such as chicken by-products, farm-made feed or commercial feed. For commercial feed, both sinking and floating pellets are preferred by catfish, tilapia and prawn farmers. The stocking density of fish varies between 30,000 and 50,000 fingerling/rai. The production obtained is 1,500–8,000 kg/rai/crop for fish, and 200–400 kg/rai/crop for prawn. Some of the farm-made feed formulas are shown in Tables 10, 11 and 12.

Table 10. Examples of practical, farm-made feed formulas used in Thailand for larvae of walking catfish and tilapia.

Ingredients	Catfish larvae	Catfish larvae	Catfish/ tilapia larvae	Tilapia larvae	Tilapia larvae (mono sex)
Cassava starch	0	15	15	15	0
Rice bran	0	3	10	30	30
Wheat gluten	25	0	0	0	0
Fish meal	50	72	65	47	68
Oil	7	7	7	5	0
Dicalcium phosphate	1	1	1	1	0
Premix	2	2	2	2	2
Binder	15	0	0	0	0
Total	100	100	100	100	100
Protein (%)	45	40	37.5	30	41
Energy (kcal/kg feed)	3000	3000	3000	2800	2700
Feed cost/kg (Baht)	39.96	19.15	18.13	15.1	14.58

Table 11. Practical, farm-made feed formula used in Thailand for walking catfish.

Ingredients	Fingerling – 3 months	3 months – marketable size (with rice bran)	3 months – marketable size (without rice bran)
Cassava (dried meal)	26	22	22
Coconut (by-product)	0	0	20
Rice bran	0	15	0
Soybean meal	41	32	32
Fish meal	25	20	20
Lupin leaf	0	5	0
Oil	5	3	3
Dicalcium phosphate	1	1	1
Premix	2	2	2
Total	100	100	100
Protein (%)	32	28	28
Energy (kcal/kg feed)	2800	2700	2600
Feed cost/kg (Baht)	11.86	10.18	9.78

3.3.3 The main problems with feed and feeding

There are two types of feed, fresh and home-made feed, that farmers use for intensive and semi-intensive culture systems. Fresh feed includes trash fish, fish by-products, poultry by-products, kitchen waste etc. These fresh feed materials are dumped directly into the fishpond, causing deterioration of water quality. Moreover, without proper storage, fresh feed spoils easily and its quality can deteriorate. This increases the risks of transmitting disease. This problem is often found on small farms which lack cold storage facilities for keeping raw materials.

For farm-made feed, the main problem is the lack of standard composition of the feed. Sometimes it is made of a single ingredient and sometimes there are many. Composition depends on the availability of local raw materials. Thus, the nutritional value of feed varies. Moreover, the feed is made by means of simple equipment, usually a manual meat mincer. This causes much poorer water stability of the feed than manufactured commercial pellets. Consequently, the feed will cause deterioration in water quality. Manufacturing compound feeds generally requires more capital than making moist feeds, as a hammer mill and mixer are required in addition to a mincer.

Commercial feed is normally used in intensive culture systems. The main problem is the high feed cost. This makes the whole operation less profitable.

Table 12. Examples of practical, farm-made feed formulas used in Thailand for tilapia and other herbivorous fish.

Ingredients	Fingerling to 2–4 months	For marketable size (in cage)	For marketable size (with rice bran)	For marketable size (without rice bran)
Cassava (dried meal)	23	23	35	22
Coconut (by-product)	0	0	0	30
Rice bran	15	20	15	0
Soybean meal	35	25	25	25
Fish meal	25	25	20	20
Lupin leaf	0	0	0	0
Oil	4	4	2	0
Dicalcium phosphate	1	1	1	1
Premix	2	2	2	2
Total	100	100	100	100
Protein (%)	31	27.5	24.5	26
Energy (kcal/kg feed)	2700	2700	2500	2500
Feed cost/kg (Baht)	11.3	10.65	9.36	8.5

3.3.4 Feed and feeding constraints

Feed and feeding constraints in inland aquaculture vary depending on the culture system (semi-intensive and intensive culture system), type of feed used (farm-made feed or commercial feed) and the economic situation of farmers.

One very important feed and feeding constraint that often restricts semi-intensive culture systems is that farmers do not have enough money to buy feed or raw materials to make their own feed. This makes the feeding regime inconsistent. As well as there being inadequate information on nutrient requirements, particularly for practical culture conditions, farmers have limited knowledge of farm management. They do not know how much and what kinds of supplementary feed should be given. Thus, research is needed to study the details of nutrient dynamics for existing fish production in both semi-intensive and intensive culture systems. Commercial feed can be used as a supplementary feed for a semi-intensive culture system or as the main feed in an intensive culture system. Although it is expensive and uneconomic to use, commercial feeds possess good water stability and floating ability, which allow easy management of feeding rate. Farm-made feeds are less stable in water and inconsistent in nutritional value in comparison to commercial feed. This is because farmers do not have proper equipment to produce high-quality feed with high water stability. Inconsistency in quantity and quality of raw materials leads to inconsistency of the nutritional value of the farm-made feed and fish production. Moreover, it was found that farmers have limited knowledge on farm-made feed preparation as well as quality control of raw materials. The research needed to solve the above constraints is as follows:

- research on new local ingredients
- on-farm research on nutrient requirements for practical culture conditions
- research to modify equipment to improve quality of farm-made feed
- research to introduce hygienic techniques to increase natural food.

Problems concerning extension capacity in Thailand may be grouped under the headings officers, media for extension units and existing training opportunities for farmers. In the government sector, especially in extension, there are inadequate numbers of officers as trainers, as they have many responsibilities. In contrast, private organisations have adequate numbers of extension officers but they look after only their own customers. Other extension capacity constraints are as follows:

1. There is a lack of appropriate media for each particular area. More varieties of media are also required for extension units.
2. Extension officers need special training on feed and feeding.

Existing constraints to training opportunities for farmers include the following:

1. Farmers have very limited opportunities for training.
2. Most training courses are in general aquaculture and do not emphasise feed and feeding.
3. Most training courses are not held at the farm site, so farmers cannot attend.
4. The timing of training is inappropriate.

We suggest some activities to overcome the aforementioned problems:

- organise a training course/workshop
- set up demonstration ponds
- establish local farmer groups and network them
- organise a study tour/field trip.

Transport on the Red River, Vietnam. Photographer: Geoff Allan.

3.4 Feeds and Feeding Constraints in Inland Aquaculture in Vietnam[6]

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3.4.1 Introduction

Vietnam has a long coastline of 3260 km, 12 lagoons, straits and bays, 112 estuaries, and thousands of islands in the South China Sea. In the inland area, a network of rivers, canals, irrigation systems and reservoirs creates an area of 1,700,000 ha with potential for aquaculture and fisheries:

- 120,000 ha in ponds, lakes, and canals
- 340,000 ha in reservoirs
- 580,000 ha in paddy fields, in which the aquaculture is integrated with rice farming
- 660,000 ha in tidal areas.

According to the 2000 statistics, Vietnam produces nearly 1.5 million tonnes of aquatic products including freshwater and marine fish from aquaculture and capture fisheries. Inland aquaculture is quite developed, with different species and various culture systems that produce around 0.5 million tonnes, 30% of the total fish production in Vietnam. Aquaculture plays an important role in supplying fish and other aquatic products for local consumption and export.

Vietnam has about 30 fish species cultured in inland aquaculture from six families (Table 1). Among them are 15 species (*Tilapia*, Chinese and Indian carps etc.) introduced into Vietnamese waters two decades ago. There are only 14 indigenous fish species in aquaculture. Domestication of indigenous species for fish culture is ongoing.

Fish species selected for aquaculture should be highly tolerant of confined conditions in ponds, cages or reservoirs, and resistant to diseases at high stocking density. Feeding behaviour also plays an important role in the domestication of a species. In general, fish are divided into four groups with different feeding habits: herbivores, filter feeders, omnivores and carnivores. More than 70% of fish species cultured in Vietnam are omnivores. They include *Pangasius hypophthalmus, P. bocourti, Clarias gariepinus, C. macrocephalus, Labeo rohita, Cirrhinus mrigala, Helostoma temmincki, Barbodes altus* etc. (Table 2). The carnivores cultured are all indigenous species and have a high market value. They include *C. micropeltes, C. striatus*, sand goby and spotted featherback. The filter feeders are nearly all exotic species. Table 2 shows that omnivores are the most favoured species in aquaculture

[6] Citation: Hung, L-T. (2004). Feed and feeding constraints in inland aquaculture in Vietnam. In: Edwards, P. and Allan, G.L., ed., Feeds and feeding for inland aquaculture in Mekong River countries. Canberra, ACIAR Technical Paper No. 56, 71–76.

in Vietnam since the fish can feed on a large range of materials such as rice bran, fresh manure, cooked rice, trash fish, vegetables, restaurant leftovers etc. Moreover, the fish are highly adaptable to changes in feed and feeding.

Table 1. Numbers of fish species cultured in Vietnam grouped under families.

Family	Number of species	Indigenous species (number)	Introduced species (number)
Cyprinidae	12	03	09
Pangasiidae	04	04	0
Ophicephalidae	03	03	0
Cichlidae	03	0	03
Anabantidae	04	02	02
Clariidae	03	02	01
Total	29	14	15

Table 2. Feeding behaviour of cultured fish species in Vietnam.

Feeding behaviour	Species	Number of species
Herbivores	Giant goramy (*Osphronemus gorami*), grass carp (*Ctenopharyngodon idellus*), silver barb (*Barbodes gonionotus*) and *Spinibarbus denticulatus*	4
Filter feeders	Bighead carp (*Aristichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*), Nile tilapia (*Oreochromis niloticus*) and red tilapia (*O.* sp.)	4
Omnivores	Rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), red finned barb (*Barbodes altus*), kissing goramy (*Helostoma temmincki*), river catfish (*Pangasius bocourti, P. hypophthalmus*) and walking catfish (*Clarias gariepinus, C. macrocephalus*)	8
Carnivores	Sand goby (*Oxyeleotris marmoratus*), spotted featherback (*Notopterus notoptarus*) and snakeheads (*Channa gachua, C. micropeltes, C. striata*)	5

3.4.2 Feed and feeding in inland aquaculture

Feed and feeding in inland aquaculture vary greatly due to differences in feeding behaviour of the species cultured, and differences in aquaculture systems, from extensive systems on a small scale to intensive cage culture with floating pelleted feed.

Herbivore feed and feeding

Herbivores are most suited to inland aquaculture since they may be fed aquatic plants and some terrestrial plants. In some cases the fish can be fed rice bran, and restaurant and household waste. Grass carp (*Ctenopharyngodon idellus*) is the best-known species in the group. This species consumes large amounts of different types of grasses. It is distributed from uplands to lowlands, from northern to southern Vietnam. The fish is raised mainly in earthen ponds, in either stagnant or running water, but also in small cages in rivers or reservoirs. Silver barb is an indigenous species of the Mekong River. In southern Vietnam, this fish is raised in ponds or rice fields to control weeds. It is also a component of an integrated pest management (IPM) system in rice farming. The fish can feed on aquatic plants and some tender terrestrial leaves. Giant goramy (*Osphronemus gorami*) is cultured chiefly in ponds in southern Vietnam and feeds on aquatic or terrestrial plants. Even though it is classified as herbivorous, it consumes artificial feed such as rice bran, cooked rice and pellet feed. In peri-urban areas around Ho Chi Minh City, the fish is raised with pellet feed to reduce the culture duration from 15–18 months to 8–10 months, and is supplied to restaurants and middle-class markets. The Research Institute for Aquaculture (RIA No. 1) in northern Vietnam has been successful in spawning the high market value, indigenous herbivore *Spinibarbus denticulatus*. It has the potential to replace grass carp in mountainous areas of northern Vietnam. Three herbivores (grass carp, silver barb and giant goramy) are cultured species at present as their seed is available on the market. In contrast, *Spinibarbus denticulatus* has not yet been widely accepted in northern Vietnam due to the limitation of seed supply.

Herbivores are good fish to culture because they consume aquatic plants which are quite abundant everywhere. However, the following constraints apply in considering the feed and feeding of these species:

- *Grass availability, particularly in the dry season*: herbivores, especially grass carp, can consume a large amount of feed, up to 60–100% body weight per day. A 1000 m^2 fishpond reserved for culture of grass carp needs 1 to 2 labourers to collect grass. In some areas, farmers have to travel for 30–50 km to cut enough grass to meet the demand. There is not enough pasture reserved for feed for fish.
- *Supplementary feed for grass carp and other herbivores:* in semi-intensive and intensive systems, feeding grass does not provide enough nutrients for grow-out and for the reduction of the culture time. Supplementary feed for herbivores is at the embryonic stage of research.
- Farmers lack information and knowledge of alternative resources for feeding herbivores.
- Newly domesticated herbivores such as *Spinibarbus denticulatus* need to be more thoroughly researched to identify the potential for culturing them in different systems with various feeding regimes.

Feed and feeding for filter feeders

Filter feeders include silver carp, bighead carp, catla, rohu and tilapia (although tilapia, like omnivores, can feed on artificial feed). Polyculture of three to five fish species is usually used for filter feeders, as it allows better use of the natural productivity of pond water, with different species feeding on different natural feeds such as phytoplankton, zooplankton and detritus.

Filter feeders are mainly raised in earthen ponds or reservoirs to make the best use of natural feed. Silver and bighead carp are favoured for culture in northern Vietnam and the central highlands, whereas catla and rohu are preferred in the Mekong River basin. The constraints on the production of these fish are as follows:

- It is usually easy to get high productivity with filter-feeding species using low inputs, but farmers complain about low prices. The farm-gate price is often only two to three times that of paddy by weight.

- Farmers lack knowledge about the use of inorganic fertilisers to enrich the natural feed in fishponds.
- Integration of fish polyculture and livestock farming is traditional in Vietnam, but there is competition for use of manure as a crop fertiliser.

Several studies on using manure to fertilise fishponds have been carried out in research institutes and universities. They are usually carried out with a farming systems approach to develop rural areas. The AIT Outreach Project, Aquaculture Development in Mountainous Area of North Vietnam, and the Extension Project in the Mekong River of Mekong River Commission, aim at developing rural areas and using filter feeders as the principal fish in ponds.

Tilapia can be raised in ponds, cages and rice fields, as well as in extensive, semi-intensive, and intensive systems. The fish can be fed either by fertilising with manure or with floating feed in cages. The following constraints apply to feed and feeding of the species:

- In extensive culture systems, feed and feeding for tilapia compete with agricultural activities for manure.
- Farmers have to pay much more for pelleted feed when the fish are raised in intensive cage culture.
- In the case of homemade feeds, farmers lack knowledge and information on how to select ingredients and formulate suitable feeds.

Feed and feeding for omnivores

Catfish of the *Pangasius* and *Clarias* genera are the most important omnivores cultured in Vietnam. In southern Vietnam, *Clarias* hybrid (*C. macrocephalus* × *C. gariepinus*) is raised mainly using restaurant wastes and manure. Pangasids are cultured extensively or intensively in the Mekong Delta.

Cage culture started initially in Cambodia nearly 100 years ago (Chevey and LePoulain 1940; Coche 1978). The activity was introduced into Vietnam when Vietnamese refugees fled from Cambodia for their security in 1960 (MRC 1992). Since then, the culture has developed and concentrated along the Vietnamese–Cambodian border, mainly in An Giang and Dong Thap provinces in Vietnam. Cage numbers increased steadily after 1992 and reached 3876 units in 1995. The annual production was 120,000 tonnes in 2001.

All species of *pangasid* in aquaculture are omnivorous. They feed on rice bran, broken rice, maize, cassava flour, trash fish, fishmeal and even vegetables. Rice bran usually comprises two-thirds of the diet for *P. bocourti* and *P. hypophthalmus* at grow-out stage. The high carbohydrate and low protein diet gives a low growth rate but high protein utilisation. In Vietnam, the traditional feeding method for cage culture is to prepare and mix ingredients on the spot and cook them to produce a wet, sticky paste. The food conversion ratio of such traditional feed is 3–4. Floating, pelleted feed has been used recently for *P. bocourti* and *P. hypophthalmus*. Protein levels are 30–40% for fingerling stage, reducing to 20–30% for grow-out stage of 500 g to 1000 g. The feed-conversion ratio varies from 1.5 to 2, depending on the rearing method. All floating feeds are manufactured by local feed mills. Annual pelleted-feed production is about 200,000 tonnes, which would represent 10–20% of the total requirements if all farmers used pelleted feed. Constraints in feed and feeding of *Pangasius* cage culture are as follows:

- Traditional feeding is largely based on trash fish, a protein source that is quite limited in Vietnam.
- Floating pellet feed is expensive and not suitable for small-scale farmers.
- Research is needed to help farmers to replace trash fish with soybean meal, groundnut meal and other plant proteins.

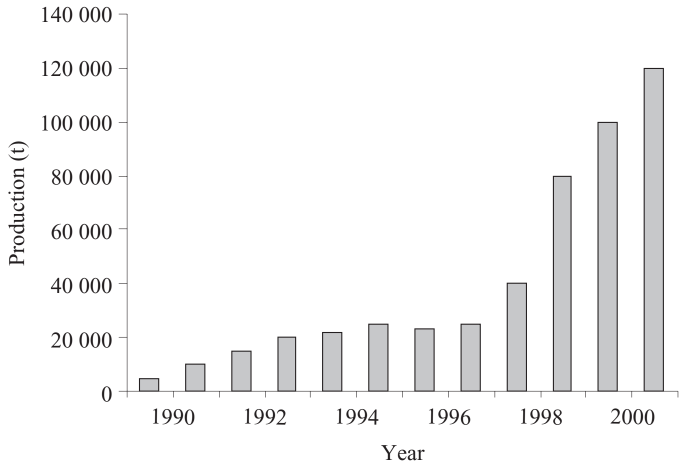

Figure 1. Annual production of *Pangasius* spp. in the Mekong Delta, Vietnam.

Feed and feeding of carnivores

Trash fish is the only feed source for carnivorous fish aquacultured in Vietnam. *Channa micropeltes* and *C. striatus* are the two main species, estimated at 90–95% of cultured carnivores. Carnivorous fish culture has been well developed in recent years, based on catching low-value fish in reservoirs as well as in Mekong Delta waters during the flood season. This raises problems for fish conservation in wetlands due to overfishing to provide feed for culture of carnivorous species. At present, farmers often use trash fish caught in the sea to feed carnivores. The food conversion ratio is approximately 4 to 5. The pressure on the trash fish supply often increases their price in the market and makes the system unsustainable and unfriendly. Constraints in feed and feeding of carnivores are as follows:

- The sources of trash fish are limited and the supply unstable. Therefore, the production system is unstable.
- The only carnivorous fish feed is trash fish, so it is necessary to undertake further studies to find alternative sources.

3.4.3 Conclusion and recommendations

Inland aquaculture systems in Vietnam are diverse in terms of species, feed and feeding, and the systems used in different areas of Vietnam. The integration of fish culture with livestock farming or cropping is a traditional method used for feeding omnivorous and filter feeders. However, inland aquaculture systems in Vietnam are intensifying to meet the demand of a growing population and the higher incomes of city dwellers. This is driving a change from traditional feeding to use of pelleted feed and other alternative feeds in the Mekong River Delta and the Red River Delta. Such a change poses great problems for research institutes, universities, and development assistance agencies. Cooperative research is needed on the following topics:

- alternative feeds for carnivores to replace or reduce the dependence on trash fish
- for herbivorous systems, identification of new indigenous species and development of supplementary feed for grass carp and other herbivores
- identification of locally available ingredients from which home-made feed can be prepared for omnivores and carnivores.

3.4.4 References

Chevey P. and LePoulain, F. 1940. La pêche dans les eaux douces du Cambodge. Nha Trang, Viet Nam, Institut Océanographique de l'Indochine, 193p.

Coche, A.G. 1978. A review of fish cage culture as practiced in inland waters. Aquaculture, 13, 157–190.

MRC (Mekong River Commission) 1992. Fisheries in the Lower Mekong River basin: review of the fisheries sector in the lower Mekong basin. Bangkok, MRC.

Houseboat for fishing family, Red River, Vietnam. Photographer: Geoff Allan.

4 Workshop Discussions

4.1 Background to Working Group discussions

The strategy behind the assessment of feed and feeding issues for freshwater aquaculture in Mekong countries was to conduct a desktop and field review (Professor Peter Edwards), solicit from experts within each of the four countries country papers to address specific issues and then to convene a workshop to further discuss and prioritise issues. At the workshop held in Siem Reap, Cambodia on 24–27 June 2002, participants (see Appendix 1) were organised into working groups for two distinct 'sessions'. The first was orientated at reviewing specific issues for each country and allocating priorities. This task was informed by the Edwards review and a presentation made by a country coordinator for each of the four countries (Chapter 4). Workshop participants were grouped by country into four groups. A summary of country priorities is provided in section 5.2.

The second working group 'session' was orientated at topics. Participants were divided into four groups and asked to discuss the following five broad 'themes':

1. Fertiliser and feeds availability, operating costs and optimal combinations
2. Alternative feeds, availability of ingredients and formulations, and manufacturing of supplementary or complete feeds
3. Diets for herbivores
4. Trash-fish-based diets
5. Knowledge, communication, capacity building and networking.

For each theme, groups were asked to clarify the 'problem', define objectives and summarise how it might be addressed, by whom and where? Participants were asked to focus on poverty alleviation and the impacts on small-scale farms and farmers. The outputs for each working group for this session are presented in sections 5.3–5.7.

4.2 Tables summarising country priorities for researchable issues

4.2.1 Cambodia

Summary of priorities for researchable issues for Cambodia (highest = 1)

Researchable issue	Priority	Comments
Small-scale pond culture		
Availability and opportunity cost of organic and inorganic fertilisers	2	
Optimal combinations of fertilisers and supplementary feeds	1	For on-farm research and extension activities

Summary of priorities for researchable issues for Cambodia (highest = 1) (cont'd)

Researchable issue	Priority	Comments
Availability of ingredients for farm-made feeds (a) on-farm production (b) local sourcing	1 1 2	
Manufacturing and storage of farm-made feeds	1	
Feed management and feeding practices	1	
Cost-effective fish diet of indigenous species (high value)	1	Link to improve use of low-value fish feed technology. Species: *Pangasius hypophthalmus, P. bocourti*, *Barbodes gonionotus, B. altus, Trichogaster pectoralis, Anabas testudineus, Oxyleotris marmoratus*, *Leptobarbus hoveni* and *Macrobrachium rosenbergii*
Seed nursing research of mentioned indigenous species	2	Study on feed diets (live and formulated)
Low-value fish (trash fish) based diets		
(a) Availability and alternative uses for different stakeholders (b) Alternative ingredients	1 2	Very high supply in short period Who will benefit from the use? What is the purpose of the use by different stakeholders? Golden snail and others
Knowledge base	1	
On-farm-made		
Capacity building	1	
Networking/communication	1	Department of Fisheries stations and NGOs, private farms

4.2.2 Lao PDR

Summary of priorities for researchable issues for Lao PDR (highest = 1)

Researchable issue	Priority	Comments
Small-scale pond culture		
Availability and opportunity cost of organic and inorganic fertilisers	1	Only inorganic fertiliser used is lime. Majority of farmers use organic (manure: buffalo, chicken etc.). Need research for effective combinations (still no details of quantitative analyses) Produce green water
Optimal use of combinations of fertilisers and supplementary feeds	1	No research ever done Don't know optimal combinations – main input rice bran
Availability of ingredients for farm-made feed	1	Large variety of naturally available feeds (e.g. kapok, cassava leaves, leucaena, various grasses, sweet potato leaves, rice bran, termites, pigeon pea) No information on nutritional matters
Methods for determining ingredient quality	3	Laboratory facilities but no research done on fish feeds

Summary of priorities for researchable issues for Lao PDR (highest = 1) (cont'd)

Researchable issue	Priority	Comments
Appropriate formulations of farm-made feeds and efficient use of agricultural by-products	1	High availability of broken rice, vegetable waste, integrated fish farming (fish-cum-pigs, fish-cum-chickens)
Manufacturing and storage of farm-made feed	3	Researchable issue that should be pursued in collaboration with private farmers
Feed management and feeding practices	1	Investigate optimal systems using local feeds Training and research at district levels
Nutrition of indigenous species	1	Six species currently under research in Lao PDR
Nutrition for herbivores	1	
Nursing feed and management	1	Research high priority as nursing mortality remains a major issue.
Trash-fish-based diet		
Competition with human consumption	2	Importance of pa keo fishery for export and human consumption
Availability of alternative feeds	1	
Alternative ingredients	1	
Feed management practices	2	
Capacity building	1	Increase capacity at LARReC, NUOL, district and provincial DLF offices
Knowledge base	1	Still low Improve knowledge base of district, provincial, and national staff through research collaboration
Communication and delivery	1	Research on how to improve farmer networks and capacity of provincial and district staff

4.2.3 Thailand

Summary of priorities for researchable issues for Thailand (highest = 1)

Researchable issue	Priority	Comments
Small-scale pond culture		
Availability and opportunity cost of organic and inorganic fertilisers	2	
Optimal combinations of fertilisers and supplementary feeds	1	For on-farm research and extension activities
Availability of ingredients for farm-made feeds (a) on-farm-made production (b) Local sourcing	1 1 2	Farmers lack information on what combinations of ingredients are best to use. Standard or recommended compositions are needed. Low-cost equipment produces feeds with poor water stability. Better equipment and methods are needed.
Manufacturing and storage of farm-made feeds	1	
Feed management and feeding practices	1	

Summary of priorities for researchable issues for Thailand (highest = 1) (cont'd)

Researchable issue	Priority	Comments
Cost-effective fish diet of indigenous species (high value)	2	
Seed nursing research of mentioned indigenous species	2	Study on feed diets (live and formulated)
Low-value fish (trash fish) based diets		
(a) Availability and alternative uses for different stakeholders (b) Alternative ingredients	1 1	Available mainly in coastal areas; cost can be high Golden snail in northeastern and northern areas
Knowledge base	1	
On-farm-made	2	Commercial feeds are good, water stable and easy to use, but too expensive. More information is needed on nutritional requirements of selected species.
Capacity building	1	Training is needed for researchers, extension workers and farmers. Demonstration farms needed.
Networking/communication	1	Very important

4.2.4 Vietnam

Summary of priorities for researchable issues for Vietnam (highest = 1)

Researchable issues	Priority	Comments
Small-scale pond culture		
Availability and opportunity cost of organic and inorganic fertilisers	2	Medium for northern Vietnam High for southern Vietnam
Optimal combination of fertilisers and supplementary feeds	1	Limited study on the combination of fertilisers and supplementary feeds
Availability of ingredients for farm-made feeds, on-farm production Local sourcing	1 1	Make use of locally available ingredients Improvement of knowledge about home-made feed Reduce use of expensive feed ingredients Reduce feed costs
Methods for determining feed ingredients	2	Medium for determining basic feed quality parameters High for determining toxicants, anti-nutritional factors
Appropriate formulations for farm-made feeds and efficient use of agricultural by-products (a) Rice bran (b) Others (c) Manufacturing and storage of farm-made feeds (d) Feed management and feeding practice	1 1 1 1	 Improper use of rice bran (ratio in feed diets) Quality variation Knowledge about nutritional values, sources and its use Knowledge limitation Farmers' knowledge limitation
Nutrition of indigenous species	1	
Diets for herbivorous species		
Availability of fodder	1	

Summary of priorities for researchable issues for Vietnam (highest = 1) (cont'd)

Researchable issues	Priority	Comments
Development of diets	1	
Trash-fish-based diets		
Availability and alternative uses for different stakeholders Alternative ingredients Manufacturing and storage of farm-made feeds Feed management practices	1 1 1 1	Reduction of trash fish supply Lack of data on alternative sources Lack of knowledge and technology Limitation of farmers' knowledge
Knowledge base	1	Improvement of knowledge of feed and feeding for extensionists, farmers and researchers
Communication and delivery	1	Lack of knowledge about feed and feeding Limitation of documents
Capacity building	1	Lack of staff and facilities to do nutritional studies
Networking/communications	1	Limitation of information exchange among the researchers and countries

4.3 Group 1 report: Fertiliser and feeds availability, operating costs and optimal combinations

Participants: Xayplodeth Choulamany, Malayphet Prounmy, Rous Chanthy, Ton That Chat, Pich Sophin, Bounthong Sengvilagkham, Marnop Chaenkij, Le Duc Trung, Khath Sakhorn, Poolsap Sirisant, Hav Viseth

Problem to be solved:

- Poor resource base
- Need to integrate aquaculture with other farming activities such as livestock and crops
- Feed ingredients are fed singly
- Limited knowledge about:
  - optimum amount of fertilisers or feeds needed for pond fish
  - best species mix (not all species are always available)
  - impact of different species and/or stocking densities on fertiliser and feed requirements
  - how to allocate resources between crops/livestock/fish (manure to the pond or crop, or rice bran to fish or livestock?).

How to solve the problem:

- Diversify farming: plant legumes, bananas, cassava etc.
- Increase nutrient flow using inorganic fertilisers – for crops or pond – high cost but available (excepting TSP that is not available)

- Introduce biogas digester
- Provide micro-credit
- Better information and extension materials

Expected outputs:

- Better use of existing resources
- Diversified agriculture and improved resource base
- Increase nutrient flow by using inorganic fertilisers (if available)
- Improve quality of organic fertilisers through biogas digester

Possible major activities:

- On-farm research on inorganic fertiliser use
- Adaptive research on resource use for different farming components
- Adaptive research on biogas digester
- Bio-economic modelling of nutrient flow

Who and where? (including partners):

- Laos (LARReC; DLF/provincial departments)
- Cambodia (DoF, RUA/SAPL, provincial departments)
- Thailand (DoF – nutrition division, Kasetsart University,)
- Vietnam (RIA 1, 2 and 3, UAF, CTU, Hue University)

Poverty focus and impact on small-scale farmers and fishers:

- Help poor farmers
- Help poor consumers

How to ensure the research 'makes a difference':

- Effective links between R and D (extension)

Risks and assumption:

- Implementation may require micro-credit if there is a need to purchase off-farm inputs.

4.4 Group 2 report: Alternative feeds, availability of ingredients, and formulations and manufacturing of supplementary and complete feed

Participants: Amararatne Yakupitiyage, Mali Boonyaratpalin, Supis Thongrod, PhillipeSerene, Nguyen Van Tien, Nguyen Tien Thanh, Orapin Jintasathaporn, Heng Ngan, Pongsai Chansri, Surapong Thumborisuth, Anusorn Somsiri

Definitions:

Alternative feeds: Defined as alternatives to existing high-cost commercial feeds and inefficient on-farm feeds.

Availability of ingredients: There are several issues on this topic. They are types of ingredients, their availability, cost and the efficient use of ingredients.

Formulations: There are two types of formulations: (1) practical formulation of supplementary feed and (2) complete diet.

Manufacture: Small-scale farmer groups or medium-scale farmers engaging in on-farm feed manufacture. Use of appropriate processing methods and equipment.

Small scale: Rural farmers engaging in pond or cage culture. This includes groups of smallholder farmers who work together to improve resource use and share technological know-how.

Problem	Solution	Output
Ingredients 1. Inefficient use of ingredients 2. Toxin contamination of feed ingredients	1. Research/extension on wet cooking (e.g. cooking of rice bran to improve digestibility), use of enzymes to improve digestibility, grinding to reduce particle size 2. Research/extension on proper storage methods	Reduced cost/ improved nutrient use efficiency
Formulation 1. Unknown nutrition requirements under different fertilisation regimes 2. Imbalanced formulations	1. Research/extension: on supplementary feed composition and supplementary feed requirement under different settings 2. Research/extension e.g. P/E ratio, ingredient digestibility and nutrient availability (extension means providing existing knowledge to farmers via existing mechanisms or through the development of new mechanisms)	Reduced cost and increased production
Manufacture 1. Low quality on-farm-made feed 2. Water stability	Develop appropriate, low-cost methods, tools and machinery	Improved feed quality

Who and where?

- Ingredients: research and extension activities in each country
- Formulation: research and extension activities in each country, but use different species, different ingredients, and settings to avoid overlaps.
- Manufacture: Thailand

Poverty focus

- Direct benefit
  – Improved efficiency of ingredient and feed use
  – Improved fish production
  – Enhanced income
- Indirect benefit
  – Employment

How to ensure the research 'makes a difference'

- Demonstrate improved resource-use efficiency and fish production
- Demonstrate that a greater number of farmers have adopted improved feed in fish production

Results and assumption

- Improved method of production is acceptable to the farmer

4.5 Group 3 report: Diets for herbivores

Participants: Xayplodeth Choulamany, Malayphet Prounmy, Rous Chanthy, Ton That Chat, Pich Sophin, Bounthong Sengvilagkham, Marnop Chaenkij, Le Duc Trung, Khath Sakhorn, Poolsap Sirisant, Hav Viseth

Problem to be solved:

- Not enough fodder for grass carp
- Limited mainly in northern and central Vietnam and Laos
- Constraint in flooding areas (grass carp eat paddy); compete with ruminants; and women spend lots of time collecting fodder
- Knowledge about supplementary feeding is limited

How to solve the problem:

- Grow fodder and use other vegetation
- Develop formulated diets

Expected outputs:

- Better use of existing resources

- Shorten growing period for both grass carp and giant goramy
- Reduce labour inputs (women) for collecting feeds
- Improve profitability of farmers and increase consumption by consumers

Possible major activities:

- Produce formulated and test diets for grass carp, giant goramy and *Spinibarbus,* with local ingredients such as rice bran and vegetable meals

Who and where? (including partners):

- Laos (LARReC; DLF/provincial departments) for grass carp and giant goramy
- Cambodia (DoF, RUA/SAPL, provincial departments) for grass carp
- Thailand (DoF – nutrition division, Kasetsart University) for grass carp and giant goramy
- Vietnam (RIA 1, 2 and 3, UAF, CTU, Hue University) for grass carp and giant goramy (in south)

Poverty focus and impact on small-scale farmers and fishers:

- Help poor farmers
- Help poor consumers

How to ensure the research 'makes a difference':

- Effective links between R&D (extension)

Risks and assumption

- If micro-credit is not available, then farm improvement is limited.

4.6 Group 4 report: Trash-fish-based diets

Participants: Le Thanh Hung, Chhouk Borin, Luke Leung, Lim Song, Iean Russell, Bounapanh Konedavong

Problems of trash fish utilisation in aquaculture

- The supply of trash fish is reduced and the price is increasing
- There is heavy seasonal supply
- Competition with human consumption and distribution of benefits

Objectives – how to solve the problem

- Improve trash fish utilisation at heavy supply periods
- Substitution of trash fish in feeding carnivorous and omnivorous fish

- Better understanding of the nature and extent of competition for the use of trash fish (stocks, market and regulatory conditions)

Expected outputs

- Improved techniques for processing and storage of trash fish as feed
- Formulations to include trash fish and alternative sources to reduce trash fish use to optimal levels
- Appropriate policy recommendations for fish catching and marketing
- On-farm recommendations and formulations for use of trash fish/alternatives

Possible major activities

- Assessment of stock of trash fish and uses (bio-economic system)
- Market and policy research (supply and demand, prices)
- Laboratory analysis of feeds
- Experimentation
- On-farm trials of formulations
- Development of appropriate technology for storage of trash fish

Monitoring and evaluation

Set up indicators such as:

- provision of and use of information by government and private operators
- adoption of recommendations
- reduced use of trash fish as a feed source (some countries).

Who and where (including partners)

- MRC is a regional partner
- In Cambodia: DoF, RUA (Prek Leap, NGOs)
- Lao PDR: Dept of Livestock and Fisheries, LARReC.
- In Vietnam: RIA 1, RIA 2, UAF, Hue University, Can Tho University
- In Thailand: DoF, Kasetsart University

Poverty focus and impacts (widest sense, direct and indirect)

- Recommendations for small-scale farmers
- Consideration of competition with human consumption leads to emphasis on interests of poor people
- Better nutrition for poor people
- Increased income for fish farmers and trash fishers

How to ensure research 'makes a difference'

- Consistent with socioeconomic constraints
- Consistent with strategic directions for research and development

- On-farm trials
- Link with extension and education network

Risks and assumptions

- Stock assessment

4.7 Group 5 report: Knowledge, communication, capacity building and networking

Participants: Sena De Silva, Sam Nouv, Pedro Bueno, Hap Navy, Simon Bush, Kamodoung Chaisiri

The group acknowledged that all participating countries recognised that there is an urgent need to enhance capacity in nutrition-related research and extension in the Mekong basin countries:

- All countries recognised the above to be the top priority to enable improvements to be made in feed and feed management in small-scale aquaculture in the region
- The group recognised that an enhancement of capacity in nutrition-related research will:
  - improve the research output of the proposed/future nutrition-related research projects, leading to more cost-effective feed development and management and practitioner satisfaction
  - improve and rationalise feed ingredient resource use
  - ensure complementarity of the research finding among researchers of different countries, and hence inter-country applicability.

The group recommends that an intensive training course be held in the region at the earliest opportunity, to cover areas such as nutritional research methodology related to the projects that are recognised as a priority to the region. The training program should be of about 14 days duration and, as far as possible, use experts available in the region as trainers. The training program should include 5 to 6 nominees from each country, preferably drawn from as many institutions as possible. The group recommends that this training program be held in Can Tho University, southern Vietnam.

The group recommends that the above course be followed by a separate training program for extentionists at a suitable time depending on the progress of the ongoing research projects. This training program should include researchers as well as other stakeholders, and be carried out on a country-wide basis.

Networking

The need for a network was accepted by all participants. However, before the formal establishment of such a network it is thought that the following needs have to be fulfilled:

- an assessment the progress of ongoing research and the degree of the interaction amongst participating researchers
- identification of a suitable regional organisation to take the lead in the initial stages in the formation of such a network.

The selected organisation will:

- facilitate the identification of participating national institutions, other stakeholders, personnel etc. over a period of one year, and explore the availability of resource support;
- draw up the *modus operandi* for the network and explore the possibilities of having:
  – a regular newsletter
  – a website
  – other means of interaction through study tours, workshops etc.
- provide suitable mechanisms for dissemination of the research results to all stakeholders
- act as a catalyst for developing in country materials and their dissemination, and
- encourage the development of research projects of common interest to all participating countries.

The selected organisation will also develop further objectives for the network, and explore collaboration with other appropriate professional bodies in the region to facilitate achieving the common goal of poverty alleviation through sustainable aquaculture.

Grass carp cages on the banks of the Red River, Vietnam. The daily ration of vegetation is on top of the cages ready to be fed to the fish. Photographer: Geoff Allan.

Appendixes

Tilapia are a popular fish in the marketplace. They are good eating and easy to culture. The challenge for many farmers is to know the best combinations of available ingredients for cost-effective fish production. Photographer: Peter Edwards

Appendix 1

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Appendix 2

Terms of reference for the Edwards Review

The terms of reference for this review are to:

1. Describe existing feeds and feeding practices in Southeast Asian inland aquaculture with a focus on the MRC Region countries.
2. Identify how and where research, training and extension can most benefit small-scale, low-income farmers, and
3. Recommend participants and topics for a follow-up workshop to develop projects to address the highest priorities.

1 Objectives and outputs

1.1.1 To describe existing species and culture practices with special emphasis on fish feed and feeding practices in four countries: Cambodia, Lao PDR, Thailand and Vietnam.

Specific output:

Descriptions of current feed and feeding practices of *Pangasius* in cages and ponds in Cambodia; *Clarias, Macrobrachium* and *Oreochromis* in cages and/or ponds in Central and Northeast Thailand; and carps and tilapias in ponds in suburban Hanoi and Red River Delta VAC systems in North Vietnam and *Clarias* in suburban HCM City and *Pangasius* in cages in Chau Doc in South Vietnam.

1.1.2 To identify research needs for improving fish feeds and feeding practices for small-scale farmers.

Specific output:

Research needs for improving fish feeds and feeding practices for small-scale farmers identified for the above species and culture practices from field survey findings and desk top work. These will be informed by current and potential on-farm and off-farm resource availability, input supply and fish market prices, and fish species demand.

1.1.3 To identify the roles of both public and private institutions in small-scale aquaculture nutrition and to suggest training and extension needs for improving fish feeds and feeding practices for small-scale farmers.

Specific output:

The roles of government research institutes, development (extension) institutes, tertiary educational institutions (public institutions), regional agencies (e.g. FAO, Network of Aquaculture Centres in Asia–Pacific [NACA] and the Mekong River Commission [MRC] and the private sector (fish farmers and suppliers of feed and feed ingredients) in small-scale fish nutrition identified for each area visited. Suggestions on possible training and extension needs provided.

1.1.4 to recommend country participants and an agenda for a workshop to facilitate expert and regional involvement in further nutrition project development.

Specific output:

Suggestions on country representatives and other experts to attend a follow-up workshop on Feeds and Feeding in Southeast Asian Inland Aquaculture. These representatives will be identified during field visits and the desktop survey and their input to planning the workshop sought. Additional consultation with the key regional agencies, NACA and MRC will ensure the workshop links with important regional initiatives. The workshop aim will be to build on the review and assist with the development of high priority research projects with input from potential beneficiaries (country representatives), regional agencies, research providers and funding agencies. Although this workshop is not funded as part of this project, it is important to identify the most appropriate participants during this project and to alert them that the workshop is being planned. The key goal will be to foster ownership of the problems and commitment to achieving research outcomes by all parties before research commences.

Besides the above specific objectives, the final report will describe the field survey and case studies of feed and feeding systems for grow-out of major freshwater species. It will include lower value species e.g., grass carp for which women and children may spend several hours daily to collect green fodder in Central and North Vietnam, as well as higher value species such as black carp and catfish which small-scale farmers seek to culture to increase household income from aquaculture. It will pay particular attention to the feasibility of on-farm feeds for small-scale farmers as a “bridge” between traditional semi-intensive practices relying largely on on-farm sources of fertilizers and supplementary feeds and large-scale commercial farming of fish intensively with commercially available, manufactured diets (e.g. steam-pelleted or extruded diets). It will identify problems with availability, cost and formulation of commercially available manufactured diets.

2 Methods

The review will comprise two interrelated parts: literature review and desk top survey (questionnaire) work; and field surveys in Cambodia, Lao PDR, Thailand and Vietnam to provide new insight into more recent farmer practice, potentials and constraints. It is proposed that it be carried out by:

Professor Peter Edwards (Team Leader and Aquaculture and Farming Systems Specialist) with assistance from Dr Geoff Allan (Fish Nutrition Specialist, Australia)

A total of 42 man-days will be required to carry out the study as follows:
Field surveys (including travel for Peter Edwards):
Cambodia 5 days
Lao PDR 3 days
Thailand (Central and Northeast) 7 days
Vietnam (North and South) 7 days
= 22 person-days

Literature review and desk top work:
PE 15 days, GA 5 days = 20 person-days
Total 20 person-days (1.1:1, field: office)

The study will involve a review of the literature in general, including recently published papers, and a field survey to fill information gaps. It will include:

– On farm practices and resources (literature, outreach databases + quick and dirty surveys). Data will include species, culture methods, inputs, on-farm and off-farm resource availability, feeding / fertilising protocols, potentials and constraints)
– Market factors (resources and fish species demand / prices in different countries / region)
– Institutional factors (on-going projects, R&D, presence of commercial sector and its role, research, extension, training, facilities for both research and extension, manpower)

Emphasis will be given to the following:

– Cambodia – *Pangasius* in cages and ponds
– Lao PDR – identification of likely species for intensification through feeding and likely issues
– Thailand – *Clarias* (including uptake of previous ACIAR research results by farmers), *Macrobrachium* and *Oreochromis* in Central and Northeast Thailand.
– Vietnam – carps and tilapias in ponds in suburban Hanoi and Red River Delta VAC systems in North Vietnam; and *Clarias* in suburban HCM City and *Pangasius* in cages in Chau Doc in S. Vietnam.

3 Chronology

The study will require 6 months, starting in June.

4 Workshop (Rough Outline)

Presentation of the findings of the study to a wider audience in a small ACIAR funded workshop (not costed). Country representatives (identified during the review) will also be asked to summarise aspects of and priorities for aquaculture feeds and feeding in different regions. The key regional agencies (e.g. FAO, NACA and MRC) have indicated their willingness to contribute and will be asked to summarise relevant regional initiatives. This will provide a forum for potential beneficiaries (country representatives), regional organizations, research providers and funding agencies to discuss issues, country needs, and potential projects identified during the review as of high priority.

Expected outputs from the workshop could be:

- MRC Regional country reports
- Stakeholder analysis (who are they? their roles? their expectations?)
- Development of problem trees
- Identify required research/development assistance
- Identify potential funding and implementing agencies
- Final workshop report.

Appendix 3

Current projects and institutional capacity

Cambodia

Projects

1. The Fisheries Component of the Agricultural Productivity Improvement Project (APIP), sub-component Freshwater Fisheries Research has a budget of US$279,000 for 2001 to renovate Bati Fish Seed Production and Research Center, including purchase of feed pellet machine for $28,000. Research proposed is breeding indigenous fish species. World Bank loan.
2. JICA proposes to establish a National Aquaculture Centre to complement the MRC initiative to develop an Institute for Freshwater Fisheries Research.
3. Breeding indigenous fish, Southeast Asian Outreach. Also nutritional trials. Funded by New Zealand Government.
4. Aquaculture of Indigenous Mekong Fish Species, Mekong River Commission.
5. Rural Extension Project for Aquaculture Development in the Mekong Delta, Mekong River Commission.
6. Scale Integrated Aquaculture Programme, Southeast Asian Outreach, Kandal Province.
7. AIT/AARM–DoF Small-scale Aquaculture project in Svay Rieng, Kompong Spen and Takeo provinces. Farming systems research.
8. Support Programme for the Agricultural Sector in Cambodia, PRASAC II, EU funded. Small-scale aquaculture development in six provinces around Phnom Penh.
9. FAO/Belgian and GTZ-funded small-scale aquaculture projects in Siem Riep and Takeo, and Kompot, respectively.

Institutional capacity

There is strong capacity to carry out farming systems research with farmers through several ongoing, field-based projects. Although provincial level extension staff overall are limited in number and capacity, they are active in some provinces, e.g. Prey Veng and Takeo visited during the field survey.

There is some capacity to carry out on-station research. Bati Station, which may be taken over by the DoF, SAO and RUA all have hatcheries, experimental ponds and basic equipment for feed preparation and analysis. SAPL currently has only ponds.

Lao PDR

Projects

1. The FAO/UNDP Small-scale Aquaculture project has finished.
2. AIT Outreach is ongoing in southern Laos.
3. Aquaculture for Indigenous Mekong Fish Species, Mekong River Commission
4. Management of Reservoir Fisheries in Mekong Basin, Mekong River Commission
5. FAO/Laos project on broodstock with Hungarian assistance
6. Assessment of the feasibility of *Pangasius* cage culture in southern Laos with French assistance
7. Rehabilitation of fisheries stations and construction of an aquaculture extension centre at Nam Suang with Japanese assistance

Institutional capacity

With the assistance of FAO/UNDP and AIT Outreach, the major focus is adaptive on-farm or farming-systems research. A research centre, LARReC, has recently been established with Danida support. There is limited on-station laboratory research capacity. More basic training is required to raise the generally limited capacity in research and extension.

The first priority of the government is seed, with feed a second priority. The Ministry is trying to increase the number of hatcheries from the current 25. Each province is to have at least one hatchery, so by the year 2002 there will be 36 hatcheries, including private ones.

The Ministry also wants to centralise extension and set up a multidisciplinary extension centre. The DLF is currently extending nursing networks to the provinces. Through a technical assistance grant from JICA for an aquaculture improvement project, an aquaculture extension centre is being built at Nam Suang to improve nursing. There is knowledge of how to breed fish in the country, but only 6% survival in nursing. The aim is to increase nursing survival to 20% in 3 years. All that is required at present for grow-out in ponds is better training and extension.

Thailand

Projects

1. Aquaculture and Indigenous Mekong Fish Species, Mekong River Commission
2. Management of Reservoir Fisheries in Mekong Basin, Mekong River Commission
3. AIT Aquaculture Outreach

4. BAAC Integrated Farming with a rolling investment fund operating in six provinces. Loan requests for farmers are assessed, and advice and training given. A recent review estimated a 60% success rate among 867 project farmers from the target of 1250 farmers.
5. NIFI/World Vision project in northeastern Thailand with ACIAR funding
6. CP company promotes cage culture of tilapia

Institutional capacity

The government gives increasing attention to aquaculture as a vehicle for rural development. The BAAC integrated farming project now operates in six provinces and cooperates with other agencies, e.g. DoF and Kasetsart University. AIT Aquaculture Outreach supports both DoF and the Colleges of Agriculture and Technology of the Department of Vocational Education. Since 1990 the DoF has reorganised, with fisheries stations, e.g. Roi Et, visited during the survey concentrating on research and seed production, and extension and development the responsibility of provincial fisheries offices.

Kasetsart University and DoF both have considerable capacity to carry out fish nutrition research.

Vietnam

Projects

1. Aquaculture and Indigenous Mekong Fish Species, Mekong River Commission
2. Management of Reservoir Fisheries in Mekong Basin, Mekong River Commission
3. Rural Extension Project for Aquaculture Development in the Mekong Delta, Mekong River Commission
4. Use of rice bran in fish diets (just completed), funded by the Can Tho University Department of Science, Technology and Environment. Partial replacement of fish meal and soybean meal in the diets for fish cultured in rice–fish integrated systems or in improved fish-culture systems — Can Tho University.
5. Nutritional requirements of, and feed development for, *Pangasius* (ongoing project). Funded by various sources including Catfish Asian project, WES-aquaculture project, Ministry of Education and Training, Can Tho University. The objectives of the study are: (i) to determine the major nutritional element requirements such as for protein, carbohydrate, and lipids of three main cultured catfishes (*P. bocourti, P. hypophthalmus,1 P. conchophilus*); and (ii) development of feeds for intensive culture in ponds and cages, in order to improve fish growth and quality and to reduce feed costs and adverse environmental effects — Can Tho University.

6. Use of low-cost and locally available feed ingredients in fish and prawn diets (ongoing project). Funded by various sources, such as JIRCAS project at Can Tho University, and WES aquaculture project, Can Tho University. The objective of the project is to use low-cost ingredients such as water spinach, water hyacinth and cassava leaf as protein sources to partially replace high-cost protein (fish meal, blood meal, soybean meal) in fish/prawn diets in semi-intensive, improved extensive and integrated farming systems — Can Tho University.
7. *Pangasius* reproduction, including nutritional aspects — AGIFISH/CIRAD.
8. Development of cage culture of red tilapia, including feed — PROCONCO.
9. Rubber seed cake as a dietary ingredient for tilapia and hybrid catfish. University of Agriculture and Forestry, Ho Chi Minh City. Funded by Ministry of Fisheries and SUFA (Danida).
10. Catfish project, especially *Pangasius*. Funded by CIRAD/EU. Completed. Involved UC as well as UAF.
11. Fatty acid nutrition of fish and *Macrobrachium*. Funded by Belgium. University of Agriculture and Fisheries
12. AIT Aqua Outreach. University of Agriculture and Forestry, HCM City and provincial governments.
13. Monosodium glutamate waste, ami-ami, as a replacement for fish meal in red tilapia, *Pangasius* and hybrid catfish diets — RIA No. 2.
14. National fish-nutrition network on survey of ingredient sources: nutritional requirements of *Penaeus monodon,* marine finfish (mainly grouper), *Macrobrachium* and *Pangasius*; feed formulation and manufacture; and feed performance i.e. FCR. RIA No. 2 as the network hub. Funded by Vietnamese Government from 2001–2004.
15. On-farm trial of tilapia feeds using local ingredients, 1996–1998 (completed). Vietnamese Government funding. RIA No. 1.
16. Fry nursing in cages 1998–2000 (completed). ACIAR Reservoir project.
17. Tilapia feeds (ingredients, protein levels, feeding frequencies) in intensive pond culture. Funded by SUFA (Danida) 2001–03. RIA No. 1.
18. Replacement of fish meal by soybean meal in fish diets. Vietnamese Government funding. RIA No. 1.
19. AIT Aqua Outreach. RIA No. 1 and provincial governments.

Institutional capacity

Through Government Decision No. 13-CP in 1993, a national agriculture extension system, including aquaculture, has been established. It has limited staff, experience and resources, and tends to work with a narrow group of better-off farmers. Nevertheless, there is considerable interaction of provincial level staff with farmers through training and demonstration farms throughout the country. Considerable assistance in farming systems research and extension is provided through donor-funded projects.

There are reasonably well equipped laboratories and experimental facilities for fish nutrition in the RIAs and major universities. RIA No. 2 has a pilot-level feed mill capable of producing 10 tonnes feed/day. However, the feed produced is reported to be of poor quality so that it cannot complete with the private sector. Furthermore, RIA No. 2 purchases commercial feed for experimentation as its own feed is of poor quality. UAF also has a feed mill for research. Its capacity is 50 kg/hour. A feed mill of 5 tonnes capacity/day is to be installed in Hai Dung Province with Vietnamese Government funds and in association with a broodstock centre project in northern Vietnam.

Appendix 4

Approximate composition of key ingredients

Summary of key nutrient composition data for ingredients used or with potential for use in aquafeeds in southeast Asia (from Tacon 1990). All values are on an 'as is' basis. Moisture, crude protein, lipid and phosphorus from Tacon (1990). Carbohydrate values were calculated as 100 – (moisture+protein+lipid+ash). Gross energy values were calculated using energy values of 23.6, 17.2 and 39.5 MJ/kg for protein, carbohydrate and lipid, respectively (NRC 1993).

		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Cereal grain/by-product								
Corn/maize	Grain, ground	12.2	9.6	3.9	1.5	0.28	72.8	16.3
	Grain, flaked	11.0	10.0	3.6	1.0		74.4	16.6
	Gluten feed	10.3	23.7	2.4	5.8	0.64	57.8	16.5
	Gluten meal	9.9	45.8	2.7	3.2	0.43	38.4	18.5
	Hominy feed	9.7	10.7	5.8	2.6	0.50	71.2	17.1
	Germ oil meal (oilcake)	8.9	17.5	14.1	3.2	0.45	56.3	19.4
	Feed meal	12.5	9.0	4.5	2.5	0.40	71.5	16.2
	Corn-and-cob meal (corn ears)	12.8	7.8	3.1	1.5	0.22	74.8	15.9
	Cobs, ground meal	9.7	2.5	0.6	1.5	0.06	85.7	15.6
	Cannery process residue (waste), fresh	77.0	2.0	0.6	1.4	0.14	19.0	4.0
	Cannery process residue (waste), silage	69.5	2.5	1.2	1.6	0.24	25.2	5.4
	Distillers dried grains	7.0	27.2	8.9	2.5	0.39	54.4	19.3
	Distillers dried solubles	6.8	26.7	9.0	7.8	1.19	49.7	18.4
	Distillers dried grains with solubles	8.4	26.7	9.9	4.7	0.76	50.3	18.9
Millet	Grain	10.7	11.2	3.9	3.3	0.30	70.9	16.4
	Hulls	8.7	4.8	1.3	5.7	0.30	79.5	15.3

(cont'd) Summary of key nutrient composition data for ingredients used or with potential for use in aquafeeds in southeast Asia (from Tacon 1990). All values are on an 'as is' basis. Moisture, crude protein, lipid and phosphorus from Tacon (1990). Carbohydrate values were calculated as 100 – (moisture+protein+lipid+ash). Gross energy values were calculated using energy values of 23.6, 17.2 and 39.5 MJ/kg for protein, carbohydrate and lipid, respectively (NRC 1993).

		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Oats	Grains	11.5	10.4	4.8	3.4	0.32	69.9	16.4
	Dehulled grain (naked oats, groats)	10.9	13.6	6.4	2.3	0.39	66.8	17.2
	Hulls	7.7	3.5	1.4	6.5	0.12	80.9	15.3
	Oatmeal/middlings (feeding)	9.5	15.9	5.7	2.2	0.43	66.7	17.5
	Oat-mill feed	7.7	5.0	1.6	6.1	0.12	79.6	15.5
	Oat shorts	9.0	12.8	5.6	4.8		67.8	16.9
	Oat sprouts, fresh	86.8	2.4	0.7	0.5		9.6	2.5
Rice	Rough (paddy) rice	11.2	8.3	1.6	4.4	0.26	74.5	15.4
	Brown (cargo) rice, dehulled	9.0	9.1	1.6	1.0	0.65	79.3	16.4
	Broken (brewers) rice (rice meal)	11.3	7.5	0.6	0.6	0.13	80.0	15.8
	Polished (milled) rice	11.8	7.1	0.3	0.8	0.18	80.0	15.6
	Hulls (husk, chaff)	9.4	3.7	1.0	16.4	0.07	69.5	13.2
	Bran	10.0	12.2	11.8	13.1	1.38	52.9	16.6
	Bran (solvent extracted)	10.5	12.3	2.1	12.6	1.33	62.5	14.5
	Polishings	10.0	12.1	11.5	8.8	1.26	57.6	17.3
	Pollards (mixture of bran/polishings)	11.1	12.8	11.7	8.8	1.41	55.6	17.2
	Rice-mill feed (mixture of hulls/bran)	8.3	6.6	5.3	14.3	0.45	65.5	14.9
	Distillers spent rice, fresh	62.0	3.4	1.3	4.0		29.3	6.4

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Rye	Grain	13.0	11.2	1.5	1.7	0.34	72.6	15.7
	Bran	11.1	15.9	2.9	4.5	0.74	65.6	16.2
	Middlings	10.5	16.4	3.3	3.6	0.62	66.2	16.6
	Mill run	10.0	16.7	3.3	3.8	0.64	66.2	16.6
	Distillers dried grains	8.0	20.9	7.4	2.4	0.43	61.3	18.4
	Distillers dried solubles	5.6	35.1	1.2	7.2	1.20	50.9	17.5
	Distillers dried grains with solubles	9.5	27.2	4.1	6.4		52.8	17.1
Sorghum	Grain	11.2	10.6	3.0	1.9	0.27	73.3	16.3
	Bran	12.0	7.8	4.8	2.1		73.3	16.3
	Gluten feed	9.6	23.7	3.6	8.0	0.63	55.1	16.5
	Gluten meal	9.2	42.0	4.9	2.4	0.40	41.5	19.0
	Hominy feed	11.0	10.0	5.8	2.4		70.8	16.8
	Distillers dried grains	6.0	31.8	8.7	3.7	0.64	49.8	19.5
	Distillers dried solubles	7.0	26.5	5.5	8.5	0.61	52.5	17.5
	Distillers dried grains with solubles	5.0	33.2	9.4	4.2	0.92	48.2	19.8
Wheat	Grain	12.1	12.0	1.7	1.7	0.36	72.5	16.0
	Bran	12.1	14.7	4.0	5.8	1.28	63.4	16.0
	Germ meal	11.1	25.0	8.0	4.7	0.98	51.2	17.9
	Mill run	11.5	15.2	4.1	5.4	1.10	63.8	16.2
	Grain screenings	9.5	13.2	3.7	5.6	0.35	68.0	16.3
	Shorts (fine bran/feed flour mixture)	11.8	16.3	4.3	4.8	0.70	62.8	16.3
	Middlings (pollard)	10.5	17.4	4.3	4.9	0.91	62.9	16.6
	Feed flour	12.0	11.7	1.2	0.5	0.18	74.6	16.1

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Oilseed/by-product								
Almond	Seed (kernel)	4.9	18.9	55.3	2.9	0.50	18.0	29.4
	Hulls	9.7	3.2	3.3	5.9	0.10	77.9	15.5
	Oilcake, mechanically extr. (without hulls)	10.7	42.8	3.8	5.7		37.0	18.0
Babassu	Oilcake, mechanically extracted	9.5	20.2	6.1	4.9	0.85	59.3	17.4
	Oilmeal, solvent extracted	7.3	19.7	2.3	6.3	0.66	64.4	16.6
Cashew	Seed (kernel)	5.0	21.4	46.8	3.6	0.86	23.2	27.5
	Oilmeal, solvent extracted	7.0	41.9	1.3	6.0	1.68	43.8	17.9
Castor	Oilmeal, solvent extracted	8.0	35.4	0.9	6.5	0.80	49.2	17.2
	Hulls	8.1	26.5	2.0	6.4	0.60	57.0	16.8
Cocoa	Bean (seed, kernel), fresh	52.8	6.7	20.2	2.2		18.1	12.7
	Bean (seed, kernel), dried	10.4	13.1	35.7	3.5	0.33	37.3	23.6
	Shell (pericarp, seed testa), dried	9.3	18.8	7.0	7.9	0.21	57.0	17.0
	Pods (without beans), fresh	85.1	1.2	0.1	1.3		12.3	2.4
	Pods (without beans), dried	11.5	5.8	0.7	7.6	0.07	74.4	14.4
	Oilcake, mechanically extracted	11.4	23.1	5.3	5.3	0.68	54.9	17.0
Coconut	Kernel (endosperm), fresh	47.9	4.2	34.0	1.5	0.13	12.4	16.6
	Kernel (endosperm, meat, copra), dried	4.0	7.2	64.6	1.9	0.19	22.3	31.1
	Oilmeal, solvent extracted	8.0	21.0	1.5	6.0	0.60	63.5	16.5
	Oilcake, mechanically extracted	8.5	20.8	6.3	7.0	0.60	57.4	17.3
	Coir dust (husk processing dust)	12.9	2.0	0.6	6.6		77.9	14.1

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Conophor/Awusa nut	Seed (kernel), whole	4.9	22.7	56.0	3.6	0.33	12.8	29.7
	Seed (kernel), without cotyledons	4.2	20.8	57.7	3.5	0.39	13.8	30.1
	Cotyledons	5.1	9.9	21.0	4.7	0.45	59.3	20.8
	Oilcake, hydraulically extracted, cooked	3.5	31.5	27.2	4.7		33.1	23.9
	Oilmeal, solvent extracted, cooked	3.2	42.6	17.9	5.3		31.0	22.5
Cotton	Seed (kernel), whole	7.9	20.4	20.0	4.3	0.64	47.4	20.9
	Hulls	9.6	4.2	1.9	2.5	0.09	81.8	15.8
	Oilcake, with hulls (undec.), mechan. extr.	10.7	21.9	4.9	5.7		56.8	16.9
	Oilcake, without hulls (dec.), mechan. extr.	7.8	41.2	5.9	6.4	1.06	38.7	18.7
	Oilmeal, dec., solvent extr., 41% protein	9.8	41.7	1.5	6.9	1.09	40.1	17.3
	Oilmeal, dec., solvent extr., 50% protein	7.5	50.0	1.6	6.5	1.08	34.4	18.3
Crambe	Seed (kernel)	12.0	13.6	48.4	2.6		23.4	26.4
	Oilmeal, solvent extracted	12.0	29.9	1.1	6.1		50.9	16.2
Groundnut/peanut	Seed (kernel), with hull (undec.)	7.1	20.2	36.3	2.5		33.9	24.9
	Seed (kernel), without hulls (dec.)	6.5	28.4	44.7	2.3	0.39	18.1	27.5
	Hulls	11.4	6.2	1.6	5.1		75.7	15.1
	Oilcake, undec., mechanically extracted	10.0	30.2	9.1	5.7		45.0	18.5
	Oilmeal, undec., solvent extracted	7.8	31.7	1.9	4.3	0.91	54.3	17.6
	Oilcake, dec., mechanically extracted	9.6	46.2	6.7	5.2	0.60	32.3	19.1
	Oilmeal, dec., solvent extracted	8.7	48.7	1.1	6.0	0.59	35.5	18.0

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Hemp	Seed (kernel)	8.9	18.2	32.6	4.2		36.1	23.4
	Oilcake, mechanically extracted	8.1	31.8	6.2	8.8	0.45	45.1	17.7
	Oilmeal, solvent extracted	11.3	34.8	1.7	9.3		42.9	16.3
Kapok/silk cotton tree	Seed (kernel)	8.0	28.0	21.3	7.5	0.89	35.2	21.1
	Oilcake, mechanically extracted	11.9	27.5	6.7	6.9		47.0	17.2
Linseed/flax	Seed (kernel)	6.7	25.6	34.7	4.7	0.54	28.3	24.6
	Hulls	9.0	7.7	1.4	9.5		72.4	14.8
	Seed screenings	9.0	16.2	9.6	6.7	0.43	58.5	17.7
	Oilcake, mechanically extracted	9.9	33.6	5.4	6.0	0.80	45.1	17.8
	Oilmeal, solvent extracted	10.7	34.1	1.3	5.9	0.80	48.0	16.8
Mustard	Seed (kernel)	8.3	21.5	42.8	4.7	0.55	22.7	25.9
	Oilcake, mechanically extracted	9.5	36.3	8.9	8.2	1.14	37.1	18.5
Niger	Seed (kernel)	5.0	23.0	38.0	5.0		29.0	25.4
	Oilcake, mechanically extracted	10.2	31.4	5.7	10.2	0.73	42.5	17.0
	Oilmeal, solvent extracted	7.8	31.4	1.1	11.1		48.6	16.2
African oil palm	Seed (kernel/nut)	7.2	9.4	47.8	1.9	0.28	33.7	26.9
	Oilcake, mechanically extracted	10.5	17.7	9.7	3.9	0.49	58.2	18.0
	Oilmeal, solvent extracted	9.7	18.8	1.5	4.0	0.77	66.0	16.4
	Press fibre bunch, fresh	34.5	4.5	7.7	4.2	0.09	49.1	12.5
	Press fibre bunch, dried	13.8	4.8	18.1	7.7	0.11	55.6	17.8
	Palm oil sludge, dried	10.2	9.4	18.1	11.0	0.47	51.3	18.2

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Para rubber tree	Seed (kernel), decorticated	7.6	21.7	39.0	3.1		28.6	25.4
	Oilcake, undecor., mechanically extracted	8.1	13.2	4.4	2.5	0.43	71.8	17.2
	Oilcake, décor., mechanically extracted	9.3	24.2	3.5	5.8		57.2	16.9
Poppy	Seed (kernel)	7.2	20.9	32.5	7.5		31.9	23.3
	Oilcake, mechanically extracted	9.6	37.1	7.3	12.4		33.6	17.4
	Oilmeal, solvent extracted	11.3	36.0	1.0	13.2		38.5	15.5
Rape	Seed (kernel)	8.2	19.2	42.0	3.7	0.60	26.9	25.7
	Oilcake, mechanically extracted	8.1	34.1	7.9	6.5	1.07	43.4	18.6
	Oilmeal, solvent extracted	9.0	37.3	1.9	7.2	0.97	44.6	17.2
Safflower	Seed (kernel)	7.0	17.1	31.1	2.9	0.62	41.9	23.5
	Hulls	8.7	3.5	4.1	1.5		82.2	16.6
	Oilmeal, undecor., mechanically extracted	8.1	21.7	5.9	4.3	0.64	60.0	17.8
	Oilmeal, undecor., solvent extracted	8.7	22.5	1.0	4.8	0.80	63.0	16.5
	Oilmeal, décor., mechanically extracted	8.6	41.1	6.4	7.3	1.00	36.6	18.5
	Oilmeal, décor., solvent extracted	9.1	42.3	1.2	7.2	1.28	40.2	17.4
Sesame	Seed (kernel)	7.0	21.1	46.5	5.6	0.75	19.8	26.8
	Oilcake, mechanically extracted	8.0	40.4	10.6	10.4	1.20	30.6	19.0

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Soybean	Seed (kernel) with hulls (undecor.)	8.8	24.1	10.0	6.6		50.5	18.3
	Hulls	9.1	9.8	1.7	4.9	0.18	74.5	15.8
	Seed (kernel), without hulls (décor.)	9.1	37.8	17.8	4.8	0.59	30.5	21.2
	Oilcake, undecor., mechanically extracted	11.0	41.6	5.3	6.1	0.61	36.0	18.1
	Oilmeal, undecor., solvent extracted	11.6	44.4	1.2	6.1	0.62	36.7	17.3
	Oilmeal, décor., solvent extracted	10.4	49.0	0.8	5.9	0.63	33.9	17.7
	Protein concentrate meal	8.0	84.3	0.5	3.5	0.68	3.7	20.7
	Mill run	12.0	11.9	1.2	4.5	0.18	70.4	15.4
	Mill feed (flour by-produced)	10.3	12.9	1.7	4.7	0.18	70.4	15.8
Sunflower	Seed (kernel) with hulls (undecor.)	6.1	14.2	32.6	3.0	0.54	44.1	23.8
	Seed (kernel) without hulls (décor.)	5.0	25.7	44.2	3.8	0.88	21.3	27.2
	Hulls	12.0	3.1	1.6	5.3		78.0	14.8
	Sunflower heads with seed	9.5	13.1	12.6	8.6		56.2	17.7
	Sunflower heads without seed	10.0	8.2	3.7	11.0		67.1	14.9
	Oilcake, undecor., mechanically extracted	7.3	31.6	8.9	6.4		45.8	18.9
	Oilmeal, undecor., solvent extracted	9.7	30.8	1.5	6.3	1.16	51.7	16.8
	Oilcake, decor., mechanically extracted	7.8	37.1	9.3	6.3	1.08	39.5	19.2
	Oilmeal, décor., solvent extracted	7.7	43.4	2.5	7.0	0.97	39.4	18.0
Grain legume/by-product								
Pigeon pea/red gram/dahl	Seed (pea), mature, dry	10.0	20.1	2.1	4.2	0.30	63.6	16.5
	Seed (pea), fresh	67.4	7.0	0.6	1.3		23.7	6.0
	Seed flour	9.3	11.5	8.2	3.5		67.5	17.6
	Pea pods with seeds	12.7	17.7	1.5	2.9		65.2	16.0
	Pod husks	7.0	6.2	0.3	3.8	0.08	82.7	15.8

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Jack/sword bean	Seed (bean), mature, dry	11.1	31.2	2.1	2.7	0.29	52.9	17.3
	Pod husks	8.0	4.1	1.4	3.5	0.01	83.0	15.8
Carob/locust bean	Seed (bean), mature, dry	13.5	7.7	0.9	2.6	0.08	75.3	15.1
	Bean pods with seeds, dry	12.1	5.4	1.4	3.1	0.11	78.0	15.2
	Germ meal	10.6	40.3	4.6	5.3	0.87	39.2	18.1
Chickpea/garbanzo bean/Egyptian pea/gram pea	Seed (pea), mature, dry	10.4	19.9	4.3	3.0	0.29	62.4	17.1
	Bean pods with seeds, dry	4.9	16.2	2.8	9.1	0.23	67.0	16.5
	Bran	11.6	13.9	3.7	6.2	0.27	64.6	15.9
Cluster bean	Seed (bean), mature, dry	8.7	28.2	3.0	3.4	0.39	56.7	17.6
	Bean pods with seeds, green	82.5	3.7	0.2	1.4	0.25	12.2	3.1
Egyptian bean/lablab/hyacinth bean/bonavist bean	Seed (bean), mature, dry	9.8	23.8	0.9	3.7	0.39	61.8	16.6
	Bean pods with seeds, immature	82.4	4.5	0.1	1.0	0.06	12.0	3.2
Grass pea	Seed (pea), mature, dry	10.3	22.8	1.2	3.3	0.27	62.4	16.6
Lentil/red dahl	Seed with hulls, mature, dry	10.9	24.4	0.9	2.5	0.31	61.3	16.7
	Seed without hulls, mature, dry	10.4	23.9	1.1	10.7		53.9	15.3
	Pod husks	12.0	11.1	0.7	3.1		73.1	15.5
Lead tree/Ipil-ipil	Seed, mature, dry	9.0	32.6	6.8	4.0		47.6	18.6
Lupin	Seed, mature, dry	11.5	40.0	6.4	4.1	0.42	38.0	18.5

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Velvet bean	Seed (bean), mature, dry	8.7	24.1	3.2	3.3	0.65	60.7	17.4
	Bean pods with seeds, dry	10.7	17.6	4.4	4.5	0.37	62.8	16.7
	Pod husks	11.1	4.2	0.7	6.1		77.9	14.7
African locust bean	Seed (bean), mature, dry	7.2	30.8	12.8	4.1		45.1	20.1
	Bean pods with seeds, dry	7.0	12.7	6.8	6.2		67.3	17.3
	Pod husks	6.4	4.4	1.1	8.3		79.8	15.2
Lima bean	Seed (bean), mature, dry	9.1	21.5	1.1	4.6	0.35	63.7	16.5
	Bean pods with seeds, dry	4.6	17.9	0.6	3.8		73.1	17.0
Kidney bean/navy bean/haricot bean/string or dwarf	Seed (bean), mature, dry	10.5	22.6	1.6	4.1	0.48	61.2	16.5
Pea/field pea	Seed (pea), mature, dry	11.7	23.0	1.5	3.0	0.54	60.8	16.5
	Bean pods with seeds, dry	12.0	9.5	1.0	4.7	0.20	72.8	15.2
Velvet mesquite	Seed, mature, dry	10.0	49.7	8.0	4.0		28.3	19.8
	Bean pods with seeds, dry	6.9	11.6	1.8	4.5		75.2	16.4
Saman/rain tree/monkey pod/cow tamarind	Seed, mature, dry	13.5	27.3	5.2	3.7	0.29	50.3	17.1
	Bean pods with seeds, dry	20.5	10.2	0.6	1.9	0.25	66.8	14.1
	Bean pods, fresh	34.8	13.5	2.4	2.4	0.17	46.9	12.2
Sesbania	Seed (bean), mature, dry	9.4	32.5	6.2	1.4		50.5	18.8

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Urd/black gram	Seed (bean), mature, dry	11.0	23.9	1.4	3.4	0.40	60.3	16.6
	Bran	11.2	6.2	3.2	7.9		71.5	15.0
Mung bean/Green gram/Golden gram	Seed (bean), mature, dry	10.8	22.1	1.0	3.9	0.35	62.2	16.3
	Pod husks	9.7	7.4	0.5	7.0	0.18	75.4	14.9
Horse gram	Seed, mature, dry	8.4	24.7	4.8	2.8	0.27	59.3	17.9
	Bean pods, dry	8.0	6.6	1.1	10.6	0.12	73.7	14.7
Broad bean/horse bean	Seed (bean), mature, dry	12.7	25.6	1.4	3.7	0.54	56.6	16.3
	Seed (bean), mature, dehulled, dry	11.7	29.2	1.9	2.6		54.6	17.0
	Bean pods with seeds, dry	11.6	11.6	1.0	6.0	0.10	69.8	15.1
Red bean/Rice bean	Seed (bean), mature, dry	10.0	22.6	1.4	4.3	0.36	61.7	16.5
Winged bean	Seed (bean), mature, dry	9.7	37.3	18.1	4.3		30.6	21.2
	Green pod, immature, fresh	84.0	2.4	0.3	1.1	0.05	12.2	2.8
Cowpea	Seed (pea), mature, dry	10.9	22.3	1.3	3.2	0.41	62.3	16.5
	Pod husks	7.4	12.0	0.6	6.7		73.3	15.7
Bambarra groundnut	Seed, mature, dry	9.8	18.4	6.6	3.2	0.28	62.0	17.6
	Seed pods, dry	3.4	17.6	5.3	5.2		68.5	18.0
Ground bean/Kerstings groundnut	Seed (bean), mature, dry	10.9	19.7	1.6	3.0	0.40	64.8	16.4

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Giant taro/alocasia	Fresh tuber	81.2	0.6	0.1		0.05	18.1	3.3
Elephant yam	Fresh tuber	74.2	5.1	0.4	1.7	0.02	18.6	4.6
Mangold/mangel	Fresh root	88.5	1.2	0.1	0.9	0.03	9.3	1.9
Taro/old cocoyam/dasheen	Fresh tuber	74.0	1.7	0.2	1.0	0.60	23.1	4.5
	Fresh tuber (peeled)	67.6	1.9	0.1	1.1		29.3	5.5
	Fresh peelings	81.2	0.9	0.2	1.3		16.4	3.1
Swamp taro	Fresh tuber	60.0	1.0	0.5	1.0		37.5	6.9
Chufa/tiger nut	Tuber	19.8	5.3	24.2	1.8		48.9	19.2
Carrot	Fresh tuber	86.8	1.5	0.2	1.2		10.3	2.2
	Pulp, fresh	86.0	0.9	1.1	1.2		10.8	2.5
Greater yam/water yam/winged yam	Fresh tuber	70.0	2.0	0.2	1.4	0.06	26.4	5.1
	Fresh tuber (peeled)	73.8	1.9	0.2	1.4		22.7	4.4
	Fresh peelings	74.1	3.0	0.3	2.5		20.1	4.3
Bitter yam	Fresh tuber	79.0	2.8	0.3	0.7		17.2	3.7
Intoxicating yam	Fresh tuber	78.0	1.8	0.2	0.7		19.3	3.8
White yam	Fresh tuber	65.5	1.5	0.1	1.6		31.3	5.8
	Fresh peelings	82.3	2.0	0.2	1.7		13.8	2.9

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Sweet potato/Spanish potato	Fresh tuber	70.9	1.5	0.3	0.9	0.06	26.4	5.0
	Dried tuber meal	12.6	4.2	0.7	3.4	0.13	79.1	14.9
	Fresh peelings	88.3	0.7	0.2	0.5		10.3	2.0
Cassava/Tapioca/Manioc/Manihot	Fresh tuber	65.9	0.9	0.2	1.0	0.05	32.0	5.8
	Tuber, dehydrated	13.5	2.1	0.5	2.2	0.11	81.7	14.7
	Fresh tuber (peeled)	68.8	0.9	0.2	1.0	0.01	29.1	5.3
	Fresh peelings	72.1	1.6	0.4	1.4		24.5	4.7
	Cassava meal (starch extracted)	14.8	1.3	0.6	2.3	0.03	81.0	14.5
Arrowroot	Rhizome (root), fresh	70.5	1.6	0.1	1.4		26.4	5.0
	Rhizome (starch extracted 'bittie', dry)	12.2	3.0	0.3	2.4	0.15	82.1	14.9
Oca	Fresh tuber	84.0	1.1	0.8	0.8		13.3	2.9
Yam bean/potato bean	Fresh tuber	82.4	1.5	0.1	0.5		15.5	3.1
	Young green pods	86.4	2.6	0.3	0.7	0.04	10.0	2.5
	Seed, mature, dry	6.7	26.2	27.3	3.6		36.2	23.2
Yacon strawberry	Fresh tuber	75.2	1.4	0.1	1.6		21.7	4.1
Kudzu	Fresh root, peeled	68.6	2.1	0.1	1.4	0.02	27.8	5.3
Potato/Irish potato	Fresh tuber	76.7	2.3	0.1	1.1	0.05	19.8	4.0
	Tuber, dry meal	9.9	7.9	0.3	4.7	0.20	77.2	15.3
	Fresh peelings	78.8	2.1	0.1	1.3		17.7	3.6
	Pulp residue (starch extracted)	11.6	7.9	0.3	3.6	0.23	76.6	15.2

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Hausa potato	Fresh tuber	75.2	1.4	0.4	1.0		22.0	4.3
African yam bean	Fresh tuber	64.7	3.7	0.1	0.7		30.8	6.2
New cocoyam/tannia	Fresh tuber	70.0	2.1	0.2	1.0	0.06	26.7	5.2
	Fresh tuber (peeled)	75.9	1.4	<0.1	1.2			
	Fresh peelings	70.5	2.4	0.4	2.5		24.2	4.9
Pineapple	Fruit, ripe, fresh	85.3	0.4	0.2	0.4	0.01	13.7	2.5
	Stump meal, fresh	54.0	1.4	0.4	0.9	0.04	43.3	7.9
	Juice presscake	79.0	1.1	0.2	0.6	0.02	19.1	3.6
	Cannery residue (pulp/bran), dehyd.	11.7	3.6	1.1	3.5	0.12	80.1	15.1
Breadfruit	Fruit, ripe, fresh	70.2	1.7	0.3	2.0	0.04	25.8	5.0
	Fruit, ripe, cooked & peeled	68.2	1.5	0.3	1.0		29.0	5.5
	Fruit meal, dehydrated	15.1	2.7	0.8	2.6	0.14	78.8	14.5
Breadnut tree	Fruit pulp, fresh	84.9	3.1	0.8	1.0		10.2	2.8
	Fruit seeds, fresh	63.0	4.7	1.6	1.4		29.3	6.8
	Fruit fibre and skin, fresh	86.6	0.9	0.6	1.5		10.4	2.2
Papaya/pawpaw	Fruit, ripe, fresh	88.0	0.8	0.1	0.8	0.01	10.3	2.0
	Fruit, immature, fresh	92.8	0.8	<0.1	0.5			

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Watermelon	Fruit, ripe, fresh	95.9	0.5	0.1	0.3		3.2	0.7
	Seeds, dry	8.5	8.3	17.5	2.2		63.5	19.8
Lime	Whole fruit, ripe, fresh	68.1	3.6	3.0	2.1		23.2	6.0
	Fruit skin (peel) and rag (fibre)	81.7	1.4	0.9	0.7		15.3	3.3
	Seed, fresh	70.9	6.4	3.6	0.6	0.09	18.5	6.1
	Silage of skins (peels)	77.0	2.4	1.5	2.2		16.9	4.1
	Fruit pulp, dehydrated	15.0	7.7	2.9			74.4	15.8
Lemon	Fruit pulp, dehydrated	7.0	6.4	1.4	5.3		79.9	15.8
Grape fruit	Whole fruit, ripe, fresh	86.6	1.0	0.5	0.5	0.02	11.4	2.4
	Fruit pulp, wet	79.7	1.3	<0.1	0.8			
	Fruit pulp, dehydrated	9.0	6.1	1.4	5.5	0.16	78.0	15.4
	Fruit skin (peels), fresh	82.1	1.2	0.3	0.7		15.7	3.1
	Silage of fruit peels, fresh	80.8	1.4	0.4	0.8		16.6	3.3
Tangerine	Fruit pulp, dehydrated	13.0	7.0	4.9	4.4	0.12	70.7	15.7
Sweet orange	Whole fruit, ripe, fresh	87.2	1.0	0.2	0.6	0.02	11.0	2.2
	Fruit skin (peels), fresh	83.9	1.1	0.3	0.6	0.02	14.1	2.8
	Silage of fruit peels, fresh	80.4	1.5	0.5	1.0	0.02	16.6	3.4
	Fruit pulp, wet	75.0	2.2	0.4	0.9	0.07	21.5	4.4
	Fruit pulp, silage	88.7	1.0	0.2	0.6		9.5	1.9
	Fruit pulp, dehydrated	11.1	7.5	2.0	3.4	0.09	76.0	15.6

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Citrus pulp	Citrus pulp, fresh	81.7	1.2	0.6	1.4		15.1	3.1
	Citrus pulp, silage	80.0	1.5	2.1	1.1	0.03	15.3	3.8
	Citrus pulp, dehydrated	9.1	6.3	3.3	6.0	0.11	75.3	15.7
Molasses	Citrus molasses, fresh	32.0	5.6	0.2	4.9	0.09	57.3	11.3
Coffee	Fruit pulp, fresh	76.8	2.4	0.5	1.9	0.03	18.4	3.9
	Fruit pulp, sun dried	11.4	10.9	2.3	7.7	0.11	67.7	15.1
	Seed hulls, dried	8.8	2.3	0.6	0.5		87.8	15.9
Pumpkin/Squash/Gourd	Fruit, ripe, fresh	91.5	1.2	0.4	0.7	0.04	6.2	1.5
Mango	Fruit pulp (immature fruit), fresh	82.3	6.2	<0.1	0.3	0.02		
	Fruit pulp (mature fruit), fresh	82.7	1.0	0.1	0.4		15.8	3.0
	Fruit kernel (seed), fresh	50.0	4.2	4.4	2.7		38.7	9.4
	Fruit silage, wet	84.0	0.8	1.0	1.5	0.01	12.7	2.8
Tomato	Whole fruit, ripe, fresh	93.8	1.0	0.2	0.7	0.03	4.3	1.1
	Pomace (pulp), dehydrated	8.1	21.4	10.3	5.3	0.56	54.9	18.6
	Pomace (pulp), silage, wet	70.5	5.7	4.3	1.3	0.14	18.2	6.2
	Fruit skins with juice, dried	10.4	18.5	2.2	8.8	0.41	60.1	15.6
Apple	Whole fruit, ripe, fresh	83.0	0.5	0.4	0.4	0.01	15.7	3.0
	Fruit pomace (pulp), dried	11.0	4.4	4.5	2.1	0.11	78.0	16.2
	Fruit pomace (pulp), silage, wet	78.6	1.7	1.3	1.0	0.02	17.4	3.9

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Banana/plantain	Banana fruit, immature/green, fresh	80.6	0.9	0.5	0.9		17.1	3.4
	Banana fruit, ripe, fresh	76.0	1.3	0.3	1.0	0.03	21.4	4.1
	Peeled fruit, immature, fresh	74.9	0.9	0.4	0.8		23.0	4.3
	Peeled fruit, ripe, fresh	69.5	1.3	0.2	1.4		27.6	5.1
	Green fruit with peel, meal	12.0	4.3	2.8	4.3		76.6	15.3
	Ripe fruit, dried	14.0	3.5	0.5	2.6	0.09	79.4	14.7
	Fruit skins (peels), ripe, fresh	85.9	1.1	1.6	1.9		9.5	2.5
	Fruit skins (peels), ripe, dried	12.0	6.8	7.1	9.2		64.9	15.6
	Fruit skins (peels), immature, dried	10.0	6.9	5.4	14.8		62.9	14.6
	Plantain fruit, ripe, fresh	68.8	1.1	0.2	1.1	0.08	28.8	5.3
	Plantain fruit, green with peel, meal	10.0	4.3	1.0	4.5		80.2	15.2
	Plantain peels, mature, fresh	81.6	1.7	1.0	3.2		12.5	2.9
Avocado	Avocado seeds, fresh	59.0	2.0	1.6	11.3	0.08	37.4	7.5
	Avocado skins, fresh	76.0	1.7	8.4		0.04	13.9	6.1
	Avocado oil meal	9.0	18.5	1.1			60.1	15.1
Date palm	Whole fruit date, dried	25.7	2.2	0.7	4.2		67.2	12.4
	Fruit seeds, ground, dried	9.8	5.9	8.1	2.9		73.3	17.2
	Fruit pulp (sugar extracted)	11.8	4.8	0.3	2.4		80.7	15.1

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Grass/green crop								
Fresh green pasture grass	Very leafy	82.0	4.0	0.6	2.3		11.1	3.1
	Leafy	81.0	3.3	0.5	2.2		13.0	3.2
	Early flowering	79.0	3.0	0.7	2.1		15.2	3.6
	Flowering	77.0	2.4	0.5	2.2		17.9	3.8
	Seed set	75.0	2.1	0.6	1.8		20.5	4.3
Fresh green fodder crops	Vetches - mid bloom	82.0	3.2	0.5	1.5		12.8	3.2
	Trefoil - aerial part	77.4	4.0	0.8	2.1	0.05	15.7	4.0
	Sesbania - leaves	77.0	6.6	0.5	2.3	0.10	13.6	4.1
	Leadtree/lpil-ipil - leaves	68.4	8.8	1.0	1.1	0.10	20.7	6.0
	Saman - leaves	60.9	8.7	2.7	2.3	0.08	25.4	7.5
	Kale - aerial crop	85.9	2.4	0.5	1.8	0.08	9.4	2.4
	Mangold - leaves and crowns (tops)	87.4	2.1	0.5	2.4		7.6	2.0
	Mangold - leaves	85.3	2.6	0.4	2.8	0.05	8.9	2.3
	Cassava - leaves and stem	76.9	4.5	1.2	1.7		15.7	4.2
	Cassava - leaves	74.4	7.7	1.3	1.8	0.10	14.8	4.9
	Sweet potato - leaves	89.2	2.1	0.4	2.8		5.5	1.6
	Sweet potato - vines	89.0	2.2	0.3	1.6	0.02	6.9	1.8
	Sweet potato - leaves and vines	84.9	2.5	0.5	2.4		9.7	2.5

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Fresh green fodder crops (cont'd)	Taro - leaves	89.8	2.2	0.8	1.3	0.05	5.9	1.9
	Taro - aerial crop	83.3	3.7	1.2	2.3	0.01	9.5	3.0
	Carrot - leaves and crowns (tops)	84.0	2.1	0.6	2.4	0.03	10.9	2.6
	Cabbage - leaves	87.4	2.1	0.5	1.6	0.03	8.4	2.1
	Broccoli - lLeaves and stems	89.0	3.6	0.3	1.1	0.08	6.0	2.0
	Lettuce - leaves	95.0	1.1	0.2	0.8	0.02	2.9	0.8
	Ramie - leaves	84.9	2.0	0.6	2.4	0.05	10.1	2.4
	Elephant yam - leaves	86.5	3.0	0.5			10.0	2.6
	Sugarcane - stems	85.0	1.2	0.1	0.9		12.8	2.5
	Sugarcane - cane tops	75.0	1.3	0.4	3.0		20.3	4.0
	Guava - leaves	62.5	3.8	2.8	2.9	0.10	28.0	6.8
	Papaya - leaves	77.4	5.3	1.1	2.9	0.06	13.3	4.0
	Breadnut tree - lLeaves	61.1	5.4	1.3	3.0		29.2	6.8
	Pineapple - leaves	79.4	1.9	0.3	1.0		17.4	3.6
	Pineapple - lreen tops	83.0	1.5	0.4	1.4	0.01	13.7	2.9
	Pumpkin - line	82.5	1.5	0.9	2.9		12.2	2.8
	Alocasia - leaves	90.4	2.3	0.6	1.7	0.01	5.0	1.6
	Banana - leaves	75.0	2.4	1.3		0.04	21.3	4.7
	Banana - pseudostem (trunk)	95.0	0.2	0.1	0.7	0.01	4.1	0.8
	Jackfruit - leaves	60.3	6.8	1.7	4.7	0.08	26.5	6.8
	Neem tree - leaves	64.2	4.8	2.2	3.7	0.06	25.1	6.3
	Groundnut - leaves	73.1	4.7	0.6	2.3	0.05	19.3	4.7
	Pigeon pea - aerial part (forage)	71.0	5.9	1.5	1.8	0.06	19.8	5.4
	Jack/sword bean - aerial part (forage)	76.8	5.2	0.5	2.7		14.8	4.0
	Carob - leaves and stem	75.7	5.4	0.6	2.3		16.0	4.3

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Fresh green fodder crops (cont'd)	Chickpea - young shoots	60.6	8.2	0.5	3.5	0.21	27.2	6.8
	Cluster bean - aerial part (fodder)	80.8	3.1	0.4	3.3	0.07	12.4	3.0
	Egyptian bean/lablab/hyacinth bean - aerial part	81.6	2.5	0.9	2.3	0.06	12.7	3.1
	Soybean - aerial part	74.0	3.7	1.1	2.4	0.07	18.8	4.5
	Grass pea - aerial part, late vegetative	82.6	3.6	0.6	1.9	0.06	11.3	3.0
	Grass pea - aerial part, early bloom	78.2	3.2	0.6	3.1	0.08	14.9	3.6
	Grass pea - aerial part, mid-bloom	72.0	5.0	0.7	3.5	0.06	18.8	4.7
	Lupin - aerial part	88.3	3.1	0.3	1.6	0.03	6.7	2.0
	Velvet bean - aerial part, vegetative	82.9	3.9	0.4	2.0		10.8	2.9
	Velvet bean - aerial part, mid-bloom	81.5	3.2	0.7	1.1	0.02	13.5	3.4
	Broad bean - stems and leaves	85.0	2.5	0.4	1.8	0.04	10.3	2.5
	Winged bean - stems and leaves	78.9	6.3	1.0	1.8	0.12	12.0	3.9
	Pea - aAerial part, late vegetative	86.6	2.3	0.4	1.7	0.05	9.0	2.2
	Pea - aAerial part, mid-bloom	84.8	2.2	0.4	2.0	0.06	10.6	2.5
	Urd/black gram - aerial part	84.0	3.1	0.4	2.6	0.04	9.9	2.6
	Horse gram - aAerial part	81.8	3.2	0.4	1.3	0.05	13.3	3.2
	Red bean - aerial part, mid-bloom	68.0	5.4	0.6	2.5	0.08	23.5	5.6

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Silages	Grass, leafy	80.0	3.5	1.0	1.8		13.7	3.6
	Grass, early bloom	75.0	3.2	0.9	2.3		18.6	4.3
	Grass, full-bloom	75.0	2.9	0.7	2.7		18.7	4.2
	Maize/corn	75.0	2.4	1.1	1.5	0.08	20.0	4.4
	Oats	76.0	2.5	0.7	1.7	0.07	19.1	4.2
	Rye	68.0	4.1	1.1	2.5	0.10	24.3	5.6
	Sorghum	70.0	2.2	0.9	2.6	0.06	24.3	5.1
	Wheat	72.5	2.8	0.7	2.2	0.08	21.8	4.7
	Soybean	73.0	4.8	0.7	2.7	0.13	18.8	4.6
	Pea, vines only	76.0	3.1	0.8	2.1	0.06	18.0	4.1
	Urd	72.7	3.8	1.3	7.2		15.0	4.0
	Sugar beet, crowns with tops	79.0	2.8	0.6	7.1	0.05	10.5	2.7
	Pineapple, leaves	80.9	1.1	0.5	1.9		15.6	3.1
Straws and chaff	Maize/corn	10.0	5.3	1.2	5.2	0.08	78.3	15.2
	Oats, straw	10.5	3.7	2.1	6.4	0.08	77.3	15.0
	Oats, chaff	14.0	6.0	2.1	10.3		67.6	13.9
	Rice	8.0	3.9	1.0	14.8	0.08	72.3	13.8
	Rye	11.7	2.9	1.5	3.8	0.08	80.1	15.1
	Wheat	10.4	2.7	1.4	7.7	0.06	77.8	14.6
	Soybean	12.0	4.6	1.3	5.6	0.05	76.5	14.8
	Chickpea	9.4	5.4	0.4	12.0	0.11	72.8	14.0
Miscellaneous plant-based feedstuffs								
	Bakery waste, dried	8.8	10.0	12.4	3.2	0.23	65.6	18.5

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
	Bread, dried	8.0	12.2	2.9	1.8	0.15	75.1	16.9
	Leaf (rye grass) protein concentrate, dried	5.4	57.7	20.6	3.7	0.35	12.6	23.9
	Potato protein concentrate, dried	8.5	78.1	0.4	1.3	0.25	11.7	20.6
	Pyrethrum, marc	22.7	11.9	0.5	6.1	0.19	58.8	13.1
	Pyrethrum, marc, sun cured	14.5	12.6	0.5	6.4	0.26	66.0	14.5
	Sago palm, meal	14.0	1.8	1.1	3.8	0.04	79.3	14.5
	Sago palm, refuse (starch extracted)	22.9	2.0	0.2	16.2	0.02	58.7	10.6
	Sugar cane bagasse, dried	9.6	1.5	0.8	5.1		83.0	14.9
	Sugar cane bagasse, fresh	45.0	0.8	0.2	3.0	0.15	51.0	9.0
	Sugar cane filter press mud, fresh	75.0	2.7	2.6	5.3	0.27	14.4	4.1
	Sugar cane strippings, fresh	55.0	1.6	0.4	4.6	0.12	38.4	7.1
Seaweed	Kelp meal, dehydrated	8.9	6.5	0.5	35.0	0.26	49.1	10.2
Aquatic macrophytes								
Alligator weed	Whole plant, fresh	84.1	2.4	0.4	3.2		9.9	2.4

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Aquatic fern	Whole plant, fresh	93.5	1.7	0.3	0.9	0.03	3.6	1.1
Coontail	Whole plant, fresh	93.1	1.3	0.3	1.6	0.04	3.7	1.1
Chara	Whole plant, fresh	91.6	1.5	0.1	2.7		4.1	1.1
Water hyacinth	Whole plant, fresh	91.5	1.2	0.3	1.3	0.09	5.7	1.4
Canadian pondweed	Whole plant, fresh	91.1	1.9	0.3	1.6	0.04	5.1	1.4
Hydrilla	Whole plant, fresh	91.7	1.8	0.3	2.0		4.2	1.3
Kangkong/water bind-weed	Leaves and stem, fresh	92.5	2.1	0.2	1.4	0.03	3.8	1.2
Water willow	Whole plant, fresh	85.0	3.4	0.5	2.6		8.5	2.5
Duckweed	Whole plant, fresh	91.9	1.7	0.5	0.9		5.0	1.5
Milfoil	Whole plant, fresh	88.7	2.0	0.3	1.9		7.1	1.8
Najas	Whole plant, fresh	90.4	2.3	0.4	1.4		5.5	1.6
Water lettuce	Whole plant, fresh	93.6	1.2	0.3	1.6		3.3	1.0
Pond weed	Whole plant, fresh	85.0	2.0	0.4	2.4		10.2	2.4
Sagittaria	Whole plant, fresh	85.0	2.6	1.0	1.5		9.9	2.7

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Salvinia	Whole plant, fresh	77.2	1.8	0.6	1.5		18.9	3.9
Burreed	Whole plant, fresh	89.1	2.6	0.9	1.2		6.2	2.0
Reed-mace	Whole plant, fresh	77.1	2.4	0.9	1.6		18.0	4.0
Wolffia	Whole plant, fresh	96.4	1.0	0.3	0.6		1.7	0.6
Marine multicellular algae	*Chaetomorpha* spp., fresh	90.4	3.1	0.6	2.3		3.6	1.6
	Enteromorpha intestinalis, fresh	81.4	3.7	0.5	6.0		8.4	2.5
SCP								
Bacterial SCP	*Pseudomonas/Methylophilus* spp.	6.4	73.1	5.7	11.7	2.33	3.1	20.0
Fungal SCP	Brewers yeast, dried	8.6	45.0	1.2	7.0	1.45	38.2	17.7
	Yeast, dried	9.2	46.8	5.7	6.2		32.1	18.8
	Bakers yeast, fresh	68.2	16.2	2.3	1.9	0.16	11.4	6.7
	W-yeast, fresh	62.1	14.6	12.7	2.2	0.25	8.4	9.9
	Torula yeast, dried	7.0	48.0	2.7	8.0	1.52	34.3	18.3
	Candida utilis, dried	8.3	47.3	5.2	7.3		31.9	18.7
	Candida spp., dried	7.6	43.3	0.2	7.1	1.42	41.8	17.5
	Pichia guillerm	2.9	48.6	11.8	5.7		31.0	21.5
	Aspergillus oryzae	6.3	44.1	3.5	7.9	1.63	38.2	18.4
	Aspergillus tomarii	8.5	44.4	9.4	4.7	0.95	33.0	19.9
	Mixed fungal SCP culture, dried	3.1	53.7	4.5	5.5		33.2	20.2

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Algal SCP - Freshwater	*Chlorella vulgaris*, dried	5.7	47.2	7.4	10.6		29.1	19.1
	Spirulina maxima	6.7	58.6	4.8	6.7		23.2	19.7
	Scenedesmus obliquus, dried	6.0	52.6	13.0	8.0	1.76	20.4	21.1
	Scenedesmus acutus, dried	8.1	43.6	10.5	7.4	3.66	30.4	19.7
	Cladophora glomerata, dried	1.6	31.0	5.2	23.2		39.0	16.1
Algal SCP - Marine	Filamentous bluegreen algae, mixed, fresh	90.1	2.3	0.2	5.1		2.3	1.0
	Oscillatoria/Phormidium spp., fresh	82.9	1.6	0.4	12.2		2.9	1.0
	Diatoms, mixed, fresh	87.1	2.9	0.9	6.5		2.6	1.5
	Phytoflagellates, mixed, fresh	88.9	3.9	1.3	0.7		5.2	2.3
	Marine chlorella (*C. vulgaris*), fresh	75.8	12.2	5.4	2.3	0.61	4.3	5.8
Mixed SCP cultures	Activated sludge - domestic sewage, dried	5.6	39.6	2.6	21.1	1.65	31.1	15.7
	Activated sludge - brewery processing waste, dried	5.0	44.4	8.0	12.6		30.0	18.8
	Activated sludge - paper processing waste, dried	3.0	42.3	0.4	27.7	2.30	26.6	14.7
Invertebrates								
Rotifers, *Brachionus plicatilis*, wet basis	Cultured on bakers yeast	90.7	6.2	1.8	0.7	0.127	0.6	2.3
	Cultured on bakers yeast + marine chlorella	88.7	7.7	2.4	0.5	0.138	0.7	2.9
Brine shrimp, *Artemia salina*	Larvae (nauplii), just after hatching, wet basis	89.0	6.7	2.1	1.1	0.14	1.1	2.6
	Brine shrimp meal (adults), dried	18.7	44.3	4.0	15.6		17.4	15.0

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Freshwater copepods, *Moina* spp., wet basis	Cultured on bakers yeast	87.2	8.8	2.9		0.18	1.1	3.4
	Cultured on bakers yeast + poultry manure	89.0	8.6	1.3		0.12	1.1	2.7
	Cultured on poultry manure	87.9	8.2	3.3		0.16	0.6	3.3
	Daphnia pulex, wet basis	94.0	3.0	1.0	1.2		0.8	1.2
	Daphnia spp., wet basis	89.3	7.5	1.4	0.7	0.15	1.1	2.5
	Diaptomus spp., wet basis	92.4	4.4	1.9	0.4		0.9	1.9
Miscellaneous freshwater invertebrates, wet basis								
	Amphipod	85.9	5.7	1.5	4.0		2.9	2.4
	Damselfly nymph	86.5	7.9	1.8	0.8		3.0	3.1
	Dragonfly nymph	86.4	4.7	2.9	0.6		5.4	3.2
	Water boatmen	78.9	12.2	5.7	0.7		2.5	5.6
	Chironomid larvae	83.9	9.1	13.6	7.1			7.5
	Blood worm	87.1	8.1	2.0	0.9		1.9	3.0
	Riversnail, whole snail	36.8	5.7	0.7	54.8		2.0	2.0
	Riversnail, snail meat	78.4	12.2	1.4	3.7		4.3	4.2

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
	Freshwater mussel	79.6	18.4	0.8	1.2		0.0	4.7
Miscellaneous marine invertebrates								
	Short necked clam, flesh, fresh	81.8	12.6	0.6	2.5		2.5	3.6
	Squid, meal, dried	8.1	74.8	8.8	3.4		4.9	22.0
	Krill, whole, fresh	82.0	6.0	5.0	5.0	0.29	2.0	3.7
	Crab, process residue, meal, dried	6.5	31.0	2.1	36.1	1.54	24.3	12.3
	Crab, protein concentrate, dried	10.0	60.5	0.4	6.8	0.60	22.3	18.3
	Mysid shrimp meal, dried	10.4	68.2	2.4	14.0		5.0	17.9
	Sergestid shrimp, whole, sun dried	14.0	46.9	3.2	13.1	1.07	22.8	16.3
	Crawfish, by-product meal		36.0	3.7	42.2	0.95	18.1	13.1
	Shrimp meal (process residue), dehydrated	10.0	40.6	2.6	30.0	1.57	16.8	13.5
	Shrimp heads, dried		58.2	8.9	22.6	1.68	10.3	19.0
	Shrimp shells (exoskeleton/hull), dried		45.9	0.4	31.7	3.16	22.0	14.8
	Shrimp head silage, fresh	81.0	14.1	1.4	3.5	0.30	0.0	3.9

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
	Shrimp head silage, dried	7.0	69.0	6.8	17.1	1.47	0.1	19.0
Terrestrial invertebrates								
	African giant snail - Snail meat meal, dried	11.1	45.6	2.4	7.0	0.48	33.9	17.5
	Snail meal (without shell), dry matter basis	0.0	60.9	6.1	9.6	0.84	23.4	20.8
	Snail shell, dry matter basis	0.0	2.8	1.0	54.5	0.14	41.7	8.2
	Whole snail (including shell), dry matter basis	0.0	16.1	2.0	46.0	0.32	35.9	10.8
	European snail - Snail meat, fresh	78.5	14.6	0.7	1.4		4.8	4.5
	Snail meat, fresh	80.3	12.9	0.6	1.8		4.4	4.0
	Snail meat, dried	5.7	62.7	7.5	7.8		16.3	20.6
	Silkworm - pupae, fresh	74.9	13.7	8.3	1.1	0.18	2.0	6.9
	Pupae, dry	10.0	55.9	24.5	1.9		7.7	24.2
	Pupae, solvent extracted, dried	7.9	72.0	1.2	6.2	1.06	12.7	19.7
	Locust - whole, fresh	68.2	22.1	3.0	2.4		4.3	7.1
	Whole, dried	10.5	46.2	9.7			33.6	20.5
	Soldier fly - Larvae meal, dried	7.9	42.1	34.8	14.6	1.5	0.6	23.8

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Terrestrial oligochaete worms								
	Eisenia foetida, fresh	83.3	9.8	1.5	2.9		2.5	3.3
	Eisenia foetida, meal, dried	7.4	56.4	7.8	8.8	0.87	19.6	19.8
	Eudrilus eugenige, fresh	85.3	8.9	1.8	1.5	0.13	2.5	3.2
	Dendrodrilus subrubicundus, dried	9.1	65.1	9.6	13.0		3.2	19.7
	Allolobophora longa, fresh	78.3	10.9	0.3	7.6		2.9	3.2
	Lumbricus terrestris, fresh	81.1	10.6	0.4	5.4		2.5	3.1
Animal by-products								
Poultry	Chicken, eggs							
	Whole egg (excluding shell), fresh	74.4	12.4	11.0	0.9	0.18	1.3	7.5
	Egg white (Albumen), fresh	87.1	11.4	0.1	0.6		0.8	2.9
	Egg yolk, fresh	49.1	16.2	33.0	1.1		0.6	17.0
	Egg-processing waste, dry matter basis	0.0	60.9	22.8	10.2		6.1	24.4
	Poultry by-product meal	6.5	57.5	15.0	15.6	1.90	5.4	20.4
	Hydrolysed feather meal	8.1	84.2	2.8	3.4	0.66	1.5	21.2
	Day-old chickens (culled), dried	4.9	55.4	32.0	7.6	1.24	0.1	25.7
	Poultry viscera, raw	73.7	13.9	11.2	1.2		0.0	7.7

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		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Slaughterhouse	Meat meal with blood (tankage)	7.3	60.0	8.7	21.2	3.62	2.8	18.1
	Meat meal	6.9	53.0	4.8	21.2	4.22	14.1	16.8
	Meat and bone meal, solvent extracted	8.1	50.0	1.8	31.7	5.25	8.4	14.0
	Meat and bone meal, rendered	7.4	49.1	10.3	29.9	4.98	3.3	16.2
	Blood (cattle), fresh	79.6	19.7	0.1	0.6	0.05	0.0	4.7
	Blood meal	10.4	81.5	1.0	4.8	0.25	2.3	20.0
	Liver, cows, fresh	73.1	20.2	4.5	1.5	0.23	0.7	6.7
	Liver, pig, fresh	70.0	20.5	5.0	1.6	0.37	2.9	7.3
	Liver meal	8.0	66.7	12.2	8.0	1.26	5.1	21.4
	Liver and lung meal	6.7	65.0	14.8	6.0	0.95	7.5	22.5
	Rumen contents, fresh	57.5	4.6	0.6	2.3		35.0	7.3
	Rumen contents, solid part (hung)	34.0	8.4	1.1	7.8	0.30	48.7	10.8
	Rumen contents liquid part	91.3	2.1	2.7	1.1	0.09	2.8	2.0
	Blood meal/rumen contents, dry matter basis	0.0	68.5	5.2	6.2		20.1	21.7
Milk by-products	Whole cows milk, fresh	87.6	3.3	3.6	0.7	0.09	4.8	3.0
Fish products	Raw fish							
	Group A - <5% lipid, <15% protein	83.0	13.3	1.3	1.9			3.7
	Group B - <5% lipid, 15-20% protein	81.5	17.9	0.6	1.6			4.5
	Group C - <5% lipid, >20% protein	72.4	26.2	0.7	1.5			6.5
	Group D - 5-15% lipid, 15-20% protein	67.5	18.0	13.0	1.5			9.4
	Group E - >15% lipid, <15% protein	52.5	11.3	36.0	0.5			16.9
	Fish processing waste - Catfish, dried		42.0	35.0	16.0	2.80	7.0	24.9

(cont'd) Summary of key nutrient composition data for ingredients used or with potential for use in aquafeeds in southeast Asia (from Tacon 1990). All values are on an 'as is' basis. Moisture, crude protein, lipid and phosphorus from Tacon (1990). Carbohydrate values were calculated as 100 – (moisture+protein+lipid+ash). Gross energy values were calculated using energy values of 23.6, 17.2 and 39.5 MJ/kg for protein, carbohydrate and lipid, respectively (NRC 1993).

		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
Fish products (cont'd)	Fish meal							
	Anchovy	8.2	65.3	7.1	15.0	2.61	4.4	19.0
	Herring	7.9	72.7	8.5	10.1	1.42	0.8	20.7
	Sardine/pilchard	8.5	65.0	6.7	15.3	2.72	4.5	18.8
	Tuna, mixed	7.0	59.0	6.9	21.9	4.21	5.2	17.5
	Menhaden	7.8	61.3	9.3	19.2	2.92	2.4	18.6
	Red fish	8.0	57.0	8.0	26.0	3.80	1.0	16.8
	White fish	9.1	63.2	4.2	21.8	3.80	1.7	16.9
	Freshwater (various species)	9.0	66.7	9.1	14.9	2.90	0.3	19.4
	Fish solubles, condensed	49.5	32.0	5.7	9.7	0.61	3.1	10.3
	Fish solubles, dehydrated	6.8	56.0	7.8	13.3	1.46	16.1	19.1
	Fish protein concentrate, dried	6.4	78.5	0.2	10.8	2.11	4.1	19.3
	Acid preserved silages, fresh							
	Tilapia, whole	71.9	15.6	4.2	5.0		3.3	5.9
	Sprat, whole	74.3	16.7	6.4	2.7		–0.1	6.5
	Winter sprat, whole	65.7	15.6	13.9	3.3		1.5	9.4
	Herring, whole	77.7	15.5	3.4	2.1		1.3	5.2
	Herring, offal	68.1	14.5	16.3	2.6		–1.5	9.6
	Sandeels, whole	77.7	15.4	3.4	2.4		1.1	5.2
	White fish offal	78.9	15.0	0.5	4.2		1.4	4.0
	Mackerel, whole	70.2	16.9	12.0	2.1		-1.2	8.5
	Whiting, whole	78.3	15.4	0.5	2.6		3.2	4.4

(cont'd) Summary of key nutrient composition data for ingredients used or with potential for use in aquafeeds in southeast Asia (from Tacon 1990). All values are on an 'as is' basis. Moisture, crude protein, lipid and phosphorus from Tacon (1990). Carbohydrate values were calculated as 100 – (moisture+protein+lipid+ash). Gross energy values were calculated using energy values of 23.6, 17.2 and 39.5 MJ/kg for protein, carbohydrate and lipid, respectively (NRC 1993).

		Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Phosphorus (%)	Carbohydrate (%)	Energy (MJ/kg)
	Fermented silages, fresh							
	Tilapia/molasses	67.8	13.9	3.1	4.8		10.4	6.3
	Tilapia/cassava starch	64.5	12.9	3.0	3.6		16.0	7.0