

# On-farm feeding and feed management in aquaculture



# document On-farm feeding and feed management in aquaculture

FAO  
FISHERIES AND  
AQUACULTURE  
TECHNICAL  
PAPER

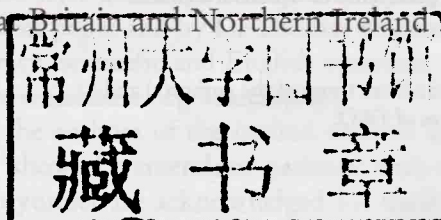
583

Edited by

**Mohammad R. Hasan**  
Aquaculture Officer  
Aquaculture Branch  
FAO Fisheries and Aquaculture Department  
Rome, Italy

and

**Michael B. New**  
FAO Consultant  
Marlow, Bucks  
United Kingdom of Great Britain and Northern Ireland



The designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations (FAO) concerning the legal or development status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The mention of specific companies or products of manufacturers, whether or not these have been patented, does not imply that these have been endorsed or recommended by FAO in preference to others of a similar nature that are not mentioned.

The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO.

ISBN 978-92-5-107978-2 (print)  
E-ISBN 978-92-5-107979-9 (PDF)

© FAO, 2013

FAO encourages the use, reproduction and dissemination of material in this information product. Except where otherwise indicated, material may be copied, downloaded and printed for private study, research and teaching purposes, or for use in non-commercial products or services, provided that appropriate acknowledgement of FAO as the source and copyright holder is given and that FAO's endorsement of users' views, products or services is not implied in any way.

All requests for translation and adaptation rights, and for resale and other commercial use rights should be made via [www.fao.org/contact-us/licencerequest](http://www.fao.org/contact-us/licencerequest) or addressed to [copyright@fao.org](mailto:copyright@fao.org).

FAO information products are available on the FAO website ([www.fao.org/publications](http://www.fao.org/publications)) and can be purchased through [publications-sales@fao.org](mailto:publications-sales@fao.org).



**Cover photographs:**

*Left top to bottom:* Feeding grow-out striped catfish (*Pangasianodon hypophthalmus*) with farm-made aquafeed from a feeding station, Mekong delta, Viet Nam (courtesy of FAO/T.P. Nguyen). A farmer feeding black tiger shrimp (*Penaeus monodon*) with commercially produced pelleted feed from levee during first month of rearing (courtesy of FAO/Umesh N. Ramasawamy).

*Right:* Feed distribution using automatic feeder for cage culture of Atlantic salmon (*Salmo salar*) near Bodo in Norway (courtesy of Trevor Telfer).

**Cover design:**

Mohammad R. Hasan



# Preparation of this document

This technical paper was prepared by a group of experts under the leadership of Dr Mohammad R. Hasan as a part of the Food and Agriculture Organization of the United Nations (FAO) Aquaculture Service's (FIRA) ongoing regular work programme on "Studies, reviews, guidelines and manuals on use of feed and nutrient in sustainable aquaculture development", under the organizational output "Aquaculture practices and technologies that comply with the Code of Conduct for Responsible Fisheries (CCRF) are developed and promoted".

This technical paper reviews the current status of on-farm feeding and feed management in aquaculture. It contains a) ten case studies on feeding and feed management practices carried out in seven selected countries of Asia (i.e., Bangladesh, China, India, Thailand, Viet Nam) and Africa (i.e., Egypt, Ghana) for eight species belonging to four major farmed species of freshwater finfish and shellfish: shrimp and prawns, Nile tilapia, striped catfish and Indian major carps; b) an analysis of the findings of these ten case studies and a case study for Indian major carps in India (published separately<sup>1</sup>); c) ten invited specialist reviews on feed management practices from regional and global perspectives and d) an overview of the current status of feed management practices with information drawn from the case studies, the invited reviews and other related publications. In addition, a targeted workshop entitled "On-farm feeding and feed management in aquaculture" was convened in Manila, the Philippines, from 13–15 September 2010 where all the above case study reports, analysis of case studies and invited review papers were presented. The workshop was organized by the Fisheries and Aquaculture Department Aquaculture Service (FIRA) and was hosted by the Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC/AQD), Iloilo, the Philippines. The report of the workshop was published as a FAO Fisheries Report ([www.fao.org/docrep/013/i1915e/i1915e00.pdf](http://www.fao.org/docrep/013/i1915e/i1915e00.pdf)).

Before editorial work, the manuscripts in this technical paper were reviewed for technical content, FAO house style and linguistic quality by Dr Richard Arthur for the invited reviews and synthesis paper and by Dr Thomas Shipton for the case studies. For consistency and conformity, scientific and English common names of fish species were used from FishBase ([www.fishbase.org/search.php](http://www.fishbase.org/search.php)).

Much gratitude is due to the authors of the invited reviews and case studies, who faced an enormous task and showed tremendous patience with the editors. Ms Tina Farmer and Ms Marianne Guyonnet are acknowledged for their assistance in quality control and FAO house style. Mr Koen Ivens prepared the layout design for printing, and Ms Danielle Rizcallah provided miscellaneous assistance. The publishing and distribution of the document were undertaken by FAO, Rome. Finally, Jiansan Jia, Chief of the Aquaculture Branch of the FAO Fisheries and Aquaculture Department is acknowledged for providing the necessary support, advice and insight to initiate the study and to complete the publication.

This publication is organized in three sections: a) Overview and Synthesis, b) Case Studies, and c) Invited Reviews. The publication is printed with the first section "overview and synthesis" while the whole volume is available on a CD-ROM accompanying the printed part of this publication.

<sup>1</sup> Ramakrishna, R., Shipton, T. & Hasan, M.R. 2013. Feeding and feed management of Indian major carps in Andhra Pradesh, India. FAO Fisheries and Aquaculture Technical Paper No. 578. Rome, FAO. 90 pp.

# Abstract

This technical paper provides a comprehensive review of on-farm feeding and feed management practices in aquaculture. It comprises of a) ten case studies on feeding and feed management practices carried out in seven selected countries of Asia and Africa for eight species that belong to four major farmed species of freshwater finfish and shellfish; b) an analysis of the findings of the above ten case studies and a separately published case study for Indian major carps carried out in India; c) ten invited specialist reviews on feed management practices from regional and global perspectives; and d) an overview of the current status of feed management practices. The country-specific case studies were carried out for Nile tilapia (*Oreochromis niloticus*) in China, Thailand, the Philippines, Egypt and Ghana; Indian major carps [rohu (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Cirrhinus cirrhosus*)] in India and Bangladesh, giant river prawns (*Macrobrachium rosenbergii*) in Bangladesh, striped catfish (*Pangasianodon hypophthalmus*) and whiteleg shrimp (*Litopenaeus vannamei*) in Viet Nam and black tiger shrimp (*Penaeus monodon*) in India. The broad thematic areas that were addressed in these case studies and invited reviews are: i) current feed types (including fertilizers) and their use in semi-intensive and intensive farming systems; ii) on-farm feed production and management; iii) feeding and feed management strategies, feed procurement, transportation and storage; iv) environmental, economic, regulatory and legal frameworks of feeding and feed management practices; and iv) identification of research needs. Based on the information presented in the eleven case studies, ten specialist reviews and from other relevant publications, an overview paper presents concluding remarks and recommendations on some of the major issues and constraints in optimizing feed production, use and management.

Hasan, M.R. & New, M.B., eds. 2013.

*On-farm feeding and feed management in aquaculture.*

FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. 67 pp.

Includes a CD-ROM containing the full document (585 pp.).



# Abbreviations and acronyms

ABW	average body weight
ADB	Asian Development Bank
AI	active ingredient
AIT	Asian Institute of Technology
ARI	Animal Research Institute, Ghana
BAFPS	Bureau of Agriculture and Fisheries Products Standards, Philippines
BAI	Bureau of Animal Industries, Philippines
BCR	benefit-cost ratio
BDT	Bangladesh taka
BFAR	Bureau of Fisheries and Aquatic Resources, Philippines
BFDC	Bangladesh Fisheries Development Corporation
BMP	better management practices
BOD	biochemical oxygen demand
BW	brackishwater
BWD	body weight per day
C	carbon
CAAC	Certification and Accreditation Administration of China
CAA	Coastal Aquaculture Authority, India
CAAP	concentrated aquatic animal production systems
CCRF	Code of Conduct for Responsible Fisheries
CFU	colony forming units
CIBA	Central Institute of Brackishwater Aquaculture, India
CIFA	Central Institute of Freshwater Aquaculture, India
CIFE	Central Institute of Fishery Education, India
COD	chemical oxygen demand
CP	crude protein
CSIR	Council for Scientific and Industrial Research, Ghana
CSIRO	Commonwealth Scientific and Industrial Research Organization, India
DAP	diammonium phosphate
DM	dry matter
DOC	days of culture
DoF	Directorate of Fisheries
EAN-UCC	European article numbering-uniform code council
ECAA	Extension Service Centre for Agriculture and Aquaculture, Viet Nam
EFS	extensive farming system
EIA	Export Inspection Agencies, India
EIC	Export Inspection Council, India
EM fungi	Ectomycorrhizal fungi
FAO	Food and Agriculture Organization of the United Nations
FaST	freshwater aquaculture centre selected tilapia
FBMA	Fisheries Bureau of Ministry of Agriculture, China
FCR	feed conversion ratio
FHS-BFAR	Fish Health Section of the Bureau of Fisheries and Aquatic Resources
FW	freshwater

g	gramme
GAFRD	General Authority for Fisheries Resources Development, Egypt
GAP	good aquaculture practices
GDP	gross domestic product
GIFT	genetically improved farmed tilapia
GST	genomar supreme tilapia
ha	hectare
HACCP	hazard analysis and critical control points
hCG	human chorionic gonadotropin
hrs	hours
ICAR	Indian Council of Agriculture Research
ICS	internal control system
IFN	international feed number
IMC	Indian major carps
INR	Indian rupee
IU	international units
kg	kilogramme
m	metre
MA	Ministry of Agriculture, China
MALR	Ministry of Agriculture and Land Reclamation, Egypt
MAR	Ministry of Agriculture and Rural Development, Viet Nam
MBV	Monodon baculovirus
MDCP	monodicalcium phosphate
MEFS	modified extensive farming system
mg	milligramme
mm	millimetre
MoFA	Ministry of Food and Agriculture, Ghana
MoFI	Ministry of Fisheries, Viet Nam
MP	muriate of potash
MPEDA	Marine Products Export Development Authority, India
MRP	maximum retail price
MSL	mean sea level
MT	million tonnes
mu	unit used for land measurement in China (1 mu = 666.7 square meters)
N	nitrogen
NACA	Network of Aquaculture Centres in Asia-Pacific
NaCSA	National Centre for Sustainable Aquaculture, India
NAFIQUAVED	National Fisheries Quality Assurance and Veterinary Directorate, Viet Nam
NFDB	National Fisheries Development Board, India
NFE	nitrogen free extracts
NPK	nitrogen, phosphorus and potassium
NR	net return
OM	organic matter
P	phosphorus
PG	pituitary gland
PL	postlarvae
ppm	parts per million
ppt	parts per thousand
RGCA	Rajiv Gandhi Centre for Aquaculture, India
RMA	rapid market appraisal
SEAFDEC	Southeast Asian Fisheries Development Center



SEERAD	Scottish Executive Environment and Rural Affairs Department
SIFS	semi-intensive farming systems
SIS	small indigenous fish species
SPF	specific-pathogen-free
SSP	single superphosphate
t	temperature
TBCAPMPA	Tilapia Branch, China Aquatic Products Marketing and Processing Association
TC	total costs
TFC	total fixed costs
TFS	traditional farming system
TGR	total gross revenue
TP	triple phosphate
TSP	triple super phosphate
TVC	total variable costs
US\$	United States dollar
USAID	United States Agency for International Development
VASEP	Vietnam Association of Seafood Exporters & Producers
VAT	value added tax
WHO	World Health Organization
WLS	whiteleg shrimp
WRI	Water Research Institute, Ghana
WSSV	white spot syndrome virus
WWF	World Wildlife Fund
YHV	yellow head virus

# Contents

Preparation of this document	iii
Abstract	iv
Abbreviations and acronyms	viii

## SECTION A – OVERVIEW AND SYNTHESIS 1

### **An overview of the current status of feed management practices**

Thomas A. Shipton, Rhodes University, Grahamstown, South Africa

Mohammad R. Hasan, Aquaculture Branch, FAO Fisheries and Aquaculture

Department, Rome, Italy

3

### **On-farm feeding and feed management practices for sustainable aquaculture production: an analysis of case studies from selected Asian and African countries**

Krishen J. Rana, University of Plymouth, Drake Circus, Plymouth PL4 8AA,

United Kingdom of Great Britain and Northern Ireland

Mohammad R. Hasan, Aquaculture Branch, FAO Fisheries and Aquaculture

Department, Rome, Italy

21

**The following case studies and invited reviews are available on accompanying CD-ROM**

## SECTION B – CASE STUDIES 69

### **On-farm feed management practices for the Nile tilapia (*Oreochromis niloticus*) in southern China**

Jiashou Liu, Zhongjie Li, Xiaowu Li and Yaohua Wang, Chinese Academy

of Sciences, Wuhan, China

71

### **On-farm feed management practices for Nile tilapia (*Oreochromis niloticus*) in Egypt**

Abdel-Fattah M. El-Sayed, Alexandria University, Alexandria, Egypt

101

### **On-farm feed management practices for Nile tilapia (*Oreochromis niloticus*) in the Philippines**

Maria Rowena R. Romana-Eguia and Manuel A. Laron, SEAFDEC

Aquaculture Department (SEAFDEC/AQD) Binangonan Freshwater Station,

Rizal, Philippines

Mae R. Catacutan, SEAFDEC/AQD Tigbauan Main Station, Iloilo,

Philippines

131

### **On-farm feed management practices for Nile tilapia (*Oreochromis niloticus*) in Thailand**

Ram C. Bhujel, Asian Institute of Technology, Bangkok, Thailand

159

**On-farm feed management practices for Nile tilapia (*Oreochromis niloticus*) in Ghana**

Lionel K. Awity, Ministry of Fisheries, Accra, Ghana

191

**On-farm feed management practices for three Indian major carp species (rohu *Labeo rohita*, mrigal *Cirrhinus cirrhosus* and catla *Catla catla*) in Bangladesh: a case study**

M. Rafiqul Islam Sarder, Bangladesh Agricultural University, Mymensingh, Bangladesh

213

**On-farm feed management practices for striped catfish (*Pangasianodon hypophthalmus*) in Mekong River Delta, Viet Nam**

Thanh Phuong Nguyen, Can Tho University, Can Tho City, Viet Nam

241

**On-farm feed management practice for giant river prawn (*Macrobrachium rosenbergii*) farming in southwest Bangladesh**

Nesar Ahmed, Bangladesh Agricultural University, Mymensingh, Bangladesh

269

**On-farm feed management practices for black tiger shrimp (*Penaeus monodon*) in India**

Umesh N. Ramaswamy and A. Bala Chandra Mohan,  
National Centre for Sustainable Aquaculture, Kakinada, India  
Marc Metian, Stockholm Resilience Centre, Stockholm University,  
Stockholm, Sweden

303

**On-farm feeding and feed management in whiteleg shrimp (*Litopenaeus vannamei*) farming in Viet Nam**

Le Thanh Hung and Ong Moc Quy, Nong Lam University,  
Ho Chi Minh City, Viet Nam

337

**SECTION C – INVITED REVIEWS**

359

**On-farm feed and feeding management strategies in tropical aquaculture**

Amararatne Yakupitiyage, Asian Institute of Technology, Bangkok, Thailand

361

**Tilapia feed management practices in sub-Saharan Africa**

Abdel-Fattah M. El-Sayed, Alexandria University, Alexandria, Egypt

377

**On-farm feeding and feed management of tilapia aquaculture in Malaysia**

Wing-Keong Ng and Sih-Win Teh, Universiti Sains Malaysia, Penang, Malaysia  
M.A. Kabir Chowdhury and Dominique P. Bureau, University of Guelph, Guelph,  
Canada

407

**Feed management of the major carps in India, with special reference to practices adopted in Tamil Nadu**

M.C. Nandeesh, V. Sentikumar and P. Antony Jesu Prabhu,  
Tamil Nadu Fisheries University, Thoothukudi, India

433

**A review of on-farm feed management practices for North African catfish (*Clarias gariepinus*) in sub-Saharan Africa**

Thomas Hecht, Rhodes University, Grahamstown, South Africa

463

**Shrimp feed management: issues and perspectives**

Albert G.J. Tacon, Aquatic Farms Ltd, Hawaii, United States of America

Darryl E. Jory, Aquatic Eco-Systems, Florida, United States of America

Alberto J.P. Nunes, LABOMAR, Ceará, Brazil

481

**On-farm feeding and feed management: perspectives from the fish feed industry**

Dave H.F. Robb, EWOS, Ho Chi Minh City, Viet Nam

Viv O. Crampton, EWOS Innovation, Dirdal, Norway

489

**Feed management and on-farm feeding practices of temperate fish with special reference to salmonids**

Sadasivam J. Kaushik, INRA, St-Pée-sur-Nivelle, France

519

**Environmental consequences of poor feed quality and feed management**

Patrick G. White, Akvaplan-niva AS, Tromsø, Norway

553

**Economic, regulatory and legal review of aquaculture feed management practices**

Thomas A. Shipton and Thomas Hecht, Rhodes University, Grahamstown, South Africa

565







# An overview of the current status of feed management practices

Thomas A. Shipton<sup>1a</sup> and Mohammad R. Hasan<sup>2</sup>

<sup>1</sup>FAO Consultant

Grahamstown, South Africa

<sup>2</sup>Aquaculture Officer

Aquaculture Branch

FAO Fisheries and Aquaculture Department

Rome, Italy

Shipton, T.A. and Hasan, M.R. 2013. An overview of the current status of feed management practices. In M.R. Hasan and M.B. New, eds. *On-farm feeding and feed management in aquaculture*. FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. pp. 3–20.

## ABSTRACT

This paper presents an overview of the current status of feed production and on-farm feed management practices. It reviews some of the major issues and constraints in optimizing feeds and on-farm feed management practices. The analysis is based on the findings of the country- and species-specific case studies, regional, and specialist subject reviews that are presented in this technical paper. Providing farmers with well-balanced feed at cost-effective prices is a prerequisite to profitable production. Formulation issues, and in particular the provision of species-specific feeds that address the nutritional requirements of the different life stages of the farmed animal (larval, fry, grower, finisher and broodstock) remain important topics for both commercial and farm-made feed production sectors. Much of the aquafeeds used in Asia and Africa are either produced on-farm or by small-scale semi-commercial feed manufacturers, and improvements to the quality and preparation of these feeds are likely to bring about improved productivity and cost savings. The small-scale production sector is currently constrained by a number of factors including inadequate access to finance, a lack of technical innovations, an absence of feed formulation and processing knowledge, and training. The potential to develop public-private partnerships with farmer groups or associations to share resources and improve access to improved manufacturing capacity should be considered. The majority of the case studies revealed that farmers across many countries and sectors were unaware of the importance of appropriate feed handling and storage techniques. The importance of feed management practices in optimizing production parameters needs to be conveyed to farmers. The use and efficacy of automated feeding systems needs to be established, and the use of feed tables, feed and production records needs to be promoted. Farmers need to be provided with simple tools to monitor farm production indices (e.g. feed conversion efficiency and growth rate) and training on how to take corrective actions. In extensive and semi-intensive production systems, there is a need to establish the qualitative and quantitative relationships between natural pond productivity and the impact that the use of supplemental and farm-made feeds have on nutrient cycling and

<sup>a</sup> Present address: Department of Ichthyology and Fisheries Science, Rhodes University, Grahamstown, South Africa.



retention in the farmed species. Developing a better understanding of these dynamics is central to optimizing feed formulations and reducing feed costs. The implications of feed type, formulation and feed management practices on the environmental footprint and economics of the farming operation are important issues that farmers need to take into consideration when planning their farming activities. If farmers understand and can quantify the economic interrelationships between feed type and costs, performance and feed management, they can significantly improve their profitability. Economic tools for this purpose to assist farmers need to be developed. Poor regulatory control and a lack of standards throughout the aquafeed value chain are constraints to feed supply, quality and use. Appropriate aquafeed policy, regulatory frameworks, and feed standards need to be developed in those countries that do not already have them, and institutional capacity needs to be strengthened in those agencies responsible for monitoring and compliance. Training and the dissemination of information to farmers, particularly small-scale farmers that have limited access to the latest technological and management developments, are issues that need to be addressed. Weak extension and information dissemination networks result in low adoption rates of new feed production technologies and management practices. Consideration should be given to promoting programs that use the local media to provide farmers with extension messages, including, amongst others, up-to-date feed ingredient availability, quality, price and supplier information, feed formulation and ingredient inclusion rates.

## 1. INTRODUCTION

In semi-intensive and intensive aquaculture systems, feed costs typically account for between 40 and 60 percent of production costs (De Silva and Hasan, 2007). In order to ensure profitability, it is imperative that farmers have access to good quality feeds at reasonable prices, and that they optimize their feed use by instituting appropriate on-farm feed management practices. This paper presents an overview of the current status of feed production and on-farm feed management practices, and provides a review of some of the major issues and constraints to optimizing them. The analysis is based on the findings of the species-specific country case studies, regional reviews, and specialist subject reviews that are presented in this technical paper.

These case studies and regional reviews focused on feed and feed management practices for Nile tilapia (*Oreochromis niloticus*) in China, Egypt, Ghana, the Philippines, Thailand, and sub-Saharan Africa, the Indian major carps (*Catla catla*, *Labeo rohita*, *Cirrhinus cirrhosus*) in Bangladesh and India, striped catfish (*Pangasianodon hypophthalmus*) in Viet Nam, North African catfish (*Clarias gariepinus*) in sub-Saharan Africa, whiteleg shrimp (*Litopenaeus vannamei*) in Viet Nam, black tiger shrimp (*Penaeus monodon*) in India and giant river prawns (*Macrobrachium rosenbergii*) in Bangladesh. The analysis also draws on selected reviews that focused on specific aspects of feed management, including environmental, economic, regulatory and manufacturing perspectives. Finally, it considers the outcomes of an FAO Expert Workshop on on-farm feed and feed management in aquaculture that was held in Manila, the Philippines, on the 13–15 September 2010 (FAO, 2010)<sup>2</sup>.

## 2. SYNOPTIC REVIEW OF FARM-MADE AND COMMERCIAL FEED USE

As feed represents one of the highest operating costs in aquaculture systems (Hasan, 2007; Hasan *et al.*, 2007), feed choice and feed management practices have a significant impact on the economic performance of a production system. The type and value of feed inputs that farmers select is dependent upon a number of factors including

<sup>2</sup> <http://www.fao.org/docrep/013/i1915e/i1915e00.pdf>



the market (local, export) and the value of the fish, the financial resources available to the farmer, the species, the culture system and intensity of production. In general, inputs for low-value species that are grown for local consumption are usually limited to fertilizers, farm-made feeds or locally produced small-scale commercial feeds comprising one or more ingredient sources. Examples of these systems would include the Indian major carps cultured under extensive or semi-intensive conditions in India and Bangladesh (Ramakrishna, Shipton and Hasan, 2012; Sarder, 2013). In contrast, commercially manufactured pelleted feed inputs are used for high-value species that are cultured in intensive systems. Examples would include the salmonids in Europe and the Americas (Kaushik, 2013), and, increasingly, the high-value marine finfish (e.g. groupers, barramundi and snappers) that are increasingly produced across southeast Asia (Hasan, 2012a).

Rising competition for land and water resources is increasing pressures to improve productively through intensification. A move towards intensification of farming systems requires the adoption nutritionally complete feeds and is increasing the demand for both farm-made and commercially produced feeds (De Silva and Hasan, 2007; Rana, Siriwardena and Hasan, 2009). The case studies revealed this gradual shift towards intensification. For example in Egypt, the intensification of pond culture practices for Nile tilapia (*Oreochromis niloticus*) and the adoption of intensive cage culture technology have manifested as increased demand for commercially manufactured feeds, which now account for 60 percent and 100 percent of the feed used in these sectors respectively. This increase in demand has seen commercial feed manufacturing capacity in the country grow from 20 000 tonnes/annum in 1999 to 420 000 tonnes/annum in 2010 (El-Sayed, 2013). Likewise, a move towards intensification in black tiger shrimp (*Penaeus monodon*) production in India (Ramaswamy Mohan and Metian, 2013), Nile tilapia (*Oreochromis niloticus*) in the Philippines (Romana-Eguia, Laron and Catacutan, 2013), and striped catfish (*Pangasianodon hypophthalmus*) in Viet Nam (Nguyen, 2013) have also resulted in increases in the demand for commercially manufactured feeds.

Commercially manufactured feeds were reported to be available in all eight countries (Bangladesh, China, Egypt, Ghana, India, the Philippines, Thailand, and Viet Nam) where case studies were conducted and, with the exception of Ghana, all the countries reported commercial manufacturing capacity. Hecht (2007) noted that locally produced commercially manufactured feeds were only available in five sub-Saharan countries indicating that, in contrast with other producer regions (Europe, Asia and the Americas), sub-Saharan Africa generally lacks access to locally manufacturing capacity, and primarily relies on farm-made feeds or imported commercially produced feeds.

While commercially manufactured feeds are usually formulated to satisfy the nutritional requirements of specific species and their life stages, farm-made feeds typically comprise simple ingredients that, depending on the culture systems, are fed as simple mixtures, doughs or compressed pellets. While the quality of the farm-made feeds is dependent upon the formulation applied, the quality and availability of ingredients and the manufacturing processes, they are generally more affordable than commercially manufactured feeds, and remain the primary feed source for many semi-intensive farmers. For resource poor farmers, the relatively low cost of farm-made feeds enable them to procure small amounts of feed at any one time, promoting affordability and enabling them to better manage their on-farm cash flows.

The intensification of farming systems and the concomitant growth in demand for good quality, cost-effective farm-made feeds makes them increasingly important to sustaining sectorial growth, and it has been noted that one of the ways to improve aquaculture production is to improve the quality of farm-made feeds (De Silva and Davy, 1992; De Silva and Hasan, 2007).

Some production sectors have already seen significant improvements to the quality of farm-made feeds. For example, farmers in Viet Nam that use farm-made feeds for striped catfish production have improved their feed formulations and manufacturing