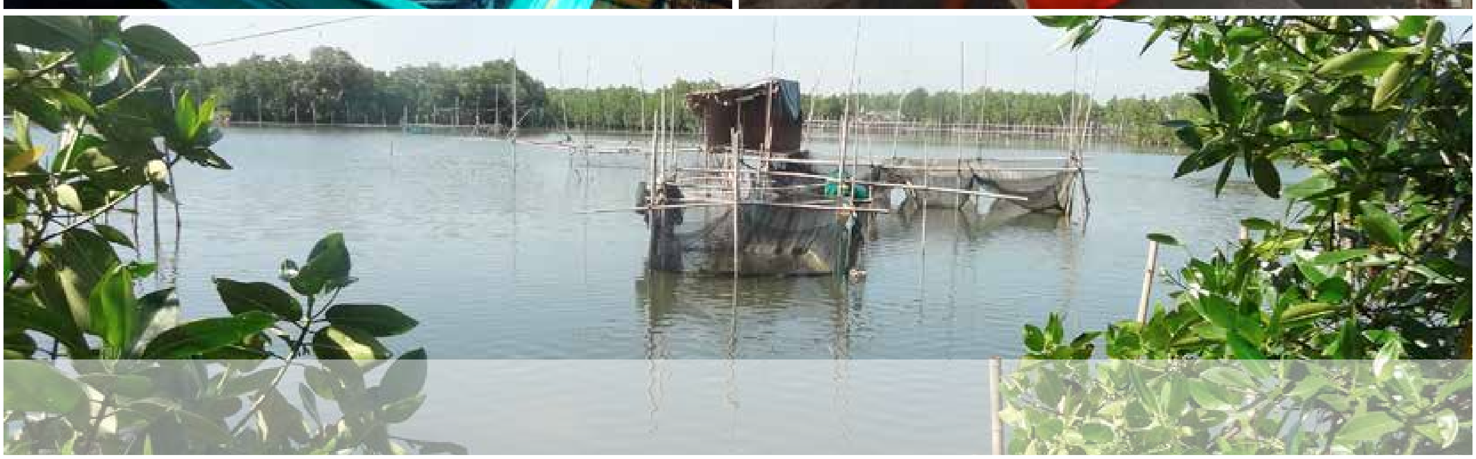
Food and Agriculture
Organization of the
United Nations

FAO
FISHERIES AND
AQUACULTURE
TECHNICAL
PAPER

ISSN 2070-7010

614

Better management practices for feed production and management of Nile tilapia and milkfish in the Philippines



Cover photographs:
Top left: Harvest of milkfish in Panabo Mariculture Park, Panabo City, Davao, Philippines (courtesy of FAO/Thomas A. Shipton). *Top right:* Harvest of Nile tilapia in Taal Lake in the province of Batangas, the Philippines (courtesy of FAO/Mohammad R. Hasan). *Bottom:* A view of cage and pen culture of milkfish in a large brackishwater pond, Dagupan, Philippines. (courtesy of FAO/Mohammad R. Hasan).

Cover design:
Mohammad R. Hasan and Koen Ivens.

Better management practices for feed production and management of Nile tilapia and milkfish in the Philippines

FAO
FISHERIES AND
AQUACULTURE
TECHNICAL
PAPER

614

by

Patrick G. White
FAO Consultant
Crest, France

Thomas A. Shipton
FAO Consultant
Grahamstown, South Africa

Pedro B. Bueno
FAO Consultant
Bangkok, Thailand

and

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

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2018

ISBN 978-92-5-130485-3

Preparation of this document

This technical paper was prepared under the coordination of Dr Mohammad R. Hasan of the Aquaculture Branch, FAO Fisheries and Aquaculture Department. It presents the results of the FAO Technical Cooperation Project “Improvement of Feeding and Feed Management Efficiency in Aquaculture Production in the Philippines (TCP/PHI/3404)”, which was implemented between November 2013 and October 2016 in the Philippines. FAO collaborated with Inland Fisheries and Aquaculture Department (IFAD) of the Bureau of Fisheries and Aquatic Resources (BFAR) of the Government of the Philippines during implementation in this project.

The authors gratefully acknowledge the contribution of Mr Ruel Villacorte Eguia and Mr Joel Dela Cruz Sumeldan for supervising and undertaking the tilapia laboratory trial; Ms Arlene Manalo de la Vega for conducting the feed millers survey; Mr Angelito C. Gonzal for conducting the feeding practice survey as well as supervising the tilapia and milkfish farmer trails; Mr Hoseas Montevilla for conducting the milkfish farmer trial at TEDSIE Farm at Sitio Dapdap, Taliptip Bulacan, and the tilapia farmer trial at JCK Farm, Sampaloc, Talisay Batangas; and Mr Edgardo T. Valenzuela of Overseas Filipinos Society for the Promotion of Economic Security (OFSPES) for assisting with the finalization of the project through a Letter of Agreement (LOA). The Office of the FAO Representation in the Philippines is deeply appreciated for their timely assistance in implementing the project.

The authors sincerely thank the feed mill owners, tilapia and milkfish farmers and all the other stakeholders involved in the broader aquaculture value chain who were interviewed, consulted or took part in workshops for their contribution to the qualitative and quantitative data and information.

Dr Richard Anthony Corner and Dr Mohammad R. Hasan edited this technical paper for its linguistic quality and technical content. Ms Marianne Guyonnet and Ms Danielle Rizcallah are acknowledged for their assistance in quality control and FAO house style. Mr Koen Ivens prepared the layout design for printing. The publishing and distribution of the document were undertaken by FAO, Rome. Mr. Jose Luis Fernandez, FAO Representative in the Philippines is acknowledged for providing the support and advice to complete this publication.

Abstract

Milkfish (*Chanos chanos*) and Nile tilapia (Oreochromis niloticus) made up 57.5 and 39.1 percent, respectively, of the Philippines' farmed finfish supply in 2015 (FAO, 2017). Studies have found that substandard feed quality, poor water stability of feed and over-feeding contributed to the negative environmental impact of aquaculture in the country. Overfeeding results in excess nutrients entering the water column. Over a number of production cycles, the excess nutrients accumulate on the sea/lake bottom and degrade water quality. Oxygen level in the sediment beneath the cages goes down making the aquaculture area prone to fish kills.

The relationship between feed management practices and the economic efficiency of the farming operation is an important consideration for farmers and provides them with the rationale for choosing one feed management practice over another. It is economically important to optimize feed management practices that impact feed conversion ratio (FCR) and, ultimately, profitability. Amongst others, these include optimizing feeding frequency, ration and rearing temperature.

The TCP project undertook to improve feed formulation and feeding strategy for these two species to improve FCR, formulate cost-effective feeds using locally available feed ingredients, improve feeding strategy to reduce FCR, feed wastage and water pollution, and provide guidelines for feed manufacturers and milkfish and Nile tilapia farmers. Food and Agriculture Organization of the United Nations (FAO of the UN) undertook the project in collaboration with the Inland Fisheries and Aquaculture Department (IFAD) of the Bureau of Fisheries and Aquatic Resources (BFAR) in the Philippines.

Improvement of feed quality was addressed through three activities: a) a detailed literature review of dietary requirements for the two species, b) a baseline survey of aquafeed manufacturer and feed ingredient suppliers in the Philippines, and c) development of a series of new feed formulations. The protein components of all the dietary formulations were chosen according to their cost, availability in the country (information derived from the baseline survey), and suitability for use in aquafeeds. In all four trial formulations, the essential amino acid (EAA) levels were calculated and where possible balanced according to the known dietary requirements. The four experimental Nile tilapia diets were formulated to contain 33.8 – 34.4 percent protein and 7.2 – 7.9 percent lipid. The gross energy levels of the formulations ranged between 17.28 – 18.00 MJ/kg. The four experimental milkfish diets were formulated to contain between 31.2 – 34.3 percent protein and 5.6 – 11.2 percent lipid. The gross energy levels of the formulations ranged between 17.42 – 19.01 MJ/kg.

Towards the objective of improving feeding strategy, a background survey of farmers' feeding practice in ponds and cages was undertaken and four feed formulations and three feeding strategies were tested for each species in small-scale trials. The three strategies included a) the development of detailed feeding tables based on specific growth rate potential and desired FCR 1.2:1 for Nile tilapia and FCR 1.5:1 for milkfish) to determine a feeding rate (percent body weight/day), b) the USSEC (United States Soybean Export Council) "90 percent satiation feeding technique" and c) standard commercial feed tables.

The best performing Nile tilapia feed had a calculated crude protein level of 34.4 percent and crude lipid level of 7.4 percent. The best performing milkfish diet had a calculated crude protein level of 34.3 percent and crude lipid level of 11.2 percent. The best feeding strategy is embodied in the detailed feeding tables.

The best performing formulation and feeding strategy were chosen and tested at farmer-scale trials in Taal Lake for Nile tilapia and Bulacan for milkfish; the results were compared with the standard feed and feeding strategy used by the farmer.

Based on the results of the trials, the project developed better feed management practice guidelines, a strategy on how farmers can cope with production and marketing risks, and recommendations on feed governance. These outputs were validated and finalized during a stakeholder workshop held in Manila in December 2016.

Improving feed formulation and feed management strategy for key aquaculture species reduces production costs for the farmer, reduces nutrient waste output to the environment leading to a more economical and environmentally sustainable industry. The results and lessons learned from this project could be used, with appropriate adaptation, by other countries in the region. Similar studies should be carried out for other key aquaculture species.

White, P.G., Shipton, T.A., Bueno, P.B. and Hasan, M.R. 2018. *Better management practices for feed production and management of Nile tilapia and milkfish in the Philippines.*
FAO Fisheries and Aquaculture Technical Paper No. 614. Rome, FAO. 98 pp.

Typical feeding technique used for Nile tilapia and milkfish by pond farmers in the Philippines.
Photo credit: FAO/Angelito Gonzal

Contents

LIST OF TABLES

LIST OF FIGURES

Contributors

Angelito Gonzal
FAO Consultant, Cavite, Philippines.
E-mail: acgonzal99@yahoo.com

Mohammad R. Hasan
Aquaculture Officer, FAO Fisheries and Aquaculture Department, Rome, Italy
E-mail: Mohammad.Hasan@fao.org
rezaulhasan@live.com

Patrick G. White
FAO Consultant, Crest, France.
E-mail: pwhitemobile@yahoo.com

Pedro B. Bueno
FAO Consultant, Bangkok, Thailand.
E-mail: pete.bueno@gmail.com

Richard A. Corner
FAO Consultant, the Gardens, Auchen Castle, Beattock, Dumfries and Galloway, Scotland, United Kingdom.
E-mail: racorner66@gmail.com

Roy Ortega
Chief, BFAR-IFAD, Quezon City, Metro Manila.
E-mail: kaulayao@yahoo.com

Thomas A. Shipton
FAO Consultant, Grahamstown, South Africa.
E-mail: tomshipton@icloud.com

Abbreviations and acronyms

ASEAN	Association of South East Asian Nations
BAFPS	Bureau of Agriculture and Fisheries Standards
BAI	Bureau of Animal Industries
BFAR	Bureau of Fisheries and Aquatic Resources
BMP	better management practice
BPS	Bureau of Product Standards
CbD	cash before delivery
CLSU	Central Luzon State University
CoD	cash on delivery
DENR	Department of Environment and Natural Resources
CP	crude protein
DO	dissolved oxygen
EAA	ecosystem approach to aquaculture
EAA	essential amino acid
eFCR	economic feed conversion rate
EMMA	environmental monitoring and modelling of aquaculture in risk areas in the Philippines
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCR	feed conversion ratio
FDA	Food and Drug Administration
FIFO	first in-first out
g	gramme
GIFT	genetically improved farmed tilapia
HSCAS	hydrated sodium calcium aluminosilicate
IDRC	International Development Research Centre
IFAD	Inland Fisheries and Aquaculture Department
JAO	joint administrative order
kg	kilogramme
KPIs	key performance indicators
LGU	Local Government Unit
ln	natural log
MJ	megajoules
NIFTDC	National Integrated Fisheries Technology and Development Centre
PAMB	Protected Area Management Bureau
PASU	protected area superintendents
PER	protein efficiency ratio
Philminaq	Mitigating Impact of Aquaculture in the Philippines
PHP	Philippine peso
PIDS	Philippine Institute for Development Studies
PNS	Philippine National Standards
SGR	specific growth rate
TCP	Technical Cooperation Programme
UN	United Nations
US$	United States dollar
USSEC	United States Soybean Export Council
°C	degree centigrade

Harvest of milkfish in Panabo Mariculture Park, Panabo City, Davao, Philippines.
Photo credit: FAO/Mohammad Hasan

1. Introduction

In aquaculture, the provision of high-quality aquafeeds that satisfy the nutritional requirements of cultured species and optimize growth is a prerequisite to increasing yields, lowering production costs, and improving economic returns for the farmers. Good management and control of feed quality and feed management strategy in fish farming is of critical importance in maintaining a cost-effective and environmentally sustainable industry.

Feeds are important for many reasons, including:

- Feeds account for a major portion of the operational costs in both semi-intensive and intensive fish farming, which makes the profitability of the operation dependent on the performance of a feed, particularly the feed conversion ratio (FCR) (Hasan and New, 2013).
- Formulation of cost-efficient, high quality and low polluting diets, and good management of the feeding regime are crucial in optimizing the efficient use of feed.
- Efficient feeding practices will improve feed conversion efficiencies (by reducing FCR) and optimize economic returns (Hasan and Soto, 2017).
- Production performance is primarily attributable to the feed quality and the feeding technique used.
- Wasted (uneaten and un-metabolized) feed affects water quality and can cause eutrophication of the water resulting in poor fish performance, health, survival and growth.

The NORAD-funded project EMMA (Environmental Monitoring and Modelling of Aquaculture in risk areas in the Philippines) in 2006 and the EU-funded project Philminaq (Mitigating Impact of Aquaculture in the Philippines) in 2008, found that poor feed quality, low stability in water and poor digestibility, particularly of commercial feed used for Nile tilapia (*Oreochromis niloticus*) in Taal Lake and milkfish (*Chanos chanos*) in Bolinao and Dagupan, were contributing to high environmental impacts in these areas. Overfeeding over repeated production cycles also resulted in excess nutrients entering the water column and being deposited on the seabed or lake bottom and accumulation of these nutrients degraded water quality and decreased the oxygen level in sediments below the cages, making these areas prone to localized fish kills. In order to reduce the risk of environmental degradation, feed quality needed to be improved, be nutritionally balanced and to be used more efficiently; and waste through uneaten feed needed to be reduced.

Despite its economic potential, existing aquaculture production in the Philippines is significantly less than its potential, due to challenges that affect farm profitability, which reduces investment potential. Feed accounts for 50 to 70 percent of production costs in milkfish and Nile tilapia production in the Philippines. When commercially produced feeds are supplied to farmers at high cost and without justifiable nutritional rational, these combine to reduce the long-term economic viability of aquaculture production.

To address the above concern, FAO in collaboration with the Bureau of Fisheries and Aquatic Resources (BFAR) implemented a TCP (Technical Cooperation Programme) project "Improvement of Feeding and Feed Management Efficiency in Aquaculture Production in the Philippines (TCP/PHI/3404)", primarily focusing on Nile tilapia and milkfish during November 2013 and October 2016. The project sought to improve aquafeed quality, feed supply and use in milkfish and Nile tilapia production in the Philippines by introducing better feed formulations and promoting international best practice in aquafeed production, management and delivery.

Preparatory work for the project showed that in many instances nutritionists responsible for formulating aquafeeds had been trained in terrestrial animal nutrition but lacked specialist training in aquatic animal nutrition. As a result, the feed formulations that were manufactured, most notably by the small-scale feed manufacturers, often fail to adequately address the nutritional requirements of the aquaculture species they are aimed at. Many of the aquafeed manufacturers surveyed reported having formal training in formulating feeds for terrestrial animals (e.g., poultry and swine), but not many of their nutritionists had technical expertise in formulating feeds for aquatic animals. A feed manufactures baseline survey revealed that only 57 percent of the feed manufacturers surveyed retained an in-house nutritionist to develop formulations and monitor feed quality. Evidentially there was a need to provide technical training to some of the nutritionists working with the smaller feed manufacturing companies, for them to understand the specific dietary requirements of aquatic animals and to improve their aquafeed formulations.

A baseline survey of on-farm feeding and feed management practices revealed that farmers followed a wide range of feeding practices, which included some good practice in selecting higher quality feeds and feeding based on feed tables or farmers' experience, to substandard practice in selection of cheap feeds that lacked appropriate nutrition and feeding control leading to inferior growth and feed conversion ratios (FCRs). The findings suggested the need to develop good feeding practice guidelines and scientifically based feeding tables to guide farmers on the quantity of feed to provide to their fish.

The gradual degradation of the culture environment and economic losses from recurring fish kills do stem directly from the linked technical issues of substandard feed quality and poor feeding and feed management. An analysis of the problem suggested however that a more effective approach would be to cast the technical and environmental, and economic problems into the broader sector management - governance perspective. At an inception workshop, it also became clear there was a need to focus on aquaculture policy and to introduce Government's incentives to develop the sector. Unlike other agricultural sectors, aquaculture had historically not been a development priority for Governmental agencies.

Management of the aquafeed sector aims to improve the effectiveness and sustainability of the value chain of fed aquaculture species. This can be achieved by a number of interventions including improving feed quality and feed management to lower production costs, improving profitability, and reducing environmental impacts. The project aimed to develop improved feed formulations based on locally available feed ingredients for Nile tilapia and milkfish to improve feed conversion ratios, improve feed management strategies that would reduce FCRs, feed wastage and water pollution, and provide better management practice (BMP) guidelines for feed manufacturers and milkfish and Nile tilapia farmers.

Thus, this three-year project aimed to (i) improve feed formulation and promote the use of cost-effective feeds using local ingredients, (ii) improve feeding strategies to reduce feed wastage and water pollution, (iii) increase feed conversion efficiency by producing better feed and improving on-farm feeding and feed management stategies and (v) finally to provide better management guidelines of feed production and managent for the feed producers and the farmers.

2. Aquafeed manufacturing practices and feed ingredient availability in the Philippines

A baseline assessment was designed to characterize the status of the aquafeed manufacturing sector in the Philippines, provide information on feed ingredient supply and availability, and assess the types of commercially manufactured feeds that are available to the Nile tilapia and milkfish farmers.

2.1 THE AQUAFEED MANUFACTURING SECTOR IN THE PHILIPPINES

2.1.1 Aquafeed production capacity

In the Philippines in 1995, there were 25 commercial feed mills and four non-commercial aquafeed manufacturers, producing an estimated 148 000 tonnes of aquafeeds per annum (Cruz, 1997). By 2014, the number of commercial and non-commercial feed manufacturers had increased to 96, and the estimated annual feed requirement had increased approximately ten-fold to over 1.5 million tonnes per annum. Between 1995 and 2014, large-scale manufacturers (classified as producing >100 tonnes/8-hour production shift) increased three-fold from nine to 30; medium-scale manufacturers (>50-100 tonnes/8-hour shift) increased by three, from 10 to 13, and small-scale manufacturers (<50 tonnes/8-hour shift) increased eight-fold from six in 1995 to 49 in 2014. Despite the increase in small-scale manufacturers overall production capacities is increasingly dominated by the large-scale producers.

2.1.2 Production technologies

All the feed mills producing aquafeeds reported producing compressed sinking pellets based on conventional ring dye production technologies. The mean production capacity for producing sinking feeds was 8 tonnes per hour but varied between 20 tonnes per hour (across multiple production lines) to only 250 kg per hour (across one production line). The exception to the production of sinking feeds was one of the large-scale manufacturers that used extrusion technology to produce sinking feeds. Six other companies reported producing extruded floating feeds. The mean production capacity of extruded (floating or sinking) feeds was 7.2 tonnes/hour but varied between 800 kg/hour and 20 tonnes/hour.

2.1.3 Feed formulations

Feed formulations are primarily developed by staff working at the feed manufacturing plants, either with or without outside assistance, with formulations usually based on least-cost use of feed ingredients. The survey revealed that 57 percent of the feed manufacturers retained an in-house nutritionist to develop formulations and monitor their feed quality. A further 29 percent relied on national or foreign consultants to develop their formulations, and 14 percent relied on their foreign business partners to provide their feed formulations, particularly the larger manufacturers. It is likely, therefore, that the companies relying on consultants or their foreign business partners to provide feed formulations have access to good quality knowledge bases, services and formulations. The smaller feed manufacturers that rely on in-house nutritionists, however, do not always have such wide access to information.

2.1.4 Quality control and feed standards

All 96 companies producing feed are registered with the Bureau of Animal Industry (BAI) as part of their license to operate, and their products are independently monitored for proximate composition on a regular basis. According to Bureau of Animal Industries (BAI) regulations, if 25 percent of the submitted/collected feed samples fail to meet the standard on three consecutive sampling occasions, the BAI has the authority to close the facility.

The majority of feed manufacturers who responded to the survey (10 companies or 66 percent) reported that they have their own in-house laboratories to monitor the quality of feed ingredients and finished products, while the remaining five companies (33 percent) reported sending samples to independent laboratories. A number of the companies with in-house laboratories also reported sending samples to independent private sector laboratories for independent analysis. The quality of finished products is usually monitored on a batch-by-batch basis.

2.1.5 Feed supply and affordability

Feed manufacturers reportedly sell their products through wholesale networks or directly to the farmers. A number of supply-payment mechanisms have been developed by individual feed manufacturing companies with respective buyers. However, in comparison with terrestrial animal production systems (poultry and swine), the feed manufacturers often view aquaculture as a high-risk sector; primarily due to the relatively long grow-out periods associated with fish production and the concomitant potential for stock losses, which may affect a company's or farmer's ability to pay.

Feed affordability and supply are issue for both farmers and the feed manufacturers. The extended credit periods that are required by the fish farmers appear particularly problematic for the smaller feed manufacturers that do not have the cash flow or credit reserves to service their medium-term debtors. In response to feed producers' need to trade their products to the farmers while minimizing their exposure to the risks of default payments, the feed manufacturers have developed a number of funding/sales mechanisms. These include cash on delivery (CoD), cash before delivery (CbD), providing credit for periods between 7 and 90 days, the development of joint ventures with the farmers, and the referral of business risks in which the feed manufacturers use distributors and retailers to sell the feeds to farmers on credit provided by the feed distributors/retailers.

2.1.6 Current constraints in the feed manufacturing industry

The feed manufacturers reported a number of constraints to their business operations, summarized as follows:

1. **Increasing input costs** due to increases in global commodity prices and the reliance on imported feed ingredients to supply much of the protein component of the feed.
2. **Increasing production costs** due to increases in electricity and transport costs. The increasing cost of spare parts for existing machinery was noted by some manufacturers as further increasing their operational costs.
3. **Increasing competition** from the large-scale international aquafeed manufacturing companies who are seen by many of the smaller feed manufacturers as having the advantage of better access to improved production technologies, resources (both raw materials and finance), and the ability to generate economies of scale, thus enabling them to manufacture cost-effective high quality products, and making it difficult for the small producers to compete on price and/or quality.
4. **High investment costs** required to manufacture extruded feeds is significant, and while many farmers show a preference for feeds produced using this methodology, many of the smaller feed manufacturers indicated that they were not able to make the significant capital investments required to produce extruded feeds into their

businesses. Many small-scale feed manufacturers viewed their inability to invest in new production technologies as a significant impediment to their growth.

5. **Government regulations** are in some instances viewed as restrictive. Examples given included the promulgation of a local ordinance (dated 20 August 2013) to regulate Nile tilapia farming, and notably the requirement to use floating feeds on Lake Taal. Most of the local aquafeed industries produce sinking feeds for Nile tilapia. This regulation will therefore effectively curtail the aquafeed manufacturing operations locally, with companies forced to revert to terrestrial feed production. They have neither the machinery to produce floating feeds nor the finance to invest in machinery upgrades and appropriate technology to produce floating feeds. In short, they cannot comply with the regulatory ordinance.

2.1.7 Commercially manufactured feeds

There is a high degree of variability in the types and quality of feeds available for milkfish and Nile tilapia production on the market. For example, prices for a Nile tilapia/milkfish fry formulation ranged from US$0.39/kg for a compressed pellet to US$0.91/kg for an extruded sinking pellet, a large difference in the cost price of a feed designed for the same size class of fish. The Nile tilapia/milkfish fry and fingerling compressed sinking feeds (US$0.42 and 0.69/kg respectively) were on average 97.6 percent and 11.6 percent cheaper than their extruded counterparts (US$0.83 and 0.77/kg respectively). Conversely, the cost of the grower and finisher formulations were generally comparable with no significant price differentials between the two manufacturing processes. Within companies producing dedicated formulations for Nile tilapia or milkfish, the cost of sinking grower and finisher feeds remained between 15 and 35 percent lower for compressed sinking feeds than for those produced by extrusion.

The comparable prices for Nile tilapia/milkfish compressed sinking, and extruded grower and finisher formulations are an interesting development, that might explain why farmers prefer extruded feeds. The major feed production costs accumulate during the grow-out/finisher production periods, and in addition to the improved binding and digestibility enabled by the extrusion process, farmers often prefer to use extruded feeds as they promote good feed management. Notwithstanding the differences between the formulations, the similar price structure between the two feed types (compressed sinking and extruded) suggests that the extruded feed manufacturers are able to compete on price with the compressed sinking feed manufacturers. If this is the case, it is likely that the superior quality of the extruded feeds is inducing many farmers to use these types of feeds.

Analysis also revealed that, with the exception of the majority of the fry feeds and a small number of the fingerling feeds, the majority of the commercially manufactured feeds comply with the Philippines National Standards for Aquafeeds. However, it should be noted that the standard sets a legal benchmark for the maximum and minimum inclusion levels for both Nile tilapia and milkfish in the same standard category (herbivorous/omnivorous fish), and not a separate benchmark based on nutritional requirements of the respective fish.

2.2 Ingredient availability

In a survey of the aquafeed manufacturing sector carried out in 1994, Cruz (1997) noted that the sector primarily relied on seven to 10 basic major feedstuffs, most of which were imported. The current survey corroborated this finding, and despite a 19-year period between surveys and an estimated ten-fold increase in aquafeed production, the feed industry remains dependent on less than ten primary ingredient sources.

The survey revealed 22 ingredient sources (excluding additives) being used in aquafeed production, based around animal protein (Table 1), plant protein (Table 2) and lipids (Table 3).

TABLE 1

Origin, cost (mean and range) and proximate composition of animal protein meals used in the Philippines

Ingredient	No. of manufacturers	Origin	Cost (US$/kg)		Proximate composition (% as fed basis)				
			Mean	Range	Crude protein	Crude lipid	Crude fibre	Ash	Moisture
Blood meal	1		0.57	–	88.5[a]	1.4[a]	0.9[a]	5.3[a]	9.0[a]
Poultry feather meal	3	USA, Canada and Australia	0.94	0.85–1.03	77.0–80.0	14.0	1.0[b]	3.6[b]	8.4[b]
Poultry offal meal	–	–	0.78	–	54.1	8.1	1.9	22.0	4.0
Meat and bone meal	–	–	0.58	–	50.3	10.2	1.0	30.1	5.2
Fishmeal (local- sardines/ tuna)	12	Philippines	1.09	0.80–1.22	44.0-55.0	9.0–10.0	0.7–2.4[c]	16.4–20.0	9.7–12.0
Fishmeal (Peruvian)	4	Peru	1.99	1.65–2.20	65.0–67.0	8.0	1.5	14.0	6.0
Pork meat meal	8	Italy, USA and Germany	0.87	0.56–1.15	48.0–51.0	3.3	4.3	36.6	4.7
Squid meal/powder	2	Korea	0.95	0.87–1.03	35.0–45.0	8.0	1.5[d]	9.8[d]	10.3[d]

Notes: where proximate composition data was unavailable, estimates for similar quality feedstuffs are provided. These estimates are based on those provided in Tacon, Metian and Hasan (2009) or are obtained from AFFRIS (http://www.fao.org/fishery/affris/en/): [a]blood meal, spray-dried (IFN 5-00-381); [b]poultry feather meal, hydrolysed (IFN 5-03-795); [c] low-value fish/fish processing waste; [d]squid liver meal.

Sources: Field survey (2016).

TABLE 2
Origin, cost (mean and range) and proximate composition of plant protein meals used in the Philippines

Ingredient	No. of manufacturers	Origin	Cost (US$/kg)		Proximate composition (% as fed basis)				
			Mean	Range	Crude protein	Crude lipid	Crude fibre	Ash	Moisture
Copra meal	12	Philippines	0.27	0.26–0.29	19.0–21.9	7.50–9.50	15.20	5.90–8.00	7.70–8.00
Corn gluten meal	1	–	–	–	60.8	0.85	7.96	0.58	7.96
Canola meal	1	India	–	–	36.1	1.57	9.01	8.42	10.82
Palm kernel meal	1	Malaysia and Philippines	–	–	16.2	5.80	23.32	4.76	10.62
Soybean meal	13	USA, Argentina, India,Brazil and Spain	0.66	0.64–0.68	44.0–47.0	1.00–1.50	3.30–5.00	6.00–7.00	10.00–10.70
Rice bran	13	Philippines	0.29	0.26–0.32	12.0–13.0	12.00–15.10	6.47	7.00–8.05	10.70–11.00
Rice grain (broken)	1	Philippines	0.32	–	12.0	12.00	4.70[a]	7.00	11.00
Cassava/tapioca flour/meal	1	Viet Nam Philippines	–	–	4.7	1.27	9.80	6.26	9.76
Wheat flour	6	Ukraine, China, Australia and USA	0.42	0.32–0.48	10.0	1.20[b]	1.30[b]	0.50[b]	12.00[b]
Wheat pollard	3	Philippines	0.30	0.30	14.0	3.5	7.5[c]	4.9[c]	10.5[c]
Maize (yellow/white)	2	Philippines and India	0.34	–	7.0	3.9[d]	2[d]	1.5[d]	12.2[d]
Molasses	7	Philippines	0.20	0.19–0.23	–	–	–	–	–

Notes: where proximate composition data was unavailable, estimates for similar quality feedstuffs are provided. These estimates are based on those provided in Tacon, Metian and Hasan (2009) or are obtained from AFFRIS (http://www.fao.org/fishery/affris/en/): [a]rice polish; [b]wheat (feed grade); [c]wheat pollard; [d]maize (ground).

Sources: Field survey (2016).

Although 22 ingredient sources are available, 50 percent of the manufacturers reported using seven staple ingredient sources only, viz fishmeal, pork meat meal, copra meal, molasses, soybean meal, and rice bran; with between one and six companies using the remaining 14 ingredient sources. Of the seven major ingredient sources reported as used, all were locally available, with the exception of fishmeal (coming from Peru), soybean meal (from the United States of America, Argentina, India, Brazil and Spain) and pork meat meal (Italy, United states of America and Germany). Animal protein meals used for aquafeed manufacturing are almost exclusively imported (Table 1). Currently, there is no substantive national rendering industry for animal by-products, and thus with the exception of fishmeal, all the protein sources of animal origin reported by the manufacturers (bloodmeal, poulty feather meal, pork meat meal and squid powder) were imported.

Five plant-based protein sources (Table 2) are available for use by the aquafeed manufacturing industry. Imported soybean meal and locally produced copra meal are the most commonly used plant protein meals in aquafeed formulations. Corn gluten, canola and palm kernel meals were also reported.

Rice and maize are the country's largest and second largest grain production sector in the country. While the relatively high cost of whole rice precludes its use as an animal feed, milling by-products (such as rice bran, sweepings, broken grains) are commonly used for animal feed. White and yellow forms of maize are produced, with white maize used primarily for human consumption and yellow maize for animal feeds.

With respect to lipid sources (Table 3), the country is self-sufficient in coconut oil, and it is commonly used in aquafeed formulations. Other lipid sources used include palm kernel oil, and marine fish oils that are available as by-products from the sardine and tuna canning industries.

TABLE 3

Origin and cost of lipid sources used in the Philippines

Ingredient	No. of manufacturers	Origin	Cost (US$/kg)	
			Mean	Range
Coconut oil	4	Philippines	1.06	0.57–1.34
Fish oil (tuna/ sardine)	6	Philippines	1.31	0.80–1.56
Palm kernel oil	2	Philippines and Indonesia	0.77	0.38–1.17
Squid oil	1	Korea	1.84	–

Sources: Field survey (2016).

2.3 On-farm feeding and feed management practices in Nile tilapia and milkfish farming

A farm production and management practices questionnaire was developed and distributed to farmers to determine on-farm feeding and feed management practices for both Nile tilapia and milkfish production within four pre-identified study areas. The questionnaire contained nine sections to assess and compare the different production management practices among commercial Nile tilapia and milkfish farmers, and was completed with supporting interviews. The geographic location of the surveys were predetermined to be representative of aquaculture management practices in the major commercial Nile tilapia and milkfish producing areas on the main Philippine islands of Luzon and Mindanao, covering production in both pond and cage systems.

2.3.1 Farms surveyed

The number of farms surveyed was 47 milkfish ponds in the municipality of Binmaley in the Province of Pangasinan; 41 milkfish cages in the Mindanao area; 42 Nile tilapia ponds at Munoz in the Province of Nueva Ecija and 48 Nile tilapia cages in Taal Lake, located in the Province of Batangas; for a total of 178 farms surveyed. From among Nile tilapia farm respondents, 53 percent and 47 percent were engaged in cage and pond operations, respectively. Of the milkfish farmers interviewed 53 percent undertook pond culture, and 43 percent undertook cage culture.

2.3.2 Ownership

The survey showed that farm business ownership varied, from family-owned enterprises, partnerships, to corporate ownership; with single owner-operators being the predominant business category.

2.3.3 Longevity

A high number of Nile tilapia cage farms in Taal Lake have been in existence for over 20 years while a considerable number of the Nile tilapia pond farms have been in operation for between five and 10 years. There was a similar wide range of time that milkfish farms have been in operation, ranging from 2 to 10 years for cages sites and 2 to 20 years for pond sites, with the oldest milkfish pond having been in operation for over 30 years.

2.3.4 Culture system

Intensive farming, in which fish are stocked at higher densities and fed formulated feeds, was practised by 98 percent of Nile tilapia cage farmers and 100 percent of milkfish cage farmers surveyed.

Sixty percent of Nile tilapia pond farmers followed an extensive culture system, in which no supplementary feed is added, relying instead on in-pond plankton production enhanced through the addition of fertilizer, and occasional or no mechanical means to improve aeration of the water; 36 percent used a semi-intensive system, occasionally adding feed and generally using aeration systems; and three percent an intensive pond system, where fish were stocked at higher stocking densities, purchased feed was added and aeration used.

Based on the survey results, a significant number of milkfish pond farms (40 percent) were using a modified semi-intensive culture system. This is an innovation developed by local milkfish farmers, in which natural food produced in ponds was supplemented with "lumot" or "moss" consisting of the filamentous algae *Chaetomorphia linum* and *Buteromorpha intestinalis* (Jennie Fernandez pers. com). The technique utilizes the natural food produced in the ponds plus the addition of lumot during the first two months of growth followed by the standard semi-intensive farming system for the following four months until the harvest period. The rest of the milkfish pond farmers were using intensive (37 percent), semi-intensive (21 percent) and extensive (2 percent) farming systems.

2.3.5 Farm size

Cage farmers producing Nile tilapia in Taal Lake generally used standardized floating cages with an area of 100 m^2 (10 m x 10 m) for ease of production management and appropriate maintenance operations. Most of the surveyed farmers producing milkfish used cages of the same cage size (10 m x 10 m), with some farms using a smaller version (8 m x 8 m), although other sizes were also visible, including 5 m x 10 m up to 15 m x 5 m depending on the type of operation.

Milkfish producers using ponds had pond areas ranging from 0.5 hectare to as large as 4.5 hectares, with one very large farm measuring 29.6 hectares. Most of the large milkfish farmers practice semi-intensive or a modified semi-intensive farming system mainly due to unavailability of aeration system and power supplies. Nile tilapia pond culture in Munoz is mostly composed of smaller scale operations with farm areas between 100 m^2 and 5 000 m^2.

2.3.6 Polyculture

Some of the farmers practice polyculture to buffer market demand and supply of the major cultured fish species. Species grown with Nile tilapia include Asian catfish (e.g., *Clarius batrachus*), giant river prawns *Machrobrachium rosenbergii*, snakehead (*Channa striatus*) and carp (mainly bighead carp *Aristichthys nobilis*). Similarly, some milkfish farmers also use polyculture with additional species including orange-spotted spinefoot (*Siganus guttatus*), shrimps (*Penaeus monodon* and *Litopenaeus vannamei*), scad (*Decapterus* sp.) and maze rabbitfish (*Siganus Vermiculatus*, known locally as malaga).

2.3.7 Stocking

Nile tilapia and milkfish farms were mostly stocked with fingerlings, in preference to other possible stocking sizes. Nile tilapia cage operators stocked fingerlings in 69 percent of cases, along with advanced fingerlings (23 percent) and fry (eight percent). Nile tilapia pond farmers' preference was for stocking fingerlings (90 percent), advanced fingerling (seven percent) and fry (three percent).

In the case of milkfish farmers, cage operators mostly preferred to stock fingerlings (94 percent), with juveniles making up a further three percent, with the remainder stocking of unknown size. Whilst fingerling remained the largest stocking size for milkfish pond operators (58 percent) there was less reliance on this size, with 40 percent stocking fry, and two percent stocking advanced fry.

There were problems in gathering fish stocking density information through surveys or interviews in most of the farm study sites. Common reasons for the lack of data were inappropriate records or no records at all and uncounted stock. There was also a reluctance by farmers in revealing this information. There was erratic Nile tilapia stocking density survey results from Taal Lake-based cages, which appeared to result from an existing strict regulation against overstocking in lake cages but with the notion that overstocking of fry or fingerlings has nonetheless become customary amongst Nile tilapia cage farmers in the Lake.

Generally the stocking density minimums and maximums being followed was 50 and 500 fingerlings/m^2 respectively in Nile tilapia cages; two and 10 fingerlings/m^2 in Nile tilapia ponds; seven and 279 fingerlings/m^2 for milkfish cages; and 0.6 and five fingerlings/m^2 for milkfish ponds.

The reason for the lower stocking density range in milkfish ponds was the unavailability of a power supply to support an aeration system. Hence pond farming of milkfish was undertaken using a modified semi-intensive or extensive system of production.

2.3.8 Fish fingerling/advanced fingerling and fry sources

The sources of fish fingerlings for stocking (Nile tilapia and milkfish) included their own hatcheries, or sourcing from other hatcheries, with a few farmers also sourcing fish from other nurseries. Wild caught fish were also used.

In the case of Nile tilapia cage farmers, they used either sex-reversed or normal fingerlings. Some farmers used fish of unknown strains and some used GET-Excel, GIFT or IDRC strains. The GET-Excel strain is most commonly used in small-scale pond based Nile tilapia production.

2.3.9 Feed use

Most Nile tilapia farmers preferred to use extruded pellet, with 52 percent of cage farmers preferring this option, and 89 percent of Nile tilapia pond farmers doing so.

All milkfish cage farmers (100 percent) and 95 percent of the milkfish pond farmers preferred extruded feeds. The remainder of the farms surveyed used compacted pellet forms of feed.

The types of feeds and feed type combinations commonly used by both milkfish and Nile tilapia farmers were a mixture of floating, sinking or a combination of both feeds. In pond culture of Nile tilapia, the use of either the sinking feeds or the use of a combination of sinking and floating feeds was dependent on pond depth and water turbidity. Generally, in ponds with higher water depth and low turbidity, sinking feed was used.

Sinking feed was utilized more in milkfish cage production to avoid frequent surfacing of fish stocks, which can cause stress in the fish. There was generally an equal utilization of sinking, floating and feed type combinations in Nile tilapia cage operations in Taal Lake, primarily for economic reasons, whereby floating feed types have a higher price than other types of commercial feeds. This was despite the requirement in the local ordinance requiring the use of floating pellets mentioned previously.

There were 23 commercial fish feed brands available in the market. Santeh (Santeh Feeds Corporation), B-Meg and Feedmix were the feed brands widely used by both milkfish and Nile tilapia farmers, though it depends on the culture type. In Nile tilapia cage aquaculture, utilization of B-Meg and Santeh feeds was higher compared to Feedmix, for example; while Santeh and Feedmix were mostly used in ponds with less use of the B-Meg feed brand. Milkfish cage farmers in Mindanao used mainly Santeh feeds due to its local availability and reliability of supply. Most semi-intensive milkfish pond farmers preferred to use Santeh and B-Meg brands.

Only milkfish cage farmers in Mindanao used the full range of feed sizes available from starter feeds, through crumbles, growers and finisher feeds. This reflects a more standardized use of feed types with regards to the growth development of the species being cultured. High utilization of grower and finisher feeds is common to other Nile tilapia and milkfish farming units.

It is important to note that additional services were given by the feed manufacturers or feed sales agents to influence purchasing decisions. This came in the form of loans to purchase feed or offers of free delivery, which influenced the bulk use of certain feed brands. More important aspects, that tended to influence specific feed brand purchase, was the availability of longer feed loan terms or a delayed payment until after harvest. However, it is noted that these types of services and the influence of the feed dealer or manufacturer could encourage uncontrolled or over feeding. Variability in price was a common problem identified by farmers at all farms that were surveyed.

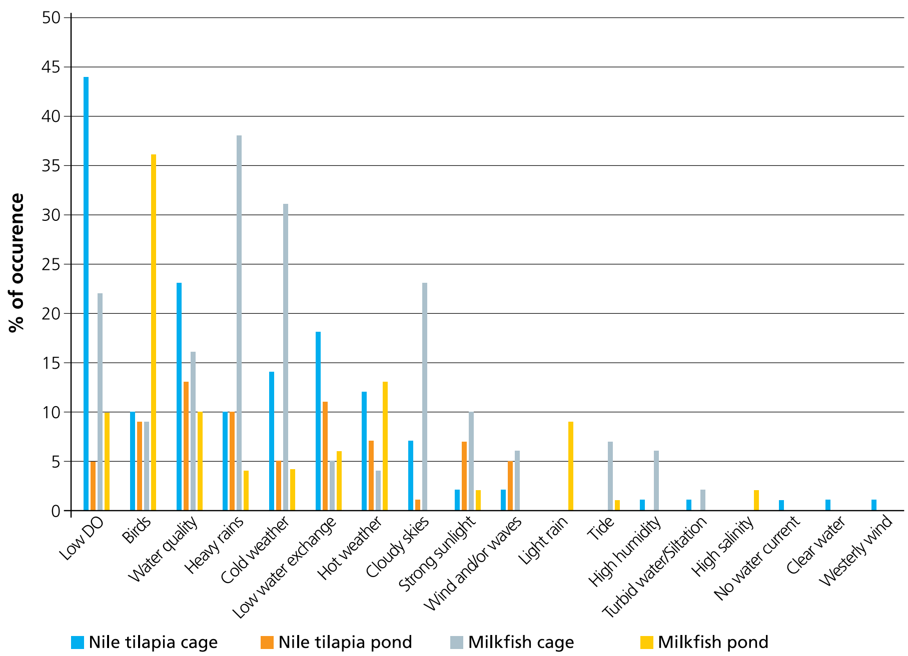
2.3.10 Feeding methods

The broadcast feeding method, in which feed is spread by hand, was the most popular means to deliver food to cages and ponds among Nile tilapia and milkfish farmers, with the exception of Nile tilapia cage operators in Taal Lake and a few milkfish farms, which used a ladle or cup, instead of by hand. The most common feeding practice followed by milkfish and Nile tilapia farmers was to broadcast feed over the entire pond area or to broadcast over part of the pond or cage. Point feeding to a restricted location is commonly used by both milkfish and Nile tilapia pond farmers, to allow the farmer to observe fish condition, fish behaviour and to make quick estimates of fish population. The use of feeding nets was used only in milkfish pond operations using floating feeds to restrict the movement of feeds when added. Use of feeding trays was only observed in some milkfish ponds.

Most feeding is done during the morning and/or afternoon with feeding durations lasting from 30 minutes to 1 hour. Some farmers feed for more than one hour, one noting feeding could last as long as 4 hours, depending on appetite.

The farmer-respondents identified several common factors that influence loss of appetite in cultured milkfish and Nile tilapia (Figure 1). Low dissolved oxygen (DO) and poor water quality were found to be the most critical and common problems in fish production, which resulted in lower feed intake and slow metabolism. Nile tilapia cage farmers in Taal Lake suffered economic losses due to seasonal low DO periods, which were also influenced by algal blooms, cloudy skies, hot weather conditions and high turbidity. It was also noted that poor water quality caused similar problems, which in discussion was primarily due to the sulphur content in the water, periodic upwelling that brought an accumulation of organic waste from the lake bottom into the water column, and ammonia toxicity. Predatory birds also highly influence fish feeding behaviour and caused stress resulting in loss of appetite.

FIGURE 1
Common factors that reduce feeding and affect appetite of fish



Source: Field survey (2016).

In most of the surveyed farms, feeding frequency was once per day, up to three times per day and in general was mostly conducted by the same person in each case, for a specified number of cages or ponds. Most feeders at all farms surveyed conducted feeding of one cage per person, up to two cages per person. Few feeders are assigned to conduct feeding of three or more cages or ponds.

2.3.11 Harvest

The frequency of harvest ranged from one harvest to several harvests per year with many farmers making one to two harvests per year in both Nile tilapia and milkfish farming systems. Farmers either made total, partial and selective harvests depending on market demand. Total harvest was undertaken during peak market demand or when the market price was high. Selective and partial harvest practices were made to generate some income during periods of financial constraint to purchase or pay for feeds, with the remaining stock held in the pond or cage whilst waiting for an increase in the market price.

2.3.12 Capital sourcing

Major sources of capital to establish and operate the farm were from personal savings, personal funds or from financiers. Other minor sources of capital included loans, credit, sponsorship or salaries from another occupation.

2.3.13 Conclusions

The farmer survey provided evidence of the wide variety of aquaculture farm production and management techniques used by milkfish and Nile tilapia farmers. In relation to the project, the results implied the absence of a coordinated management protocol related to feeds and feeding, particularly for farming of Nile tilapia in ponds and cages, including milkfish ponds, which use commercial feeds within an intensive culture system. The use of the full range of feed sizes practiced by nearly all milkfish cage farmers in Mindanao, combined with an appropriate feeding strategy, could be a good model to reduce wastage and over feeding. The local use of the modified semi-intensive system in milkfish ponds in the Province of Pangasinan, demonstrated a novel approach that appears to be effective and productive, and environment-friendly given it recycles nutrients and uses less fossil fuel. If this technique is combined with better feeds and a good feeding strategy, it could be promoted as an environmentally friendly best management practice approach.

Recurring problems of low DO and poor water quality must be addressed, which in part can be done through better on-farm feeding and feed management and reducing feed wastage. Hence, there was a need to produce guidelines for responsible farming practices. The problems associated with predatory birds, low water exchange, and the effects of low and high temperatures, heavy rains and low water level could be addressed by improvements in the design and construction of ponds and the deployment of cages.

The conclusion from the survey were that farm management practices have a large scope for improvement. Use of the full range of available feed sizes, combined with good feeding strategy that is specific to the species and culture system used, was needing to be developed. This could increase production efficiency by targeting the correct feed, feed size and feeding strategy to specific growth stages of the fish. Stocking of a uniform size and quality of fingerlings are important, along with better knowledge needed on appropriate stocking densityies. Farmers tended to stock more in anticipation of high mortality, for example, and this practice can create serious problems for the environment and increased disease potential, for example, and complicates farm management. Seed certification can promote the production of quality fingerlings for the industry.

Cages used for on-farm farmer scale trial for Nile tilapia in Taal Lake. The cages were designed and constructed by FAO consultants with assistance from the farmers participated in the study.
Photo credit: FAO/Mohammad Hasan

3. Improving feed formulation, on-farm feeding and feed management in the Philippines: results from the small-scale and farmer's field trials

Improving the quality of feed available to farmers and improved on farm-feed management practices are of critical importance to increasing a farmer's economic efficiency and production outcomes. Following analysis of feeding and feed management practices applied by milkfish and Nile tilapia farmers, and based on a review of the nutritional requirements of both species and feed management practices that have been successfully applied to other culture species, improved feed formulation and feed management practices were developed for both species. The formulations developed, and feed management practices defined, were assessed through a series of small-scale experimental and large-scale farmer trials.

3.1 Feed formulation trials for Nile tilapia and milkfish

A baseline survey was conducted on the feed manufacturing sector, which identified the availability of potential feed sources for use in aquafeeds within the country.
Once availability was known, four Nile tilapia trial feed formulations and four milkfish feed formulation were developed, according to the known dietary requirements of the species.

The protein components of the formulations were chosen according to their cost, availability in the country, and suitability for use in aquafeeds, and to make the most cost-effective use of local raw materials. In all formulations, the essential amino acid (EAA) composition and levels were calculated and where possible balanced according to dietary requirements. In all formulations the EAAs were in excess of the published dietary requirements, to ensure sufficient availability to the fish, and where appropriate a crystalline amino acid (di-methionine) was added to improve the EAA profile. In some of the formulations, fish oil and/or soy lecithin were added to maintain levels of essential fatty acids and phospholipids. Available vitamin and mineral premixes were used.

3.2 Overview of nutritional requirements in Nile tilapia and trial formulations

The gross protein requirements of Nile tilapia were established. First feeds for fry should contain a protein ration of 45–50 percent and fry in the weight range of 0.02 g to 1.0 g have a requirement of 40 percent gross protein. This is reduced to 35–40 percent in fingerlings (weight range 1 to 10 g), to 30–35 percent in juveniles (10–25 g), and finally to 28–30 percent in adults.

Nile tilapia have been shown to require the same ten essential amino acids as other fish species. With regard to the total sulphur amino acids (namely tyrosine, cystine, methionine and phenylalanine), tyrosine and cystine are best considered semi-essential in that the fish can utilize cystine as a precursor for the biosynthesis of methionine and phenylalanine, thus reducing the dietary requirement for these two essential amino acids. The optimum gross dietary lipid requirements for Nile tilapia ranges between 10 and 15 percent.

A considerable body of work has been undertaken to establish the vitamin and mineral requirements of the species. While vitamin and minerals are usually incorporated in formulated feeds in excess, dietary levels required as supplements vary according to a number of factors including culture conditions, salinity, availability of natural feeds containing vitamins and minerals, feed formulation and the feed ingredients used in the formulation, which also contain vitamins and minerals.

Following review of the dietary requirements of the species (not shown), four experimental Nile tilapia diets were developed, using the ingredients listed in Table 4, and with a proximate composition and essential amino acid content defined in Table 5.

TABLE 4
Ingredient composition (% as fed basis) of four feed formulations developed for Nile tilapia feeding trials

Ingredient	Formulation[1]			
	FAO-TF1	FAO-TF2	FAO-TF3	FAO-TF4
Tuna fishmeal (55% protein)	10.50	5.00	10.00	10.00
Blood meal	–	–	–	4.00
Pork meat meal (53% protein)	4.50	6.00	8.00	–
Meat and bone meal	–	–	–	9.00
Poultry offal meal	18.00	12.00	–	–
Soybean SSBM[2] (45% protein)	25.00	31.50	30.50	32.40
Corn gluten meal	–	4.00	7.00	–
Copra (coconut) meal	10.00	10.00	15.00	15.00
Rice bran	10.00	8.00	7.00	7.00
Wheat (10% protein) soft	20.00	20.00	20.00	20.00
Fish oil	–	1.00	–	–
Coconut oil	1.00	1.00	1.00	1.00
Soy lecithin (70% protein)	0.45	0.45	0.45	0.45
dl- methionine	–	–	–	0.10
Mycotoxin binder (HSCAS[3])	0.10	0.10	0.10	0.10
Mould inhibitor	0.05	0.05	0.05	0.05
Vitamin premix	0.50	0.50	0.50	0.50
Trace mineral premix	0.25	0.25	0.25	0.25
Antioxidant	0.05	0.05	0.05	0.05
Choline chloride	0.10	0.10	0.10	0.10

[1]Experimental formulation are coded according to target species and experimental feed number: e.g., FAOTF1 denotes FAO diet Nile tilapia formula 1; [2]SSBM = solvent extracted soybean meal; [3]HSCAS = hydrated sodium calcium aluminosilicate.

These diets were formulated to contain 34.0 percent protein and 7.5 percent lipid. The gross energy levels of the formulations ranged between 17.28 and 18.00 MJ/kg. With respect to the types of oils used in commercial Nile tilapia feeds, fish oil are commonly used, but its increasing price and limited availability suggest that alternative plant-based oils should also be considered. Soybean oil has been found to be an acceptable alternative, for example. Nile tilapia do not have a carbohydrate requirement per se, like all fish species, but rather they have a capacity to utilize carbohydrates as an energy source.

TABLE 5
Proximate composition and amino acid content (calculated and analyzed) of the four Nile tilapia feed formulations (dry matter basis)

Calculated values[1]	**Formulation**[2]			
	FAO-TF1	**FAO-TF2**	**FAO-TF3**	**FAO-TF4**
Crude protein	34.33	34.25	33.80	34.39
Crude lipid	7.94	7.92	7.24	7.42
Dry matter	93.22	93.10	92.61	92.47
Ash	10.63	9.29	8.35	8.64
Gross energy (MJ/kg)	17.96	18.00	17.42	17.28
Cost (US$/kg)	0.57	0.56	0.55	0.58
EAA[3] (r^2)	0.76	0.59	0.52	0.64
Arginine	8.43	8.20	8.36	7.26
Histidine	2.35	2.40	2.51	2.68
Isoleucine	4.10	4.20	4.42	3.54
Leucine	7.52	8.44	9.53	7.75
Lysine	6.54	6.11	5.93	6.00
Methionine + cystine	3.42	3.25	3.26	3.75
Phenylalanine	4.52	4.81	5.18	4.75
Phenylalanine + tyrosine	8.36	9.07	10.03	7.94
Threonine	4.47	4.35	4.43	3.88
Tryptophan	1.90	1.99	2.40	1.08
Valine	5.05	5.07	5.39	5.13
Analyzed values (%)[4]				
Crude protein	34.66	35.07	35.11	34.24
Crude lipid	4.93	4.22	4.94	4.97
Crude fibre	0.82	0.50	1.17	1.85
Ash	12.50	12.57	12.02	10.65
Moisture	7.04	6.50	7.01	8.00

[1]All values are in percent unless otherwise indicated, amino acids are expressed as percentages of crude protein; [2]Experimental formulation are coded according to target species and experimental feed number: e.g., FAOTF1 denotes FAO diet Nile tilapia formula 1; [3]EAA = essential amino acid - the r^2 is a correlation coefficient and is based on the EAA profile of the feed and the body composition of the animal and provides an indication of the balance of EAAs in the feed; [4]analyzed at the laboratory of Santeh Feeds Corporation.

3.3 Overview of nutritional requirements of milkfish and trials formulations

The dietary protein requirements for milkfish fry and fingerlings have generally been established, but there have been few studies to determine these requirements in grower, finisher or broodstock fish feed. Under intensive cage culture conditions where natural productivity is low, and the entire nutritional requirements of the animals will need to be provided by a formulated feed. The dietary protein requirement is likely to be more than 30 percent. The essential amino acid requirements have been quantitatively defined, and a high correlation (r^2 = 0.82, data not shown) has been found between the dietary essential amino acid requirements of the fish and the essential amino acid pattern of milkfish tissue proteins. This indicates that the balance of the essential amino acids derived from the body profile is a good predictor of the dietary requirements.

The gross lipid requirements of the species across different size classes are poorly understood. The gross lipid requirements for fry indicate that a dietary level of 9 percent is suitable. It has been established that milkfish can use both linolenic and linoleic acids as precursors for the biosynthesis of long-chain polyunsaturated n-6 and n-3 fatty acids, and therefore, both cod liver oil (high in linolenic acid) and corn oil (high in linoleic acid) would be suitable for use in milkfish formulations.

The dietary carbohydrate requirements of the species have not been established. Likewise, little is known of the dietary vitamin and mineral requirements. However, juvenile milkfish have been shown to have a phosphorus requirement of 0.85 percent of the dry diet.

Based on the limited dietary information for this species, four experimental milkfish diets was developed, containing ingredients listed in Tables 6, with a proximate composition defined in Table 7. These diets were formulated to contain beteeen 31.2 – 34.3 percent protein and 5.6 - 11.2 percent lipid. The gross energy level of the formulations ranged netween 17.42 - 19.01 MJ/kg.

TABLE 6
Ingredient composition (% as fed basis) of four feed formulations developed for milkfish feeding trials

Ingredient	Formulation[1]			
	FAO-MF1	FAO-MF2	FAO-MF3	FAO-MF4
Tuna fishmeal (55% protein)	13.00	13.00	10.00	10.00
Pork meat meal (53% protein)	–	–	5.00	5.00
Poultry offal meal	12.00	12.00	15.00	15.00
Corn gluten meal	2.00	2.00	4.00	4.00
Soybean SSBM[2] (45% protein)	27.00	27.00	25.00	25.00
Cassava meal	12.00	7.00	5.00	–
Copra (coconut) meal	5.00	5.00	5.00	5.00
Rice bran	5.00	5.00	7.00	7.00
Wheat (10% protein) soft	21.95	21.95	21.95	21.95
Fish oil (sardines)	–	5.00	–	5.00
Soy lecithin (70% protein)	1.00	1.00	1.00	1.00
Vitamin premix	0.50	0.50	0.50	0.50
Trace mineral premix	0.25	0.25	0.25	0.25
Mycotoxin binder (HSCAS[3])	0.10	0.10	0.10	0.10
Antioxidant	0.05	0.05	0.05	0.05
Choline chloride	0.10	0.10	0.10	0.10
Mould inhibitor	0.05	0.05	0.05	0.05

[1]Experimental formulation are coded according to target species and experimental feed number: e.g., FAOMF1 denotes FAO diet milkfish formula 1; [2]SSBM = solvent extracted soybean meal; [3]HSCAS = hydrated sodium calcium aluminosilicate.

TABLE 7

Proximate composition and amino acid content (calculated and analyzed) of the four milkfish feed formulations (dry matter basis)

Calculated values[1]	Formulation[2]			
	FAO–MF1	FAO–MF2	FAO–MF3	FAO–MF4
Crude protein	31.20	31.16	34.31	34.27
Crude lipid	5.64	10.64	6.20	11.20
Dry matter	92.27	92.89	92.94	93.56
Ash	9.76	9.06	10.54	9.83
Gross energy (MJ/kg)	17.42	18.63	17.81	19.01
Cost (US$/kg)	0.59	0.62	0.60	0.63
EAA[3] (r^2)	0.82	0.76	0.76	0.76
Arginine	7.44	7.45	7.82	7.83
Histidine	2.34	2.34	2.35	2.35
Isoleucine	4.14	4.15	4.25	4.25
Leucine	7.84	7.85	8.85	8.86
Lysine	6.23	6.24	6.17	6.18
Methionine + cystine	3.36	3.37	3.38	3.38
Phenylalanine	4.61	4.61	4.82	4.83
Phenylalanine + tyrosine	8.03	8.04	9.01	9.02
Threonine	4.17	4.17	4.39	4.40
Tryptophan	1.09	1.10	1.84	1.84
Valine	4.86	4.87	5.08	5.09
Analyzed values (%)[4]				
Crude protein	31.78	31.44	32.46	35.21
Crude lipid	4.11	7.99	4.04	8.38
Crude fibre	0.75	2.67	1.81	1.60
Ash	12.55	9.59	16.21	12.53
Moisture	7.49	7.00	7.07	6.65

[1]All values are in percent unless otherwise indicated, amino acids are expressed as percentages of crude protein; [2]Experimental formulation are coded according to target species and experimental feed number: e.g., FAOMF1 denotes FAO diet milkfish formula 1; [3]EAA = essential amino acid - the r^2 is a correlation coefficient and is based on the EAA profile of the feed and the body composition of the animal and provides an indication of the balance of EAAs in the feed; [4]analyzed at the laboratory of Santeh Feeds Corporation.

3.4 Nile tilapia laboratory trial

The Nile tilapia laboratory trial was conducted at the BFAR National Integrated Fisheries Technology and Development Centre (BFAR-NIFTDC), based at Central Luzon State University (CLSU) in Munoz Nueva Ecija.

3.4.1 Trial protocol

The Nile tilapia trial was conducted in a one-hectare pond, using twenty-one 4 m x 4 m x 1.25 m hapa cages, with a mesh size number 14. Each hapa cage was supplied with a feeding ring (2 m x 2 m x 0.6 m) (Figure 2).

FIGURE 2
Small-scale feeding trials showing the layout of hapas for Nile tilapia and milkfish

Courtesy of FAO/Joel D.C. Sumeldan

Courtesy of FAO/Mohammad R. Hasan
Top: Nile tilapia feeding trial in freshwater pond at the BFAR National Freshwater Fisheries Technology Centre, Luzon City. *Bottom:* Milkfish feeding trial feeding trial in brackishwater pond at a commercial fish farm in Kiamba, Sarangani Province.

Two separate trials were conducted simultaneously:

- **Trial 1** tested the effect of three different feeding strategy/feed management practices on production parameters;
- **Trial 2** tested the effect of four different feed formulations on production parameters.

Four formulated feeds (Table 4) were assessed against a commercially available tilapia feed (Santeh Feeds Corporation). Both trials shared a common treatment (control: feed strategy 1; formulation 1) to give a total of seven treatments conducted in triplicate. To minimize the impact of environmental variables, trial treatments were allocated according to a randomized block design.

One thousand Nile tilapia with an average weight of 100 g (range 80 to 120 g) were purchased from University Business Affairs Program growout facilities and were transported to BFAR- NFFTC. The fish were placed in four cages (2 x 8 x 1.25 m) inside a grow-out pond nearby the reservoir and were conditioned for one week, during which they were fed ad libitum. Thorty two fish were randomly selected from the stock and allocated into each trial hapa net. Before putting the fish into cages, the length and weight of each fish was measured, using a fish board and top loading balance. Sub-sampling of fish length and weight was then conducted every week for the duration of the trial, and all fish were counted, weighed and measured on day 48 and at the end of the trial at day 97. Weekly sampling of fish was also done to monitor their growth and to compute necessary feeding adjustments. Sampling was done by partial lifting of the cage then taking ten fish using fine mesh scoop net. The bulk weight of fish was then obtained using top loading balance.

The calculation of the daily feed ration was undertaken prior to feeding for each of the three feeding strategies being trialed. The calculated feed ration was weighed using a top loading digital balance with being placed into plastic containers, ready for delivery. Pellet size was changed according to body weight with 81 g to 150 g fish fed using a 3.5 mm pellet and above this size, a 4 mm pellet was. All feed was added to feeding trays, and feeding allowed to continue for a maximum of 20 minutes.

The three feeding strategies tested were:

- United States Soybean Export Council (USSEC) 90 percent satiation step feeding strategy;
- Commercial tilapia feeding tables developed by Santeh Feeds for Nile tilapia;
- Feeding tables developed by the project based on ProaAqua feeding tables for marine gilthead seabream with fish size and water temperature optimized to give an FCR of 1.2:1.

The USSEC 90 percent satiation feeding strategy

The USSEC feeding method is based on a seven-day cycle. At the start of the seven-day feeding schedule, a single feed ration was calculated from the amount of feed that was consumed (satiation) during a 20-minute period feeding. This was undertaken by initially weighing the feed, placing the floating feed in a feeding ring, allowing the fish to feed for a period of 20 minutes, removing and weighing the remaining uneaten feed to be able to calculate the amount of feed consumed (Levy Manalac, USSEC, Personal communication, 2017). Then, the same amount of feed was given three times a day for the seven-day feeding cycle at 09:00, 13:00 and at 17:00.

The 90 percent satiation level refers to the estimated percentage of the original satiation level (on day one) that the fish are fed during the whole seven-day period.

Tilapia feeding using commercially available feeding tables

The Nile tilapia were fed according to the feeding table published by Santeh, with feeding amount based on a percentage of average body weight (Table 8), delivered in 3 meals as follows:

- 09:00 at 40 percent of ration
- 13:00 at 30 percent of ration
- 17:00 at 30 percent of ration.

The duration of the feeding was 20 minutes for fish below 50 g, and the duration adjusted accordingly in the later stages (from 100 g to market size).

TABLE 8

Feeding quantities of Nile tilapia feed produced by Santeh, based on 25 kg bags as delivered

	Fingerling pellet	Juvenile pellet	Grower pellet
Weight range (g)	20–100	100–300	300–500 and above
Days of feeding (number)	45	50	45
Feeding rate (% BW/day)	5.0–4.0	4.0–3.5	3.5–2.0

Note: BW = body weight

Sources: Field survey (2016).

TABLE 9

Detailed daily feeding rate for Nile tilapia to achieve a feed conversion ratio of 1.2:1

SPECIFIC GROWTH RATE (SGR)															
Temperature (° C)		Mean weight range (g)													
		20	35	48	60	80	100	150	200	250	300	350	400	450	500
Min	Max	35	48	60	80	100	150	200	250	300	350	400	450	500	<
20	22	0.50	0.38	0.30	0.24	0.22	0.20	0.14	0.14	0.12	0.10	0.10	0.10	0.10	0.08
22	24	1.00	0.86	0.68	0.52	0.48	0.44	0.34	0.30	0.28	0.24	0.20	0.18	0.18	0.16
24	25	1.88	1.50	1.18	0.92	0.84	0.76	0.62	0.54	0.48	0.42	0.34	0.32	0.28	0.24
25	26	2.95	2.56	2.06	1.62	1.48	1.30	1.04	0.92	0.82	0.72	0.60	0.54	0.48	0.40
26	27	4.22	3.84	3.18	2.54	2.30	1.98	1.56	1.40	1.24	1.08	0.90	0.80	0.72	0.60
27	28	5.65	4.86	4.08	3.32	2.98	2.52	2.00	1.78	1.58	1.38	1.14	1.02	0.92	0.80
28	29	7.10	6.04	5.08	4.12	3.70	3.14	2.48	2.20	1.98	1.72	1.42	1.28	1.14	1.00
29	30	7.50	6.50	5.48	4.44	3.98	3.38	2.68	2.38	2.12	1.84	1.54	1.38	1.22	1.06
30	31	7.50	6.60	5.56	4.50	4.40	3.44	2.72	2.42	2.16	1.88	1.56	1.40	1.24	1.08
32	33	6.00	5.20	4.38	3.56	3.18	2.70	2.14	1.90	1.70	1.48	1.24	1.10	0.98	0.84
33	34	4.50	3.90	3.28	2.66	2.40	2.04	1.60	1.42	1.28	1.10	0.92	0.82	0.74	0.64

DAILY FEEDING RATE (DFR)															
Temperature (° C)		Mean weight range (g)													
		20	35	48	60	80	100	150	200	250	300	350	400	450	500
Min	Max	35	48	60	80	100	150	200	250	300	350	400	450	500	<
20	22	1.8	1.3	1.0	0.8	0.8	0.8	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5
22	24	1.9	1.4	1.1	1.0	1.0	1.0	0.8	0.8	0.8	0.6	0.6	0.6	0.5	0.5
24	25	2.7	2.1	1.6	1.3	1.3	1.3	1.1	1.1	1.0	1.0	0.8	0.8	0.6	0.6
25	26	3.5	3.0	2.6	2.1	1.9	1.9	1.8	1.6	1.4	1.4	1.3	1.1	1.0	1.0
26	27	4.6	3.8	3.2	2.7	2.6	2.4	2.2	2.1	1.9	1.8	1.6	1.4	1.3	1.1
27	28	5.8	4.6	3.8	3.4	3.2	2.9	2.6	2.4	2.2	2.1	1.9	1.8	1.6	1.4
28	29	6.6	5.8	5.0	4.2	4.0	3.7	3.2	3.0	2.9	2.6	2.4	2.2	1.9	1.8
29	30	7.7	6.6	5.6	4.8	4.5	4.2	3.7	3.5	3.2	3.0	2.7	2.4	2.2	2.1
30	31	7.8	6.9	5.9	5.1	4.8	4.3	4.0	3.7	3.5	3.2	2.9	2.6	2.4	2.2
32	33	6.7	5.8	5.0	4.3	4.0	3.7	3.4	3.0	2.9	2.7	2.4	2.2	2.1	1.8
33	34	5.4	4.5	3.8	3.4	3.2	2.9	2.6	2.4	2.2	2.1	1.9	1.8	1.6	1.4

FEED CONVERSION RATIO (FCR)															
Temperature (° C)		Mean weight range (g)													
		20	35	48	60	80	100	150	200	250	300	350	400	450	500
Min	Max	35	48	60	80	100	150	200	250	300	350	400	450	500	<
20	22	2.40	2.40	2.40	2.60	2.70	2.90	3.30	3.50	3.70	3.90	4.20	4.30	4.40	4.60
22	24	1.27	1.29	1.31	1.39	1.46	1.60	1.80	1.90	2.00	2.10	2.20	2.30	2.40	2.50
24	25	1.02	1.03	1.04	1.11	1.17	1.25	1.43	1.50	1.60	1.70	1.80	1.80	1.0	2.00
25	26	0.88	0.89	0.91	0.96	1.01	1.09	1.24	1.30	1.37	1.44	1.50	1.60	1.60	1.70
26	27	0.74	0.75	0.76	0.80	0.85	0.91	1.04	1.09	1.15	1.21	1.30	1.34	1.37	1.44
27	28	0.79	0.71	0.72	0.76	0.80	0.86	0.98	1.03	1.08	1.14	1.22	1.26	1.30	1.36
28	29	0.70	0.71	0.73	0.77	0.81	0.87	0.99	1.04	1.09	1.15	1.24	1.27	1.31	1.37
29	30	0.74	0.75	0.76	0.80	0.85	0.91	1.04	1.09	1.15	1.21	1.30	1.34	1.37	1.44
30	31	0.78	0.79	0.80	0.85	0.90	0.96	1.09	1.15	1.21	1.28	1.37	1.41	1.45	1.50
32	33	0.82	0.84	0.85	0.90	0.95	1.02	1.16	1.22	1.28	1.35	1.45	1.49	1.50	1.60
33	34	0.86	0.87	0.89	0.94	0.99	1.06	1.21	1.27	1.33	1.41	1.50	1.60	1.60	1.70

Source: Modified from feeding tables developed by ProaAqua for marine gilthead seabream (*Sparus aurata*) feeds.

Project developed feeding strategy

A daily feeding rate table for Nile tilapia was developed based on the potential growth rate and feed conversion ratio at different fish size and different temperatures that would give an overall feed conversion ratio of 1.2:1 (Table 9).

The table (Table 9) was further simplified to prepare a table (Table 10) for daily feeding rate on a monthly basis adjusted for the local temperature in North Luzon ponds where the small-scale tilapia trial was held.

TABLE 10
Simplified daily feeding rate (SFR) adjusted for pond water temperatures of North Luzon State

		Mean weight range (g)													
		20	35	48	60	80	100	150	200	250	300	350	400	450	500
Month	Temperature (° C)	35	48	60	80	100	150	200	250	300	350	400	450	500	<
January	26.0	4.6	3.8	3.2	2.7	2.6	2.4	2.2	2.1	1.9	1.8	1.6	1.4	1.3	1.1
February	26.0	4.6	3.8	3.2	2.7	2.6	2.4	2.2	2.1	1.9	1.8	1.6	1.4	1.3	1.1
March	26.0	4.6	3.8	3.2	2.7	2.6	2.4	2.2	2.1	1.9	1.8	1.6	1.4	1.3	1.1
April	28.4	6.6	5.8	5.0	4.2	4.0	3.7	3.2	3.0	2.9	2.6	2.4	2.2	1.9	1.8
May	28.4	6.6	5.8	5.0	4.2	4.0	3.7	3.2	3.0	2.9	2.6	2.4	2.2	1.9	1.8
June	29.0	7.7	6.6	5.6	4.8	4.5	4.2	3.7	3.5	3.2	3.0	2.7	2.4	2.2	2.1
July	29.0	7.7	6.6	5.6	4.8	4.5	4.2	3.7	3.5	3.2	3.0	2.7	2.4	2.2	2.1
August	29.0	7.7	6.6	5.6	4.8	4.5	4.2	3.7	3.5	3.2	3.0	2.7	2.4	2.2	2.1
September	29.0	7.7	6.6	5.6	4.8	4.5	4.2	3.7	3.5	3.2	3.0	2.7	2.4	2.2	2.1
October	28.5	6.6	5.8	5.0	4.2	4.0	3.7	3.2	3.0	2.9	2.6	2.4	2.2	1.9	1.8
Novemebr	28.5	6.6	5.8	5.0	4.2	4.0	3.7	3.2	3.0	2.9	2.6	2.4	2.2	1.9	1.8
December	26.5	4.6	3.8	3.2	2.7	2.6	2.4	2.2	2.1	1.9	1.8	1.6	1.4	1.3	1.1

Source: Compiled by authors.

The tilapia were fed according to a simplified daily feeding rate (Table 10). Feed was distributed in three meals as follows:

- 09:00 at 40 percent of ration;
- 13:00 at 30 percent of ration; and
- 17:00 at 30 percent ration.

Similarly, a daily feeding rate table for milkfish was developed based on the potential growth rate and feed conversion ratio at different fish size and different temperatures that would give an overall feed conversion ratio of 1.6:1 (Table 11). Both the feeding tables for Nile tilapia (Table 9) and milkfish (Table 11) were adapted from feeding tables developed by ProAqua for marine gilthead seabream. ProAqua Company has been purchased by BioMar and does exist anymore.

TABLE 11
Detailed daily feeding rate for milkfish to achieve a feed conversion ratio of 1.6:1

SPECIFIC GROWTH RATE (SGR)															
Mean weight range (g)															
Temperature (° C)		20	35	48	60	80	100	150	200	250	300	350	400	450	500
Min	Max	35	48	60	80	100	150	200	250	300	350	400	450	500	<
20	22	0.50	0.38	0.30	0.24	0.22	0.20	0.14	0.14	0.12	0.10	0.10	0.10	0.10	0.08
22	24	1.00	0.86	0.68	0.52	0.48	0.44	0.34	0.30	0.28	0.24	0.20	0.18	0.18	0.16
24	25	1.88	1.50	1.18	0.92	0.84	0.76	0.62	0.54	0.48	0.42	0.34	0.32	0.28	0.24
25	26	2.95	2.56	2.06	1.62	1.48	1.30	1.04	0.92	0.82	0.72	0.60	0.54	0.48	0.40
26	27	4.22	3.84	3.18	2.54	2.30	1.98	1.56	1.40	1.24	1.08	0.90	0.80	0.72	0.60
27	28	5.65	4.86	4.08	3.32	2.98	2.52	2.00	1.78	1.58	1.38	1.14	1.02	0.92	0.80
28	29	7.10	6.04	5.08	4.12	3.70	3.14	2.48	2.20	1.98	1.72	1.42	1.28	1.14	1.00
29	30	7.50	6.50	5.48	4.44	3.98	3.38	2.68	2.38	2.12	1.84	1.54	1.38	1.22	1.06
30	31	7.50	6.60	5.56	4.50	4.04	3.44	2.72	2.42	2.16	1.88	1.56	1.40	1.24	1.08
32	33	6.00	5.20	4.38	3.56	3.18	2.70	2.14	1.90	1.70	1.48	1.24	1.10	0.98	0.84
33	34	4.50	3.90	3.28	2.66	2.40	2.04	1.60	1.42	1.28	1.10	0.92	0.82	0.74	0.64

DAILY FEEDING RATE (DFR)															
Mean weight range (g)															
Temperature (° C)		20	35	48	60	80	100	150	200	250	300	350	400	450	500
Min	Max	35	48	60	80	100	150	200	250	300	350	400	450	500	<
20	22	2.2	1.6	1.2	1.0	1.0	1.0	0.8	0.8	0.8	0.6	0.6	0.6	0.6	0.6
22	24	2.4	1.8	1.4	1.2	1.2	1.2	1.0	1.0	1.0	0.8	0.8	0.8	0.6	0.6
24	25	3.4	2.6	2.0	1.6	1.6	1.6	1.4	1.4	1.2	1.2	1.0	1.0	0.8	0.8
25	26	4.4	3.,8	3.2	2.6	2.4	2.4	2.2	2.0	1.8	1.8	1.6	1.4	1.2	1.2
26	27	5.8	4.8	4.0	3.4	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4
27	28	7.2	5.8	4.8	4.2	4.0	3.6	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8
28	29	8.2	7.2	6.2	5.2	5.0	4.6	4.0	3.8	3.6	3.2	3.0	2.8	2.4	2.2
29	30	9.6	8.2	7.0	6.0	5.6	5.2	4.6	4.4	4.0	3.8	3.4	3.0	2.8	2.6
30	31	9.8	8.6	7.4	6.4	6.0	5.4	5.0	4.6	4.4	4.0	3.6	3.2	3.0	2.8
32	33	8.4	7.2	6.2	5.4	5.0	4.6	4.2	3.8	3.6	3.4	3.0	2.8	2.6	2.2
33	34	6.8	5.6	4.8	4.2	4.0	3.6	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8

FEED CONVERSION RATIO (FCR)															
Mean weight range (g)															
Temperature (° C)		20	35	48	60	80	100	150	200	250	300	350	400	450	500
Min	Max	35	48	60	80	100	150	200	250	300	350	400	450	500	<
20	22	4.40	4.21	4.00	4.17	4.55	5.00	5.71	5.71	6.67	6.00	6.00	6.00	6.00	7.50
22	24	2.40	2.09	2.06	2.31	2.50	2.73	2.94	3.33	3.57	3.33	4.00	4.44	3.33	3.75
24	25	1.81	1.73	1.69	1.74	1.90	2.11	2.26	2.59	2.50	2.86	2.94	3.13	2.86	3.33
25	26	1.49	1.48	1.55	1.60	1.62	1.85	2.12	2.17	2.20	2.50	2.67	2.59	2.50	3.00
26	27	1.37	1.25	1.26	1.34	1.39	1.52	1.79	1.86	1.94	2.04	2.22	2.25	2.22	2.33
27	28	1.27	1.19	1.18	1.27	1.34	1.43	1.60	1.69	1.77	1.88	2.11	2.16	2.17	2.25
28	29	1.15	1.19	1.22	1.26	1.35	1.46	1.61	1.73	1.82	1.86	2.11	2.19	2.11	2.20
29	30	1.28	1.26	1.28	1.35	1.41	1.54	1.72	1.85	1.89	2.07	2.21	2.17	2.30	2.45
30	31	1.31	1.30	1.33	1.42	1.49	1.57	1.84	1.90	2.04	2.13	2.31	2.29	2.42	2.59
32	33	1.40	1.38	1.42	1.52	1.57	1.70	1.96	2.00	2.12	2.30	2.42	2.55	2.65	2.62
33	34	1.51	1.44	1.46	1.58	1.67	1.76	2.00	2.11	2.19	2.36	2.61	2.68	2.70	2.81

Source: Modified from feeding tables developed by ProAqua for marine gilthead seabream feeds..

The table (Table 11) was further simplified to prepare a table (Table 12) for daily feeding rate on a monthly basis adjusted for the local temperature in Sarangani Province where the small-scale milkfish trial was conducted.

TABLE 12
Simplified daily feeding rate (SFR) adjusted for seawater temperatures for milkfish

		Mean weight range (g)													
		20	35	48	60	80	100	150	200	250	300	350	400	450	500
Month	Temperature (° C)	35	48	60	80	100	150	200	250	300	350	400	450	500	<
January	27.0	7.2	5.8	4.8	4.2	4.0	3.6	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8
Februry	27.0	7.2	5.8	4.8	4.2	4.0	3.6	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8
March	27.5	7.2	5.8	4.8	4.2	4.0	3.6	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8
April	28.0	8.2	7.2	6.2	5.2	5.0	4.6	4.0	3.8	3.6	3.2	3.0	2.8	2.4	2.2
May	29.0	9.6	8.2	7.0	6.0	5.6	5.2	4.6	4.4	4.0	3.8	3.4	3.0	2.8	2.6
June	29.0	9.6	8.2	7.0	6.0	5.6	5.2	4.6	4.4	4.0	3.8	3.4	3.0	2.8	2.6
July	29.5	9.6	8.2	7.0	6.0	5.6	5.2	4.6	4.4	4.0	3.8	3.4	3.0	2.8	2.6
August	29.5	9.6	8.2	7.0	6.0	5.6	5.2	4.6	4.4	4.0	3.8	3.4	3.0	2.8	2.6
September	29.0	9.6	8.2	7.0	6.0	5.6	5.2	4.6	4.4	4.0	3.8	3.4	3.0	2.8	2.6
October	29.0	9.6	8.2	7.0	6.0	5.6	5.2	4.6	4.4	4.0	3.8	3.4	3.0	2.8	2.6
November	28.0	8.2	7.2	6.2	5.2	5.0	4.6	4.0	3.8	3.6	3.2	3.0	2.8	2.4	2.2
December	27.0	7.2	5.8	4.8	4.2	4.0	3.6	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8

Sources: Compiled by authors.

Although both Tables 10 (for Nile tilapia) and 12 (for milkfish) were initially developed for two sites, these feeding tables may be used at any sites taking water temperatures and mean fish weight into consideration.

3.4.2 Measures taken

Water quality parameters in the pond were measured on a regular basis, namely:

- Temperature, measured daily
- pH, turbidity (using a Secchi disc), and dissolved oxygen, measured weekly

The following parameters were measured and used to establish the efficacy of the feed formulations and feed management practices:

- Weight gain (%) = [(final weight – initial weight) x 100]/initial weight
- Specific growth rate, SGR (%/day) = [(ln FW – ln IW) x 100]/n days, where FW is the final body weight (g), IW is the initial body weight (g), and "n days" is the number of days for the trial.
- Weight gain (%) = [(final weight – initial weight) x 100]/initial weight
- Feed conversion ratio (FCR) = total dry feed fed (g)/wet weight gain (g)
- Protein efficiency ratio (PER) = wet weight gain (g)/total protein fed (g)
- Economic feed conversion ratio (eFCR) = total cost of feed fed (g)/total value of wet weight gain (g)
- Survival rate (SR, %) = (final fish number/initial fish number) x 100
- Condition factor (CF) = [{whole body weight (g)/{body length (cm)}^{3}] x 100

- Daily feed consumption (as % body weight per day) was recorded using the formula: consumption (%) = cg / wt x 100 where cg is the mean daily feed consumption and wt is the mean fish weight at time t (days). Wt was calculated using the formula: wt = wo x [(SGR/100) + 1]/t.

An economic analysis based on the FCRs, feed cost and growth rates were carried out to establish which feed and feed management strategy are the most cost-effective for the farmers to adopt.

3.4.3 Statistical analysis

At the start of the trial, mean initial weights from each replicate sub-sample were tested for normality (Shapiro-Wilk test) and homogeneity of variance (Levene's test) and compared using a one-way analysis of variance (ANOVA). This ensures that no significant differences exist between the treatments. Growth rates were determined as SGRs. The slopes of the growth models were compared using analysis of covariance (ANCOVA) followed by a one-tailed F-test. One-way ANOVA and Tukey post-hoc multiple comparison procedures were carried out to determine significant differences in feed consumption, condition factors, FCR and PER and feed consumption. Differences were considered significant at $P<0.05$.

3.4.4 Trial results

a) Survival, condition factor and mortality

The condition factors of the fish throughout the experimental period and the mortality rates of the fish during the experiment are presented in Table 13 A one-way ANOVA indicated that there were no significant differences between the condition factors of the fish at the start of the experimental period. On day 98 it was established that there were no significant differences between the condition factors of the fish fed either the experimental formulations or the control feed (one way ANOVA: $F (4, 10) = 2.3301$, $p = 0.12675$). Likewise, diet did not significantly affect the mortality rates over the experimental period (one way ANOVA: $F (4, 10) = 0.59579$, $p = 0.67$).

TABLE 13

Condition factors and mortality rates of Nile tilapia over 98-day experimental period

Experimental and control feeds	Condition factor		Mortality (%)
	Day 0	Day 98	
Formulation 1	1.88 ± 0.03	2.10 ± 0.04	22
Formulation 2	1.86 ± 0.00	2.06 ± 0.01	16
Formulation 3	1.86 ± 0.02	2.11 ± 0.03	11
Formulation 4	1.84 ± 0.00	2.13 ± 0.01	22
Control	1.87 ± 0.02	2.01 ± 0.05	27

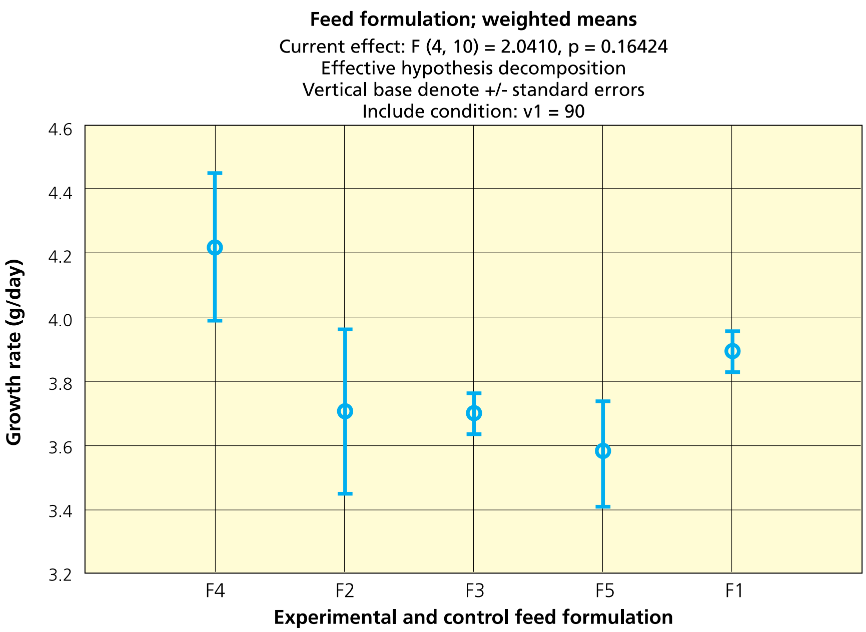
b) Growth and FCR

The SGR of the fish fed the trial diets, and the respective FCR are presented in Table 14 and Figure 3. Without exception, the growth rates of the fish fed the experimental diets were higher than those fed the control diet (i.e. the commercially available feed). However, a one-way ANOVA revealed that there were no significant differences between the growth rates ($F (4, 10) = 2.0408$, $p = 0.16$). While the result is not significant, the low p value ($p = 16$) suggests that there are differences in the growth rates and it is possible that had the trial been extended for a longer period, the differences in growth rates may have become significant. Evidently, formulation 4 is the most successful formulation in terms of maximizing the growth rate. With respect to FCRs, all the experimental feeds produced lower FCRs than the control feed indicating enhanced feed efficiency over the control feed. The lowest FCR (most efficient feed) was found to be formulation 4.

TABLE 14
Specific growth rate and feed conversion ratio of Nile tilapia fed the experimental and control feeds

Experimental and control feeds	Growth		FCR
	g/day	SGR (%BW/day)	
Formulation 1	3.90 ± 0.06	1.68 ± 0.01	2.47
Formulation 2	3.71 ± 0.26	1.63 ± 0.06	2.45
Formulation 3	3.70 ± 0.06	1.63 ± 0.02	2.29
Formulation 4	4.22 ± 0.23	1.75 ± 0.05	2.26
Control	3.58 ± 0.17	1.61 ± 0.04	3.32

FIGURE 3
Growth rates (g/day) of fish fed the experimental and control feeds (F1 - F4 = experimental formulations, F5 = control formulation) for Nile tilapia



c) Feed production cost

The feed costs (feed formulation and manufacturing costs) range between 30.0 to 31.3 PHP/kg and are comparable to the commercial feed cost of 30.2 PHP/kg (Table 15). Taking into consideration the FCRs attained using the experimental and control feeds, the cost of producing 1.0 kg fish was calculated. While the feed production cost for 1.0 kg of fish using the control feed was US$2.24, the feed production costs from the use of the experiental feeds were significantly lower (between US$1.51 – 1.73/kg). The most efficient feed in terms of production cost was formulation 3.

TABLE 15
Feed production costs (PHP and US$ per kg) of Nile tilapia

Experimental and control feeds	Feed cost (PHP)	FCR	PHP/kg production	US$/kg production
Formulation 1	31.3	2.47	77.44	1.73
Formulation 2	30.0	2.45	73.52	1.64
Formulation 3	29.6	2.29	67.69	1.51
Formulation 4	30.9	2.26	69.84	1.56
Control	30.2	3.32	100.26	2.24

Notes: PHP = Philippine peso

3.4.5 Laboratory trials conclusions

In comparison with the control feed, the best performing feed formulation in terms of growth was formulation 4 (Table 16). Using formulation 4, the fish grew at a rate of 4.22 g/day, representing an increase in growth rate of 17.8 percent over the growth attained using the control feed (control feed growth rate: 3.58 g/day). Likewise, in terms of feed production cost, formulation 3 elicited the most efficient feed production cost, reducing these costs by 32.5 percent over the control feed. The feed production cost using formulation 4 was only slightly lower than that of formulation 3, and taking into consideration the higher growth rate attained using formulation 4, it was chosen for further assessment in the farmer trials.

TABLE 16
Best performing feed formulation in terms of growth and feed production costs for Nile tilapia

Experimental and control feeds	Growth (g/day)	Change in growth rate (%)	Feed cost/kg production (US$)	Change in feed costs
Formulation 1	3.9	+ 8.9	1.73	- 22.76
Formulation 2	3.71	+ 3.6	1.64	- 26.67
Formulation 3	3.7	+ 3.3	1.51	- 32.49
Formulation 4	4.22	+ 17.8	1.56	- 30.34
Control	3.58		2.24	

Table 17 shows the growth, survival, FCR and condition factor after the first 43 days of the trial period, and Table 18 present the same over the whole trial period which highlight major shifts in indicators during the two periods. Growth and FCR were compromised during the second half of the trial by natural spawning in the pond and small fry feeding and growing together with the trial fish in the same hapa.

Overall, however, although the fastest growth was achieved using the USSEC strategy, it gave the highest FCR. The commercial and optimized feeding strategy had very similar results, but the optimized feeding strategy gave slightly better survival rates.

TABLE 17
Best performing feeding strategies during first 43 days of feeding trial for Nile tilapia

Strategy	Growth (g/day)	Survival (%)	FCR	Condition factor
Commercial feeding table	5.04	81.25	1.56	2.25
Optimized feeding table	4.67	85.42	1.61	2.27
USSEC 90%	5.04	84.38	1.57	2.33

Note: None of the results were significantly different.

TABLE 18
Best performing feeding strategies during whole 97 days of feeding trial for Nile tilapia

Strategy	Growth (g/day)	Survival (%)	FCR	Condition factor
Commercial feeding table	3.32	78.19	2.99	2.01
Optimized feeding table	2.94	82.38	3.09	1.95
USSEC 90%	4.63	80.07	3.69	2.39

Note: None of the results were statistically significantly different.

3.5 FARM-SCALE TRIALS

3.5.1 Rationale for the trials

Following the Nile tilapia laboratory trials, the feed formulation that performed best in terms of growth performance and on-farm production costs was feed FAOTF4 (Table 4) developed by the project. This feed was subsequently tested under standard farm-scale conditions, in cages installed at the JCK Farm on Taal Lake at Talisay, Province of Batangas. The trial lasted for five months including initial preparation and harvesting.

The milkfish laboratory trial failed to produce meaningful results that could be used to establish the growth and nutritional performace of the four trial feeds. Due to cost and logistic constraints, the efficacy of only one of the feed formulations could be assessed under farm-scale conditions. It was decided that the efficacy of the FAOMF1 formulation would be tested at the farm-scale. The rationale for this was that while in comparison with the other trial formulations, the FAOMF1 formulation contained a relativly low protein (31.7 percent) and lipid content (4.1 percent), the EAA profile of the formulation indicted that it had a better EAA profile than the alternative formulations, and it would therefore likley be a cost effective feed that would support good growth (Table 7). The field trial was conducted in cages installed in a saline pond at TEDSIE Farm, Sitio Dapdap, Taliptip Bulacan, Province of Bulacan. The trial lasted for approximately five months, including initial preparation and harvesting.

3.5.2 Context for feeding mechanisms used

In Nile tilapia laboratory trial, the best performing feeding strategy was application of the feed table developed by the project. This feeding strategy was applied to all farmer trials. Following analysis of Nile tilapia laboratory trial results, the daily feeding rate chart for the farmer's trial was adjusted by reducing the daily feeding rate slightly to reflect a more realistic growth rate at commercial scale (Box 1). Similarly the feeding rate for milkfish farmer's trial was adjusted (Box 2).

The amount of food added per day was based on the average fish weight, total fish per pond or cage, and water temperature; with the amount of food defined as a percentage of body weight. Fish were fed three times per day as follows:

- 09:00 delivering 40 percent of ration;
- 13:00 delivering 30 percent of ration; and
- 17:00 delivering 30 percent of ration.

For both species the duration of feeding was typically 20 minutes for fish below 50 g, shortened progressively in the later stages of growth (e.g. from 150 g up to market size). During periods with poor water quality or extreme weather conditions, fish could be fed in moderation to maintain energy intake, or not at all, depending on severity of the conditions.

This means of determining feed added to cages was compared against standard feeds and standard means of application used by farmers at their sites.

For Nile tilapia the trial feed formulation was tested against commercial feed produced by Santeh (Tateh Surfer), a grower formulation with a crude protein of 31 percent and lipid content of six percent, used as the control feed. The farmers feeding strategy was to feed ad libitum three times per day, with the amount feed added calculated as follows;

- Known weight of feed brought to farmer's cages (B1, B2 & B3) every feeding time (0700 hours; 1200 hourds; 1500 hours);
- *ad libitum* feeding conducted;
- excess or remaining feed weight taken and recorded; and
- total feed consumed every feeding time was calculated.

For milkfish the trial feed FAOMF4 used in the trial contained 34.27 percent protein, 11.2 percent lipid and contained a gross energy level of 19.01 MJ/kg (Tables 6 and 7). The trial feed formulation was tested against the same feed used in the Nile tilapia trial, namely Santeh Surfer grower formulation containing 31 percent crude protein and six percent lipid; as a control feed. The standard farmer approach to feeding consisted of daily feeding off five percent of body weight, given as two rations at 08:00 and 14:00 hours each day. When calculating the feed ration and feeding fish, the farmer took the following into account:

- Increase in feed weight was calculated weekly (similar to project developed protocol) considering weekly mortality
- Known weight of feed brought to farmer's cages every feeding time (08:00 and 14:00)
- Milkfish were fed until they cease to feed
- Excess or remaining feed weight taken and recorded
- Total feed consumed/feeding time was calculated

BOX 1

Optimized feeding table: Nile tilapia farm trial

The following feeding table indicates the amount of feed to be added to Nile tilapia cages, as a percentage of body weight, based on water temperature and average weight (g) of the fish. Colours are present for clarity of feeding rates only, banded as 6-8 percent of BW (dark blue), 4-6 percent of BW (green), 2-4 percent of BW (yellow) and below 2 percent of BW (clear).

SIMPLIFIED DAILY FEEDING RATE (SFR)

Mean weight (g) range		20	35	48	60	80	100	150	200	250	300	350	400	450	500
Temp (° C) range		35	48	60	80	100	150	200	250	300	350	400	450	500	<
20	22	1.5	1.1	0.8	0.7	0.7	0.7	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4
22	24	1.6	1.2	1.0	0.8	0.8	0.8	0.7	0.7	0.7	0.5	0.5	0.5	0.4	0.4
24	25	2.3	1.8	1.4	1.1	1.1	1.1	1.0	1.0	0.8	0.8	0.7	0.7	0.5	0.5
25	26	3.0	2.6	2.2	1.8	1.6	1.6	1.5	1.4	1.2	1.2	1.1	1.0	0.8	0.8
26	27	4.0	3.3	2.7	2.3	2.2	2.1	1.9	1.8	1.6	1.5	1.4	1.2	1.1	1.0
27	28	4.9	4.0	3.3	2.9	2.7	2.5	2.2	2.1	1.9	1.8	1.6	1.5	1.4	1.2
28	29	5.6	4.9	4.2	3.6	3.4	3.2	2.7	2.6	2.5	2.2	2.1	1.9	1.6	1.5
29	30	6.6	5.6	4.8	4.1	3.8	3.6	3.2	3.0	2.7	2.6	2.3	2.1	1.9	1.8
30	31	6.7	5.9	5.1	4.4	4.1	3.7	3.4	3.2	3.0	2.7	2.5	2.2	2.1	1.9
32	33	5.8	4.9	4.2	3.7	3.4	3.2	2.9	2.6	2.5	2.3	2.1	1.9	1.8	1.5
33	34	4.7	3.8	3.3	2.9	2.7	2.5	2.2	2.1	1.9	1.8	1.6	1.5	1.4	1.2

The table was simplified for the farmer scale trials, to aid clarity and make it easier for farmers to follow during the trials. A limited number of temperatures were applied based on averages within specific months and identified by month only, adjusted to the location of the trials, in this case Taal Lake water temperatures; and application of a more limited number fish size classes.

Weight	Min (g)	20	48	80	150	250	350	450 +
Month	Max (g)	48	80	150	250	350	450	
December to March		4.0	2.8	2.4	2.0	1.7	1.4	1.2
April and November		4.9	3.5	2.9	2.4	2.1	1.8	1.4
May to October		5.7	4.2	3.5	2.9	2.5	2.1	1.7

To calculate feed input required within a particular month the mean weight of each fish is required to determine the amount of feed to add.

For example, fish of 52 g (in the range 48 to 80 g) being fed in April should be fed 3.5 percent of mean fish body weight or 1.82 g of feed per fish.

Assuming 2 000 fish are present in the cages, at an average weight of 52 g results in a total biomass of 104 kg, multiplied by a feed rate of 3.5 percent gives a daily feed ration of 3.64 kg of feed to be added to the cages in one day. This is then further sub-divided based on the number of feeds given and an assumed percentage for each feed. In the case of the trials, 3 feeds were given through the day, so feed delivered per feeding for the example above would be as follows:

- 40% in the morning = 1.46 kg of feed added
- 30% at midday = 1.10 kg of feed added
- 30% in the evening = 1.10 kg of feed added

It is critical to maintain good stock management, with estimates of average weight (e.g. calculated through specific growth rate and feed added) made regularly, or a sub-sample of fish removed from the water temporarily and weighed.

BOX 2
Optimized feeding table: milkfish farm trial

The following feeding table indicates the amount of feed to be added to milkfish cages, as a percentage of body weight, based on water temperature and average weight (g) of the fish. Colours are present for clarity of feeding rates only, banded as 8-10 percent of body weight (BW) (brown), 6-8 percent of BW (dark blue), 4-6 percent of BW (green), 2-4 percent of BW (yellow) and below 2 percent of BW (background colour).

SIMPLIFIED DAILY FEEDING RATE (SFR)

Mean weight (g) range		20	35	48	60	80	100	150	200	250	300	350	400	450	500
Temp (° C) range		35	48	60	80	100	150	200	250	300	350	400	450	500	<
20	22	2.2	1.6	1.2	1.0	1.0	1.0	0.8	0.8	0.8	0.6	0.6	0.6	0.6	0.6
22	24	2.4	1.8	1.4	1.2	1.2	1.2	1.0	1.0	1.0	0.8	0.8	0.8	0.6	0.6
24	25	3.4	2.6	2.0	1.6	1.6	1.6	1.4	1.4	1.2	1.2	1.0	1.0	0.8	0.8
25	26	4.4	3.8	3.2	2.6	2.4	2.4	2.2	2.0	1.8	1.8	1.6	1.4	1.2	1.2
26	27	5.8	4.8	4.0	3.4	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4
27	28	7.2	5.8	4.8	4.2	4.0	3.6	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8
28	29	8.2	7.2	6.2	5.2	5.0	4.6	4.0	3.8	3.6	3.2	3.0	2.8	2.4	2.2
29	30	9.6	8.2	7.0	6.0	5.6	5.2	4.6	4.4	4.0	3.8	3.4	3.0	2.8	2.6
30	31	9.8	8.6	7.4	6.4	6.0	5.4	5.0	4.6	4.4	4.0	3.6	3.2	3.0	2.8
32	33	8.4	7.2	6.2	5.4	5.0	4.6	4.2	3.8	3.6	3.4	3.0	2.8	2.6	2.2
33	34	6.8	5.6	4.8	4.2	4.0	3.6	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8

The table was simplified for the farmer scale trials, to aid clarity and make it easier for farmers to follow during the trials. A limited number of temperatures were applied based on averages within specific months and identified by month only, adjusted to the location of the trials, in this case northern Luzon seawater temperatures; and application of a more limited number fish size classes.

Weight	Min (g)	20	48	80	150	250	350	450 +
Month	Max (g)	48	80	150	250	350	450	
December to March		5.9	4.1	3.5	2.9	2.5	2.1	1.7
April and November		7.1	5.1	4.3	3.5	3.1	2.6	2.1
May to October		8.3	6.1	5.1	4.2	3.7	3.1	2.5

To calculate feed input required within a particular month the mean weight of each fish is required to determine the amount of feed to add.

For example, fish of 75 g (in the range 48 to 80 g) being fed in May should be fed 6.1 percent of mean fish body weight or 4.58 g of feed per fish.

Assuming 3 200 fish are present in the cages, at an average weight of 75 g results in a total biomass of 240 kg, multiplied by a feed rate of 6.1 percent gives a daily feed ration of 14.6 kg of feed to be added to the cages in one day. This is then further sub-divided based on the number of feeds given and an assumed percentage for each feed. In the case of the trials, 3 feeds were given through the day so feed delivered per feeding for the example above would be as follows:

- 40 percent in the morning = 5.8 kg of feed added
- 30 percent at midday = 4.4 kg of feed added
- 30 percent in the evening = 4.4 kg of feed added

It is critical to maintain good stock management, with estimates of average weight (e.g. calculated through specific growth rate and feed added) made regularly, or a sub-sample of fish removed from the water temporarily and weighed.

3.5.3 Farm-scale trial design

The experiment, for both species, was based on a 2 x 2 factorial design to test the efficacy of the new dietary formulations and the feed management strategies against the standard commercial feed and the farmer's standard feed management practice. The experimental design (Table 19) made it possible to interrogate the effect of each factor (project developed feed type and feeding strategy against the farmer's current feed and feeding strategy/feed management practices) on response variables. Only the efficacy of the farmers' current feed management practice was tested against the project developed feeding strategy using the current farmer's (control) feed and not the formulated feed. The two feeds (formulated and farmer's control feed) were compared using the project developed feeding strategy.

TABLE 19
Experimental design for farmers' trials for Nile tilapia and milkfish

Strategy	FAO feed	Farmers feed (control feed)
FAO feeding strategy	3 replicates	3 replicates
Farmers feeding strategy	3 replicates	–

The tilapia trial was undertaken using commercial scale cages measuring 10 m x 10 m x 4 m deep, subdivided in to 4 equal size cages on 5 m x 5 m x 4 m deep. The milkfish trial were undertaken in commercial cages with a size of 5 m x 20 m x 2 m deep, which were sub-divided into four compartments each measuring 5 m x 5 m x 2 m deep. In each of the replicate nets fish were stocked at a density of 37 fish/m^3.

On the day of stocking a representative sub-sample of 100 fish per replicate were weighed (g) and measured for length (mm). A sub-sample of 200 fish from each replicate were weighed and measured at 30-day intervals for the duration of the trial. At the end of the trial, the weight of all the fish harvested was taken. Prior to weighing and measuring, the fish were left unfed for 24 hours.

Feed consumed over the growth period was recorded and feed consumption measured monthly. The data was used to establish the effect of feed formulation and feed management practice on the FCR, the SGR, and condition factors. Statistical analysis was based on those previously described for the small-scale trials (Section 3.4.3). An economic analysis based on the FCRs, feed cost and growth rates were undertaken to establish which feed and feed management strategy would be the most cost-effective for farmers to adopt.

3.5.4 Nile tilapia farm-scale trial results and conclusions

At the start of the trial there were no significant differences in the homogeneity of length and weight of the fish in the cages (Levene's test: initial weight: $F = 110$, $P = 0.39$; initial length: $F = 0.25$, $P = 0.78$) and measurements were distributed with normality (Shapiro-Wilk test: initial weight: $W = 0.95$, $P = 0.72$; initial length: $w = 0.91$, $P = 0.34$). These parameters satisfy the assumptions for a one-way ANOVA. Final weights were also homogeneous and normally distributed (data not shown) and a one-way ANOVA showed that between the three treatments there were no significant differences in the mean final fish weights (F [2,5]= 3.3, $P = 0.12$).

TABLE 20
Comparison of results from farmer-scale Nile tilapia trial (± standard error)

Parameter	A Control feed + FAO fee-ding strategy	B FAO feed + Farmers' feeding strategy	C FAO feed + FAO feeding strategy
Initial weight (g)	29.32 ±0.88	30.68 ±0.88	29.44 ±0.89
Initial length (mm)	9.33 ±0.12	9.33 ±0.15	9.07 ±0.19
Final weight (g)	343.4 ±2.4	317.4 ±6.24	330.1 ±7.86
Final length (mm)	20.14 ±0.18	19.72 ±0.15	19.83 ±0.15
SGR (%/day)	2.65	2.49	2.65
Growth (g/day)	6.79	6.10	6.73
FCR	1.03	0.86	1.07
Feed cost (US$ kg)	0.67	0.69	0.69
Production cost of feed (US$/kg fish)	0.69	0.59	0.73

At the end of the experimental period (Table 20), no significant differences were observed in the final fish weights between each of the treatments groups. The FCR was good across all the treatments (FCRs range: 0.86 – 1.07) and could be attributed to a combination of the good feed quality/feed management techniques, and the high level of natural productivity in the Taal Lake system providing supplementary feed to the fish. The best FCRs were recorded in those fish maintained under Treatment B (FCR = 0.86; FAO feed and the farmer feeding strategy – ad libitium feeding). There was minimal difference in the FCRs attained between Treatment A (FCR = 1.03; control feed and FAO feeding strategy) and Treatment C (FCR = 1.07; FAO feed and FAO feeding strategy). This suggests that notwithstanding the feed management practice, there was little difference in the performance of the FAO feed and the control feed with respect to optimizing feed conversion efficiency.

The specific growth rates were highest when the FAO feeding strategy was used (SGR = 2.65; Treatments A and C), and this result was irrespective of the feed used (FAO feed or the control feed). The lowest SGRs were reported in Treatment B (SGR = 2.49). The feed cost (US$/kg) for the FAO feed was slightly higher than that of the control feed (FAO feed = US$0.69/kg; control feed = US$0.67/kg). Despite the slightly higher feed cost, the low FCR attained in Treatment B (FAO feed and the farmers feeding strategy) indicated that while this strategy resulted in a slightly lower growth rate, feed production cost (US$ to produce 1 kg fish) was U$0.59/kg, and lower than the US$0.69/kg and US$0.73/kg required to produce fish under treatments A and C, respectively.

To conclude, the results suggest that farmers can minimize their feed use in production by adopting Treatment B (FAO feed and feeding strategy *ad libitum*). However, it should be noted that this feeding paradigm would result in slightly reduced growth rates and a concomitant increase in the grow-out period.

Furthermore, it should be noted that the farmers that collaborated in the trials became convinced that the stocking of larger fish in the cages (pre-on grown fish) and the use of feeding nets within the cages that was advocated in the trials significantly improved production outcomes. In this regard, the farmers have since changed their commercial production protocols utilizing 20–40 g fingerlings, called "lagpusan", during the warm season (March–September) and 50–100 g fish during the colder periods (September to February), which allows the fish to be harvested in a much shorter period. The advanced size fish fingerlings are known to be more resistant to extreme and abrupt changes in water temperature.

The collaborator farmers have now built live-fish delivery boxes to cope with the larger demand for bigger sized fingerlings for stocking in commercial ponds and cages around Luzon area.

3.5.5 Milkfish farm-scale trial results and conclusions

At the start of the trial there were no significant differences in the homogeneity of sizes and weights between the replicate treatments (Levene's test: initial weight: $F = 1.26$, $P = 0.34$; initial length: $F = 0.83$, $P = 0.47$) or normality (Shapiro-Wilk test: initial weight: $w = 0.97$, $P = 0.93$; initial length: $w = 0.99$, $P = 0.99$). These parameters satisfy the assumptions for a one-way ANOVA, which showed there were no significant differences in starting weight. At the end of the experimental period, length and weight data failed tests for an ANOVA and were compared using Kruskal-Wallis ANOVA by ranks that revealed there were no significant differences between in mean final fish weights ($H(2, n = 9) = 3.4$, $P = 0.17$).

TABLE 21
Comparison of results from farm-scale milkfish trials (± standard error)

Parameter	A Farmers' feed + FAO feeding strategy	B FAO feed + Farmers' feeding strategy	C FAO feed + FAO feeding strategy
Initial weight	28.32±1.02	28.09±1.20	29.99±2.25
Initial length	11.68±0.98	11.62±1.24	11.79±2.35
Final weight	104.82±17.31	81.18±0.66	94.15±7.10
Final length	179.1±8.57	168.0±0.45	178.1±4.81
SGR (% BW weight/day)	2.62	2.16	2.33
Growth (g/day)	1.56	1.08	1.30
FCR	1.89	1.40	1.40
Feed cost (US$/kg)	0.67	0.61	0.61
Feed production cost (US$/kg fish)	1.26	0.85	0.85

At the end of the experimental period (Table 21), no significant differences were observed in the final fish weights between each of the treatments groups. Nevertheless, the results provided interesting insight into the impact that feed formulation and feed management had on the production outcomes. With respect to the specific growth rates, Treatment A (farmers' feed and FAO feeding strategy) produced the highest SGR = 2.62). This outperformed Treatment C (FAO feed formulation and the FAO feeding strategy (SGR = 2.33), suggesting that notwithstanding the feeding strategy, the farmer's control feed elicited the highest growth rates. However, the FCR attained in Treatment A was higher (FCR = 1.89) than that attained in Treatment C (FCR = 1.40), suggesting that feed conversion to body mass using the FAO feed formulation was better than that obtained using the farmer's control feed. Furthermore, cost of the FAO feed was 0.61 US$/kg as opposed to 0.67 US$/kg for the farmer feed. The combination of a lower feed cost for the FAO feed and improved FCRs when using the FAO feed (Treatment C) resulted in the feed production costs (feed cost per kg of fish produced) being lower in Treatment C (FAO feed: 0.85 US$/kg) than in Treatment A (Farmers feed: 1.26 US$/kg).

A comparison between Treatment B (FAO feed and farmers' feeding strategy) and Treatment C (FAO feed and the FAO feeding strategy) indicated that the FCRs were the same for both treatments, suggesting that feeding strategy had no impact on feed conversion. As these treatments employed the same feed (FAO feed), the feed production costs were the same (0.85 US$/kg fish). Nevertheless, the SGR recorded for Treatment C (SGR = 2.33) was higher than that recorded in Treatment B (SGR = 2.16) suggesting that in comparison with the farmers' feeding practices, using the FAO feed strategy resulted in a higher growth rate. Thus, while the feed production costs between Treatments B and C were similar, the fish grew faster in Treatment C, suggesting that from the farmer's perspective, Treatment C would be the preferred production choice.

It is reasonable to conclude that irrespective of the feed management practice, the FAO feed formulation resulted in lower feed production costs than the farmers' traditional feed. Furthermore, using the scientifically based feeding tables (FAO feeding strategy) as opposed to the farmer's normal feeding strategy resulted in higher SGRs. Thus, with respect to optimizing production outcomes, the strategy recommended for adoption by the farmers would be to use the FAO feed formulation in combination with the FAO feeding strategy.

4. Better Management Practices (BMPs) for feed formulation, on-farm feeding and feed management for Nile tilapia and milkfish aquaculture in the Philippines[1]

4.1 INTRODUCTION TO BEST MANAGEMENT PRACTICES

Best management practices (BMPs) in aquaculture can generally be defined as the application of sound management practices that promote the sustainable growth of the industry whilst achieving the minimum of harm to the environmental, through the application of cost-effective and continually assessed management measures. BMP's refer to a wide range of interventions that can be made to improve or optimize performance, whether this is financial, social, environmental or other areas.

The term has been widely adopted in the realm of responsible environmental management, and in this context the incorrect use of feed ingredients in the development of feeds and use of feed on aquaculture sites has the potential to impose significant environmental harm and must therefore be managed appropriately using best practices. In this section these BMPs in feed development and use are defined for aquaculture in the Philippines, particularly for Nile tilapia and milkfish, although they are more generally applicable.

4.2 Feeding strategy

Feed quality should adhere to the Philippines National Standards PNS/BAFPS 84:2010 which, according to the forward to that document, defines:

> "….the feed products and forms, specifies their essential composition and quality factors (including nutrient standards for complete feeds, physical requirements at plant and pellet feed water stability and floatability), provides the presentation, packaging and labelling requirements, indicates the methods of sampling, examination and analyses….."

Farming practice should follow the Code of Practice for Aquaculture defined by Fisheries Administrative Order No. 214 (2001)[2]. The section on feeds, feed use and management is provided in Box 3.

The basic principles and practice, therefore, for optimizing feed development and feeding strategy are as follows:

- Build a foundation of practical knowledge and skills in feed development and feeding.
- Prepare feeds using the best available raw materials.
- Develop a feed for a specific species; that contains the correct nutrient and energy requirements for the species, with good pellet integrity so that it maintains shape and density when added in to the water at feeding time.

[1] Parts of this chapter have been adapted from Feed production and management: a training manual for small-scale aquafarmers. FAO Fisheries and Aquaculture Technical Paper No. 611. 2018. Rome, FAO. (in press).

[2] Available at http://oneocean.org/download/db_files/fao214-code_of_practice_for_aquaculture.pdf

- Use the most appropriate feeding technology to develop that feed (e.g. floating, sinking).
- Target training for the farm manager and feeding staff in the most appropriate storage and use of feed on site.
- Seek advice from more experienced farmers, feed companies, Government technical officers, and share experience.
- Record feed use and assess the feed conversion ratio (FCR), and consider cost-benefit by assessing the economic feeding conversion ratio (eFCR).
- In many cases feed quality and good FCR outplays feed cost (e.g., eFCR).
- Build and maintain goodwill and trust with feed suppliers.
- Assess the performance of the crop just harvested, and expected against actual results and try to understand the reasons for the difference.
- Small farmers should consider building association with others, in order to bulk purchase feed with others to get a discount and reduce feed purchase costs.

BOX 3

Feed, feed use and management

Verbatim extract from Fisheries Administrative Order No. 214 (2001), Code of Practice for Aquaculture for the Philippines.

The following practices shall be adopted to improve the efficiency of supplemental feeds and feed management in aquaculture and reduce the amount of waste entering the ponds.

a. Feeds shall be selected as to their high utilization rates to reduce nutrient pollution from uneaten feeds and excretory products;
b. Feed characteristics shall include balanced levels of amino acids and other nutrients appropriate for the age of the fish, high palatability to stimulate rapid consumption and high stability to prevent nutrient release;
c. Ideally, extruded feeds shall be used;
d. Feeds shall be stored in cool, dry areas to prevent mold and other contaminants from forming;
e. Medicated feeds shall be used only if and when necessary for the control of specific disease;
f. Feeding management in lake-based aquaculture shall be in conformity with the carrying capacity of the lake as specified in Chapter C of this order;
g. Good feeding practices shall include frequent feeding in small quantities of feed several times through the day, using feeding trays and even distribution of feeds in the pond;
h. DA[1] Administrative Order No.16 on the "Nutrient standard for aquaculture feeds" and other regulations of the Bureau of Animal Industry shall be complied with; and
i. Records of daily feed application rates shall be kept to assess feed conversion ratio (FCR).

[1] Department of Agriculture

4.3 Aquafeed manufacturing: raw ingredients

Raw material and ingredient purchases represent the major production cost for feed manufacturers. The cost of buying poor or adulterated materials can be high, both in terms of financial losses and with respect to the production of poor quality feeds.

When purchasing feed ingredients, a range of quality checks should be undertaken. These include:

- compliance with expected nutritional quality;
- contamination;
- adulteration; and
- damage

Compliance - The supplier should supply proximate composition information that can be verified by laboratory analysis. For traded raw materials, this should include a specification sheet outlining the proximate composition of the feed ingredient. If the information is not forthcoming and a laboratory analysis is not possible, avoid purchasing the material.

Contamination - On receiving the raw materials, the feed ingredients should be inspected for contamination with unwanted substances. Some crop harvesting procedures risk the inclusion of stones, soil or other plant materials in the products, which should be avoided. Their presence reduces the nutritional value of the raw materials, so if these materials are present, a discounted price should be paid. Large quantities of these materials will damage machinery being used to process the feed and should be avoided. Containers used to store the raw materials may have previously been used for other substances. Oil or other chemicals will transfer to the feed and in the worst cases, will result in the food produced being toxic to the fish. Any sign of chemical contamination should be avoided. In some cases, plastic, wood or other chips can also get into the raw materials from old containers. These may or may not be dangerous to the fish, but may cause problems with processing the feed, and will also lower the nutritional quality of the raw materials.

Processing of raw materials can introduce broken metal, plastic or glass. Such raw materials should be avoided at all costs, for fear of damaging feed production equipment, and ending up in feed, which could physically damage the fish.

Contamination by insects or rodents is a particular risk in warmer climates, where these animals breed rapidly. Rodents will eat raw materials and foul the remaining material with their faeces and urine, spreading potentially dangerous bacteria and mould. Insects can eat through a material store very quickly. If there are pests present on arrival at the factory, the buyer will also have to quarantine the material and treat it quickly before allowing it into the store, to ensure it does not cross-contaminate existing stock. Any sign of pests in the raw materials should be considered for rejection by the processor, or at a minimum price discount should be negotiated, noting that treatment will be required before they can be used.

Adulteration - Deliberate adulteration of raw materials is potentially common as the traded value and volumes are so large that the rewards for cheating are high. Careful inspection of the materials is the only solution to this issue – noting that some feed manufacturers will check every bag taken into their store before use to ensure there is no adulteration. Some examples of adulteration include:

- mixing in low-value raw materials;
- adding stones to increase weight;
- replacing completely with low-value raw materials; and
- adding chemicals such as urea or melamine to increase apparent protein content.

Damage – Raw materials can be damaged before they are supplied to the buyer. Crops can be damaged in the field or after harvesting; processing carries several risks for damage; and can also occur during transport and storage.

Water damage and damp conditions increase the likelihood of moulds developing. Moulds can grow on crops in the field or during post–harvest storage, particularly if the materials are exposed to water (damp) during transport and storage or were not properly dried at the time of harvest. Moulds reduce the nutritive properties of the raw materials and certain moulds also produce mycotoxins that may contaminate raw materials and are dangerous to consume. Typical signs of water damage include clumping of powdered materials and changes in their colour and odour.

Heat damage is mainly caused during processing. A poorly controlled processing system can result in overcooking or over drying of products, burning them. Dark colors and burned smells are clear indicators of overcooking. Burning reduces the nutritional properties of the raw materials, and if processed at high temperatures can destroy the proteins in the raw material or making them less digestible.

4.4 Aquafeed manufacturing: feed formulation

No single feed ingredient will be able to satisfy the nutritional requirements of a fish. As with all animals, fish require a complex mix of nutrients, proteins, lipids, amino acids and energy to grow. However, by mixing a range of different feed ingredients, it is possible to formulate those ingredients in a combination, which meets the nutritional requirements of the animal. In order to formulate a feed, it is necessary to consider the:

- nutrient composition of the individual feed ingredients;
- nutritional requirements of fish – which varies with species and life stage (fry, fingerling, grower, broodstock);
- price of the feed ingredients expressed as a unit cost per kg (e.g. US$/kg), which can vary considerably, especially for internationally traded commodities;
- ability of the fish to utilize specific nutrients in the feed ingredients. Where possible, it is useful to know the digestibility of the various nutrients in the ingredient source, e.g. protein, energy, lipid, essential fatty acids and amino acids.

Feed formulation is often a trade-off between using nutritionally appropriate raw materials that maintain a good nutritional profile that will promote good growth and productivity for the fish while trying to keep the costs of a formulation as low as possible. Critically, the cheapest formulations (use of cheapest raw materials) are rarely the most cost-effective, because they are usually deficient in one or more limiting nutrient resulting in reduced feed performance and growth rates, poor FCR, and increased waste to the environment through uneaten feed and excess faeces. It is also important not to add certain nutrients in excess. A good example is phosphate, which fish cannot digest directly, so it needs to be added at a level that is higher than the fish's requirement, so digestive processes can provide an adequate level to the fish; diatary inclusion should not be so excessive that high levels of phosphorus are wasted because this causes unnecessary environmental problems.

Over the long-term, it is often more cost-effective to use slightly more expensive formulations that adequately satisfy the nutritional requirements of the fish and support good growth. Feed formulations should not be viewed as static recipes; feed ingredient prices and availability change, often on a seasonal basis, with some feed ingredients becoming available and relatively cheap at certain times of the year, and others becoming less common and more expensive. Feed formulators need to keep abreast of changes in ingredient supply and costs and alter their formulations accordingly, whilst still maintaining necessary compositions and energy requirements. Finally, good quality feeds are produced using good quality ingredients in which the nutrients are highly digestible and are available to the fish. Where possible fresh, high-quality feed ingredients should be used.

4.5 Aquafeed manufacturing: feed types and feed production

Well-made extruded feeds offer the greatest potential to support optimal fish growth. Provided the price remains affordable, these feeds are generally preferable to other forms of feed. They should be more efficient and more nutritious than pellet feeds produced using other means (e.g. standard compacted feeds or farm-made feeds), as well as being convenient for the farmer to buy and use. This view is clearly supported by developing aquaculture areas, where farmers switch from farm-made feeds to commercially extruded suppliers once supply becomes reliable.

Pellet feeds can be processed into a number of different products, including sinking and floating forms. Which one to use is dependent on the feeding behaviour of the species being cultured. Floating or extruded pellets are generally recommended for Nile tilapia and milkfish. Although these feeds are more expensive, they allow for observation during feeding time. It is critical for farmers to take the time to watch their animals feed and to share this information with feed producers to ensure the correct form of feed is used. Some species of fish and prawns, for example, are bottom feeders and sinking pellets should be used under these circumstances.

Floating feeds are commonly used in the production of finfish in order to monitor feeding behaviour. Floating feed has the advantage in that the farmer knows when the fish have started feeding and when they have stopped feeding, and they can therefore evaluate the overall feeding response. Uneaten pellets can also be easily netted out of the water, so they are not wasted which increases costs and potentially damages the environment. Some fish species do prefer to feed in mid-water, but they can easily be trained to feed wherever the food is, even at the surface. Floating feeds can only be produced by extrusion and usually cost more. It is therefore up to the farmer to decide if a floating feed is worth the added expense by evaluating fish performance, feed conversion and evaluating the overall cost-benefit of its use.

When using sinking feeds the feeding behaviour is more difficult to monitor. The fine mesh trays placed on the bottom of the cage or pond in the feeding area can be inspected during feeding to measure and monitor the amount of any uneaten feed. Semi-floating or slow-sinking feeds can be given to finfish that are shy feeders, or for fish that do not feed at the surface, which is particularly useful in species like grouper.

The general process of feed production includes grinding and mixing of the raw materials, which are then cooked using heat and forced under pressure from the machine, to produce pellets of a specific size and texture. Pellets are then dried and bagged. There are two main ways to make good quality pellets – pellet mills and extrusion technology.

Pellet mills or a pellet press, is a machine that typically involves a period of controlled cooking using steam as the cooking medium, followed by forcing the material through a die to create pellets. In some designs for small feed mills, water is added as opposed to steam, resulting in less cooking. A dry mix of raw materials is added into a unit called a conditioner. The mix has steam added to it, consisting mainly of vapour (>97 percent vapour) to cook the materials, rather than adding moisture. A screw works the mix and steam through the conditioner, with more steam added if required. The temperature in the conditioner should be 70 to 90°C. The mixture of steam and heat cooks the starches in the mix, gelatinizing them and causing them to bind together. The screw then forces the cooked mixture into the pelletizer, where the mixture is pushed out of small die holes, carefully sized and positioned to ensure that each pellet is the same size and shape. Friction across the surface of the die increases the temperature a few degrees, creating the final cook. Such pellets have a relatively high density and will sink in water.

Extrusion technology is used to manufacture floating pellets, although sinking pellets can also be produced using this method. Extrusion allows the feed mixture to undergo expansion at the end of the process, which decreases the pellet density below water density, which means the pellet floats. The mix of raw materials has hot water added to it in a unit called a conditioner, which starts the cooking process. The mix is forced through a die at high pressure, set at temperatures ranging from 110 to 120°C and after forcing, the mix suddenly comes into contact with air at ambient pressure and temperature. The change in pressure causes the starches in the mix to expand, which dramatically reduces the density of the pellet, which is then cut from the die by a knife. Maintaining control over the level of expansion results in the specific pellet density, and how well the dried pellet will float or how slowly it will sink. The extra cooking achieved in the extrusion process tends to make the mix more digestible for the fish, which increases the overall nutritional value of the feed.

4.6 Feed quality

There are several factors that affect quality of the feed and its effect on fish growth, including:

Pellet composition - the nutritional requirements, growth stage, feeding habit and behaviour of individual species should be taken into consideration when selecting a pellet feed of suitable nutritional value, with appropriate pellet size and density.

Pellet size – When fish are fed they prefer a specific pellet size related to the size of the fish and their mouth gape and ability to swallow the feed. The pellet feed should therefore be of appropriate size for the size of the animal being cultured. Pellets come in various sizes, with smaller pellets for fry, increasing in size for fingerlings, juvenile animals and adult fish. Pellet size used should be increased with animal growth.

Pellet integrity – It is important that the pellets remain whole and are not broken to produce small grains of feed called "fines". Under standard production scenarios, fines are less of an issue when using extruded feeds because the starch gelatinization process results in good binding and the production of a robust pellet. In contrast, feeds from pellet machines tend to be more brittle than extruded feeds, and if poorly handled during transport and storage, may become broken. Whole pellets are more likely to be eaten by the fish, so fines, or small pieces of broken pellets, significantly reduces the likelihood that they will be eaten by the fish, and are easily dispersed in the water column increasing environmental load. This results in higher FCRs and feed use and increased economic losses to the farmers. All feed bags will contain a certain level of unavoidable fines, but as a general rule, fines should not exceed 5 percent of the feed material in the bag and delivered to fish.

Moisture - The target moisture content in feed after cooling and drying is normally 10 to 12 percent by weight. Moisture is needed to make the pellet palatable to the fish and feed should not, therefore, be over-dried, but moisture should not be so high that there is a risk of mould developing in the feed. When the moisture content is 10 to 12 percent, it is safe to bag and seal for storage.

Pellet palatability - The palatability of the feed is very important in prepared diets. Feeds can be nutritionally complete, but if the cultured animal will not ingest the pellets, then feed is wasted increasing farmer costs and will result in deteriorations in water and environmental quality. Feed palatability depends on the ingredients used in the feed, their quality, and on the chemical, nutritional and physical characteristics of raw materials and the produced feed, which can be influenced during the processing and manufacture of the feed. Feed should smell like the natural feed of the fish being cultured; thus feed for carnivorous species should have the aroma of fresh fish and feed for omnivorous species should have a grassy or wheat bran aroma.

Organoleptic qualities of feed - Fish have a complex behaviour when feeding, which generally involves searching for and locating feed, being attracted to eat it and "attacking" the feed to capture it, ingesting it, followed by processes of digestion (removing nutrients and energy needed) and evacuation (e.g. production of faeces). The ability of fish to detect and ingest feed can be affected by its appearance such as color (e.g. contrast), texture (e.g. hardness), flavor (odour) and feed density (e.g. sinking rate), collectively called organoleptic properties.

Appearance: - the fish must be able to detect the feed according to the color of the feed. Feed coloration can be influenced by substances that are added in trace amounts to a diet or feed mixture to facilitate its ingestion (through improved visibility of feed particles) or to impart a desired coloration within the flesh of the cultured fish, if required. The feed color preferences may be expected to differ depending upon environmental setting, tank color and light intensity.

Texture: - the texture of feed affects palatability, with softer feed often proving to be more acceptable to the fish. The texture of feed depends on how feeds have been manufactured and their moisture content.

Flavour: - the flavor and odour of feed are related to sensory (olfactory) attributes of the fish and can affect the palatability of the feed. Feeds that have a high level of fishmeal or fish oil have a have a strong odour in water, for example. Spoiled feeds taste bitter, sour or rancid. Therefore, it is important to buy fresh feed, store them properly in cool and dry stores, and use before the expiry date, so the feed is in a good condition when added to the tank, pond or cage.

Density: - sinking rate affects the time available that a fish has to locate and capture the food. If the fish being grown typically feed from the water column then the sinking rate needs to be sufficiently slow to allows enough time for this to happen before the feed settles on the tank or pond bottom where it may remain uneaten, or falls through the net in cages which means it is no longer available.

Moulds – Moulds can grow on crops in the field or develop during post-harvest storage - particularly if pellets were not properly dried during production, or if the feed is exposed to water or were damp during transport and storage. Moulds reduce the nutritive properties of the materials in the feed, which may make then less palatable to the fish, and, depending on the type of mould, can result in the release of dangerous mycotoxins in the feed, which may kill fish when eaten.

Packaging – The supplier should provide feed in bags that are sealed and of appropriate size to ensure that they can be stacked, but not damage the pellet integrity. The bag should have a label on the outside that lists the basic proximate composition data for the feed so the farmer can check the nutritional composition and energy content of the feed, and it should contain a production date and a sell by date to enable the farmer to ensure it is fresh to use.

4.7 Feed storage

No actions can be taken to improve the feed once it has been delivered to site. What is done by the farmer with on-farm storage, however, can substantially affect whether a feed can remain acceptable for use over the intended shelf life of the product. A practical knowledge of the most important factors that contribute to feed degradation and attention to maintaining proper storage conditions can significantly minimize losses of nutritional value and vitamin potency, reduce mould growth, lower fat rancidity and reduce infestation by insects and rodents (ADCP, 1987).

Manufactured feeds are highly perishable products with a finite shelf life and should be stored accordingly. The potency of most vitamins contained in formulated feeds declines during storage. This is because many of these organic compounds are highly reactive and unstable. Under certain conditions, they can be easily denatured by heat, oxygen, moisture and ultraviolet light.

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.

Feed quality will rapidly deteriorate if feed is not packed well and properly stored. Feeds should be stored in a cool, dry facility. In general, two types of storage facilities are required on a farm:

A building/shed is used for storing large quantities of bagged feeds. A smaller storage facility (i.e., shed, silo, bins, or similar) is kept alongside the fish production pond or fish cage. This is particularly important for farmers operating large farms with large production ponds, where feeds may remain outside for more than one day.

4.7.1 Pest control

The presence of insects and rodents in feed storage areas can often be overlooked but cause serious problems. These pests not only consume feed but also cause additional and sometimes greater feed losses through packaging damage and the creation of environmental conditions that promote mould growth (e.g. urine on the feed). They can also serve as vectors for transmission of disease to humans.

Insects: Insect infestation can be a very serious problem in feeds stored over a prolonged period. An actively reproducing population of insects can quickly consume significant amounts of food and deteriorate the physical quality of the remaining feed.

Grain weevils and warehouse beetles can bore through feed sacks, providing a port of entry for other insects such as flies which lay eggs to produce larvae that will consume the feed. If present in sufficient numbers in bulk feed, infesting species can induce localized heating, moisture migration and mould development. External infesting species, such as the Indian meal moths and flour beetles, which prefer to obtain nourishment from processed grain products, along with carpet beetles that feed on meat meal, feather meal and other ingredients of animal origin are frequently the cause of problems in complete feeds.

Appropriate storage is a primary method to reduce insect infestation, but if infestation does occur it would be necessary to employ several methods of control in a concerted manner in order to effectively reduce it.

Rodents: Populations of rats and mice that become established in storage areas can consume significant quantities of feed. However, the losses that they cause through packaging damage and the resultant feed spillage and exposure to insects and conditions suitable for the development of mould are probably far greater. Rodents also pose a substantial health hazard to workers handling the feed.

The basis for a rodent control programme should be good housekeeping, both inside the feed store as well as around the exterior perimeter, including not leaving open bags of feed, clearing up feed spills and so on. Combining this with the maintenance of physical barriers that limit entry and aggressive trapping minimize feed losses caused by rodents.

Use of poisons should be a last resort to control rodent populations in feed storage areas. Poisons can cause an increased risk of feed cross-contamination and are dangerous in contact for humans or pets, or other non-target organisms such as birds.

4.7.2 Good feed storage practice

Good feed storage practice requires several activities and conditions to maintain control over the quality of feed (Isyagi *et al.*, 2009). Namely;

- Feed should be stored in an appropriate shed or building that is dry and well ventilated, should be kept out of the sun and off the ground to prevent mould and other contaminants from forming. Preferably, use white, wooden buildings with reflective metal roofs for storing feed.
- Do not stack bags of feed directly against a wall or on a concrete floor, which are cold and can develop moisture in warm environments. Stack feed bags on wooden planks or pallets, and these should be placed a minimum of 10 cm away from walls to prevent moisture coming in to contact with the bags.
- Install pest control systems, and ensure they are checked regularly.
- Ensure that feed is used within the manufacture's recommended shelf life period. Feed degradation can include loss of nutrients and vitamins, especially vitamin C,

and an increase in mould and other factors that reduce the quality of the feed.

- Discard of weather damaged, mouldy, contaminated or old feed. Do not leave lying around, which will increase the pest infestation potential.
- Do not stack bags or pallets of bags too high, as this is liable to crush feed at the bottom and increase the level of fines.
- Use feed bins where appropriate.
- Do not leave feed uncovered or exposed overnight.
- Clear up feed spillages.
- Separate feed storage areas from other supplies including fertilizers and pesticides, to reduce cross-contamination potential.
- Feed stores should be locked to prevent theft or malicious damage.
- Avoid placing feed stores in areas prone to flooding.
- Use the oldest feed in storage first. "First in, first out" policy in feed handling. This will require rotation of feed when new feed deliveries are made, so the older feed remains accessible first.
- Keep good stock control by recording quantities delivered and delivery dates, quantities present at satellite feed stores (e.g. next to ponds, on cages), and quantities used in feeding fish. Stock control management should be a daily activity.

4.8 Feed handling

Feed handling is important to maintain the condition of the feed and requires careful handling, as follows:

- Transportation and manual handling of feed is important to retain the integrity of the feed and to ensure that it is in good condition when delivered to the fish.
- Feed is heavy, so take care when handling to avoid undue injury, especially when unloading vehicles above head height (Figure 4).
- During transportation, minimize handling to avoid physical damage to pellets. Do not stack pellets too high on vehicles, which can crush lower bags.
- Ensure careful handling during feed delivery, storage and feeding to minimize damage to the pellet and the creation of fine particles of feed (fines).
- During transportation and handling, protect the feed from moisture, heat and direct sunlight. Heat and sunlight directly destroy feed nutrients like vitamins.
- Do not use pesticides or other toxic materials near the feeds.
- All used feed bags, spoiled feed, packaging materials must be collected and disposed of properly. Recycling (e.g. bags, pallets) is strongly encouraged.
- If feeding during the rain and the feed gets wet, feed all that wet feed that day or as soon as possible. Do not store wet feed, as this increases the potential for mould to develop and for pests to invade.

4.9 Feeding systems

A good feeding system is of a combination of using high quality feeds, and using good feed management practices in terms of feeding frequency and timing of feeding. Farmers can thus select the most appropriate methods and systems for their circumstances, that may include:

- manual, semi-automated or automated feeding;
- feeding by continuous broadcasting or use of submersible feeding trays;
- monitoring feed intake and fish growth/survival by periodic netting of fish for weighing and measurement and/or by visual inspection of feeding trays;
- feeding to match appetite by visual observation or by using a fixed feeding regime (such as a feed table); and
- adjusting the frequency and timing of feed application as the fish grow and according to fish appetite.

FIGURE 4
Feed delivery to farm conducting tilapia farmers' trials in the Philippines

Courtesy of FAO/Angelito Gonzal

In the past feeding was often conducted through trial and error, where the lack of experience may have resulted in over-feeding, under-feeding or uncontrolled feeding, often dictated by the size of the fish farm and production unit and the exerpience of the farm workers. It is now generally recognized that feeding can be more controlled and should be done according to fish appetite so that all feed is consumed to minimize feed wastage from uneaten feed and nutrient loss through leaching from uneaten pellets.

Use of a feeding tray in the application of feed and as a monitoring system in pond production systems is now common, for example.

4.9.1 Feeding methods

Fish can be fed by hand, by using semi-automated demand feeders or using automatic feeders. Hand feeding allows the farm worker to visually assess feeding behavior, but only allow the dispersal of small quantities of feed at a time, over a relatively small area. Demand feeders do not require electric supply but are semi-automated in the sense that when fish push a pendulum in the water feed is delivered, and allows fish to eat when they are hungry and/or they perceive environmental conditions are optimum. Examples of automatic feeders include belt feeders, which work on wind-up springs, or electric vibrating feeders, which can be programmed according to a specific timetable for feeding. More sophisticated automated systems are also available, for example to automatically count and assess pellets falling through the water column in cage aquaculture.

Demand and automatic feeders save time, labour and money. Large fish farms use trucks to transport feed to ponds and feed can be distributed by using machines such as air-blowers to broadcast the feed over the pond or cage surface. What is critical is that, whatever method is used, visual inspection of stock by farm workers still needs to be undertaken during feeding to assess appetite and feeding behavior, to adjust feeding accordingly if needed, and more generally to learn about fish behaviour during feeding.

The choice of any of the feeding methods outlined below comes down to personal experience, availability of resources, including money to invest and availability of electricity to run specific systems.

Hand feeding is a method in which the farmer physically adds feed with hands or using a scoop that can be used for both pond and cage farming. Feeding by hand is the most labour intensive method but allows the farmer to closely monitor feeding behaviour and to have more control over feed inputs, simply stopping feeding when fish are observed to no longer be feeding or when environmental conditions change. With careful observation no excess feed is added and the amount of feed added is easily controlled and monitored. This type of feeding is ideal for small facilities and for operator observation and management of stressed or diseased fish.

The feed can be offered to fish in ponds by one of several ways, including:

- By continuous slow broadcasting (with floating and sinking pellets) in which feed is added over a long period, that may last one to three hours, one or two times per day. Slow continuous broadcasting of pellets is the traditional way for administering pellets to milkfish in cages in the Philippines.
- Feeding relatively large portions at specific times over a relatively short duration of 20 to 30 minutes (up to one hour), such as applying feeding tables or the USSEC 90 percent satiation method.

It is important in hand feeding not to distribute the feed over the same place each time feed is added. Distributing feed randomly within a pond or cage reduces the likelihood of dominant and territorial behavior in the fish.

Feed trays are a derivation of hand feeding in ponds, which uses trays as a monitoring mechanism. Feed is broadcast over the pond with some feed being placed on a number of trays located in various areas of the pond. By monitoring the feeding trays, adjustments of feeding rates by hand can be made. If after a certain period of time the feed on the tray is consumed it can be replenished, and if still consumed quickly fish are hungry and feeding rates may be increased. Conversely if there is still feed left on the tray after a period, fish are not so hungry and feeding levels can be decreased or stopped.

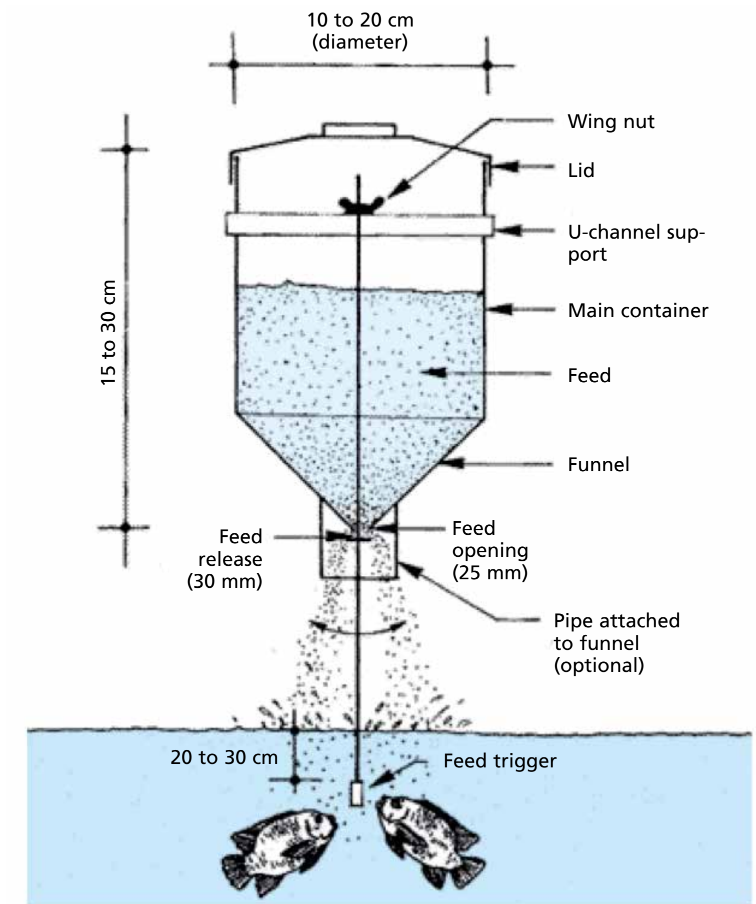
The advantages of using feeding trays for monitoring and/or administering feed to the fish include that they:

- reduce FCR by eliminating over- and underfeeding;
- reduce feed usage and wastage due to overfeeding;
- prevent pond bottom deterioration and water quality deterioration due to excess feed accumulation;
- facilitate adjustment of feeding rates to fish appetite, fish developmental stage, and environmental conditions, including for example shrimp moulting activity;
- serve as a useful tool for estimating fish survival and monitoring fish health;
- help provide controlled administration of medicated feeds; and
- offset increased labour costs by reducing FCR and improving pond conditions—providing increased economic benefit for the farmer

Feeding trays or hanging bags 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 pond dynamics. In general, more feeding trays (or bags) should be positioned in areas where water quality is best and fewer elsewhere.

Observation by the farmer and the use of feeding trays are examples of **interactive feedback systems**. The supply of feed is adjusted by monitoring of uneaten feed and/or evaluation of fish feeding activity. Interactive feedback systems can be more sophisticated and expensive using specially designed echo-sounders to detect uneaten feed, or simple and cheap using trays placed under the feeding area that can be used to monitor uneaten pellets as they sink through the water column and collect on the tray. The feedback received following detection of feed waste, or reduced feeding activity is usually used to introduce an abrupt stop to feed delivery, but can also be used to gradually decrease the rate of feed delivery.

FIGURE 5
Diagrammatic representation of a pendulum feeder



Source: www.fao.org/fishery/static/FAO_Training/FAO_Training/General/x6709e/x6709e10.htm

The use of feeder blowers or pneumatic feeders are an extension of hand feeding, which uses the power of compressed air to push feed through a pipe, generally held by the farmer, to force feed into the culture system under pressure. They have the advantage of being able to push feed over a larger area and a further distance than hand spreading, and can be convenient for distributing feed quickly from a central source. However, because it is forced under pressure, the pellet velocity can cause fracturing in the pellets, and especially when the feed comes in contact with a hard surface, leading to increased quantities of fine particles entering the water that can rapidly degrade water quality.

Demand feeders (example in Figure 5) are a form of semi-automated feeding that are suspended above a fish tank/pond/cages allowing fish to trigger the release of a small pre-determined amount of feed by striking a hanging probe or pendulum extending into the water. Fish thus dictate the timing of feed delivery. The portions delivered per touch are relatively small and fish continue to hit the pendulum until they are satiated. This can minimize feed wastage, for example, if used well. To some extent demand feeders have the advantage over hand feeding in that they take into consideration the behavioural rhythms of the farmed species, including satiation point and return of appetite. However, fish can develop social hierarchies and agonistic behaviour around the pendulum, that can result in large variations in size of the stock, with some fish feeding well, and other fish not feeding enough, and is one of the problems of using demand feeders in large ponds that are not easily monitored. They are useful for small ponds and tanks.

Feed rings (Figure 6) are enclosures that are held or float at the water surface, and are used in conjunction with floating feeds and prevent or at least reduce feed loss from hapas or cages. Feed is added within the feed ring only and fish can come up from underneath to feed at the water's surface. Feed rings are also used in pond culture to stop the dispersion of feed by wind, for training fry to consume commercial feed, or to provide medicated feeds for treatment of diseases where more control is needed. Given the relatively smaller area of a feed ring, the farmer is easily able to observe the amount of floating feed that is uneaten, also reducing the amount of feed wastage.

FIGURE 6
Example of feeding rings in a fish cage

Source: Nguyen *et al.* (2015).

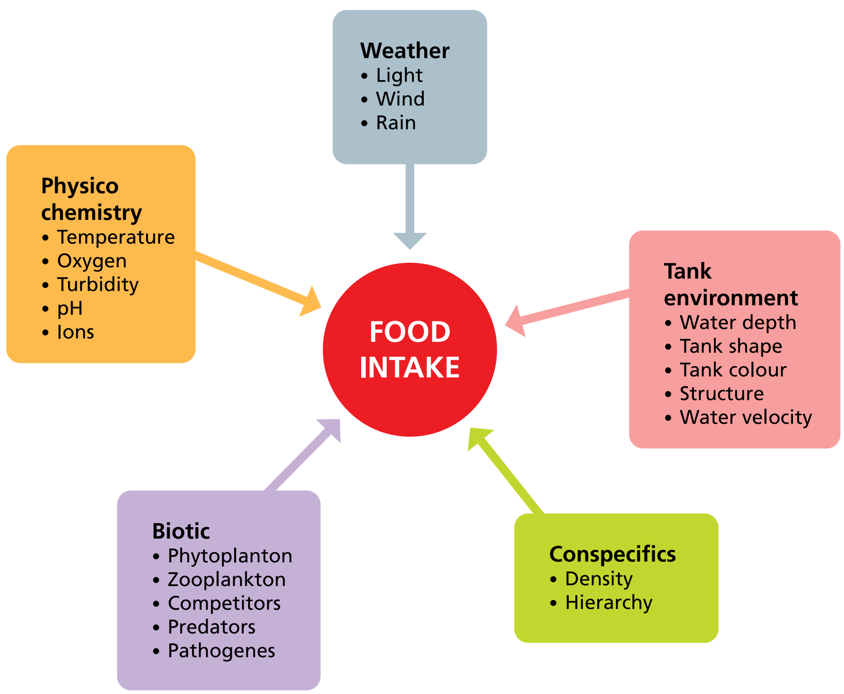
Automatic feeders can be a cost-effective means to deliver feed, especially in large scale production systems by allowing large volumes of feed to be fed efficiently (either floating or sinking pellets), with savings by reducing the labour requirement. The choice and complexity of automated system required is dependent on the species being farmed, size of the fish, design of the culture system and the investment funding available. Automated systems generally require the largest initial investment.

The use of computer controlled automated feeders can be particularly useful for fish species where feeding hierarchies develop, where the use of submerged video or infrared sensors can be deployed to monitor consumption and to ensure that all the fish are fed to satiation. Automated systems tend to use a centralized hopper from which feed is distributed. There are a number of means to distribute feed to the required destination including use of tubes, along with belts (belt feeders) or vibrating belts (electric vibrating feeders), the amount of feed delivered, and timing of feed delivery is made by computer control, pre-programmed by farm operatives. The use of automated systems requires a more sophisticated understanding of feeding behaviour, to then be able to convert that in to pre-programming of the feeding software.

4.10 Appetite and feeding

Feeding by fish is dependent upon their sensory capacities to locate food, ability to capture, handle and ingest food items, and their physiological and biochemical capacities to digest and transform the ingested nutrients into added energy and weight (de la Higuera, 2001). A fish's willingness to eat is inherently driven by appetite, and in an aquaculture context dependent on the quality and qualities of the feed being presented. Feeding ability, level of feeding and digestion are, however, also influenced by several physio-chemical and biotic factors (Figure 7). Some factors, such as light level, may impact on a single step in the feeding process (e.g. locating feed), whereas others, such as temperature, are known to influence a number of processes (Kestemont and Baras, 2001).

FIGURE 7
Schematic diagramme of some factors affecting fish appetite



Source: Kestemont and Baras (2001).

Fish do necessarily feed at the same time each day (depending on day length, for example) and do not feed at the same rate every day. For most farmed species, feed intake has been found to vary primarily with water temperature, day-length, light intensity, farm activity, oxygen level, presence of predators and fish size.

The following summarizes some of the ways in which some of the physical, chemical and biological factors impact appetite and feeding level;

- **Light:** Many fish in fed aquaculture are visual feeders, needing daylight to be able to see the feed to capture it. Light level is variable throughout the day and can change over time; changes can occur often and rapidly. Sunlight is the main natural source of light, while moonlight is a secondary source of light for some fish. In sophisticated systems light of a specific irradiance can be used under water to simulate daylight. Too much light can also stress the fish. If light is low, such as during low cloud periods, fish cannot catch the feed. Having good light also supports visual observation of fish behaviour by the fish farmer.

- **Photoperiod** (day length): The day length (and alternation from day to night) is one of the most important factors affecting feeding. Longer (or increasing) photoperiods stimulates feeding through increased activity and allows the farmer to feed earlier and later into the evening, whereas shorter (or decreasing) photoperiods leads to a reduction in activity and feeding, and a shorter period available in which the feed needs to be added to the system.
- **Temperature:** Temperature of water affects fish metabolic processes, with increases affecting metabolic rate, oxygen consumption and energy consumption, and therefore affects the feeding requirements to maintain growth. Up to a fish's specific physiological limits (note: all fish will die above the incipient lethal level, and feeding and growth are reduced above the upper optimum temperature) fish in warmer water became more active, their rates of digestion is increased and they need to take on more feed to compensate. As temperature decreases, the metabolic rate and all other processes decrease proportionately. Therefore, the feeding regime must be adjusted according to prevailing temperature regime. This is taken account of in feeding tables, which adjust the percentage (of body weight) of feed to be added to ponds or cages with temperature. Temperature of the water should, where possible, be measured every day, particularly before feeding times, and if necessary, based also on the amount of fish present and their average weight, be adjusted accordingly. It is also important to know the temperature tolerances of species being grown, to ensure they can tolerate the natural water conditions and changes in temperature with season. Generally speaking Nile tilapia and milkfish will feed normally at temperatures ranging between 18 °C and 32 °C; outside of this range fish lose appetite and will grow more slowly.
- **pH of water:** Under most circumstances the pH of freshwater and seawater is stable. pH is measured on a logarithmic scale, so small changes can represent large changes in water conditions, and can affect the fishes' palatably of feed. Fish tolerance to changes in pH are affected by their development phase, and some fish species are able to tolerate more acid or alkaline conditions for short periods without affecting appetite and feeding.
- **Oxygen:** Oxygen (O_2) is necessary for respiration, which drives all other internal physiological processes. Fish extract oxygen from the water, so maintaining good oxygenation in water is critical to good fish health, and to support activity, appetite and feeding. Oxygen concentrations are liable to change throughout the day depending on the level of light and amount of photosynthesis taking place (which produces oxygen) during daylight, and the general respiration of all living things in the water at night, which consume oxygen, including fish. Oxygen concentration will therefore generally be lower first thing in the morning, for example, and increase during the day. However, the level of oxygen consumed by fish increases during feeding and through digestion after feeding so there will be peaks and troughs in oxygen concentration throughout the day, depending on when feeding takes place. The maximum oxygen holding capacity of water varies with water temperature; and at higher temperatures is lower, and has a high capacity to hold oxygen at colder temperatures. Ideally the oxygen concentration of water should be measured daily. However, if temperature is measured instead there are a number of conversion tables available via webpages, which will show the likely oxygen concentration for that temperature, as a simple way to estimate it.

Oxygen concentration also varies with salinity, with seawater able to hold more oxygen that freshwater. Fish can tolerate a certain level of changes in oxygen concentration, but will become stressed and diseased if concentrations remain low for extended periods, and will eventually die. Stressed and unhealthy fish will have a lower appetite and consume less food. In systems that have persistent low oxygen in the water column, levels of oxygen can be stimulated manually by adding paddle wheels. Paddle wheels create turbulence at the water surface and mix water with air to generate increase oxygen levels in the water. This happens very slowly naturally, but paddle wheels and others similar actions accelerate this natural process to create dissolved oxygen more quickly. In feeding, it is very important not to over-feed the fish. Any waste material that is lost to the lake or pond bottom or marine sediments will be broken down by bacteria, which increases the level of oxygen consumption massively, and will reduce overall water quality. When the oxygen level reduces feeding should be undertaken with caution, so as not to make the situation worse.

- **Other water quality parameters:** Fish are also affected by other water quality parameters, such as ammonia concentration, particularly in ponds where water flows may be low or non-existent. Ammonia is produced naturally in fish urine and through gill respiration but is converted to ammonium by bacteria in the water column relatively quickly, provided there is sufficient oxygen in the water for example. It is possible, however that ammonia can build up within ponds. Ammonia is toxic to fish (ammonium is not) and fish respond it (and other potentially harmful substances), by avoidance and moving away from the source, where possible. Even at low concentrations, the presence of ammonia may impact appetite and feeding behaviour. Provided other water conditions are good (e.g. oxygen concentration) ammonia will not generally able to build up, and there should be no ill-effects.
- **Handling:** Routine operations on fish farms are necessary, such a handling of fish (e.g. when measured for weight and length during the growing cycle), cleaning of nets or tanks, and crowding of fish to undertake a disease treatment. Such handling will increase the stress in fish, which lowers their appetite and will affect feeding in fish. Direct disturbances, such as weighing or transporting fish can reduce feed intake for several hours or days after the stress has been removed. During this recovery period fish should remain unfed, or fed slowly, to ensure that there is no high feed waste generated.
- **Human activity:** Even temporary disturbances such a movement or walking near to cages ponds and tanks may affect fish, as they move to avoid the activity. Generally, however, fish become accustomed to such activity and quickly resume feeding after these events have occurred.
- **Presence of predators:** Fish have a variety of behaviours or tactics to avoid, deter or evade predators. The risk of predation may be higher when a fish is foraging. Therefore, most fish will naturally reduce or avoid feeding in the presence of predators. Attempts should be made to remove the predator threat, where possible, or to limit feeding until the threat is removed.
- **Stocking density:** A high stocking density is often considered to be a stressor with detrimental effects on feeding, growth and a range of physiological responses. It has been shown for some species, under certain circumstances, that stocking fish at high density may lead to increased survival, better growth and reduced size heterogeneity (size variation) within the population (e.g. in tanks). High stocking densities can, however, increase the risk of harm and disease, can affect fish welfare and reduce appetite and feeding. In general, research is required to identify the most appropriate stocking density for the method of production used, for the species being grown.
- **Time of feeding:** Each species has an endogenous feeding rhythm controlled by the central nervous system and the entraining endocrine factors, governed

by environmental cues to feed, especially photoperiod. Certain fish may feed all day and other have specific times of day when they would forage and feed naturally. The aim of feeding in aquaculture is to mimic these natural feeding times when possible. Nile tilapia displays a predominantly diurnal rhythm of feeding activity although they may sometimes feed during the night. Some species, such as European seabass and common carp, are able to phase shift their rhythm of feeding from nocturnal to diurnal and vice versa, showing some plasticity in behaviour and adaptation to changing conditions.

- **Wind and rain:** Storms, strong winds and heavy rain can have short-term but very pronounced effects upon feed intake. This may be most pronounced in saline ponds, where rainwater can reduce the salinity, change the temperature and change the pH of the water column. Such changes take place quickly, and fish are therefore unable to respond in the short term. Winds can disturb the water surface, which may prompt fish to seek shelter lower in the water column, on the bottom in ponds. Under these circumstances feeding is reduced. After heavy rains, farmers should take care not to overfeed fish, until the system has recovered from the short-term shock caused
- **Waves and water speed:** Waves and water currents may not impact appetite specifically, but will affect the ability of the farmer to feed fish. High waves may limit access to cages for feeding. Strong currents will increase the energy used by fish, simply to swim against the prevailing current, and the farmer may be a tempted to add more food to compensate. However, waves and water currents or a combination of both, is likely to push feed very quickly out of the cages, and reduce the ability of the fish to locate and capture that food. The amount of feed added to cages, and feeding behaviour, should be monitored closely to ensure no excess feed is wasted.
- **Disease:** Disease, in addition to having pathological effects, will stress fish. The combination of poor health and stress results in loss of appetite and much lower feeding than under normal circumstances. Disease may not necessarily affect all fish in a pond on cage, so some level of feeding may still be required. If disease breaks out, treatment will be required to resolve the specific disease; and during the treatment period, appetite will reduce and feeding should be slowed, or stopped for a short period, to allow the fish to respond to the treatment.

Overall, there are number of physical, chemical and biotic factors that affect a fishes' appetite and response to feeding. Each species has a preferred feed pattern that varies according to size and season. It is therefore fundamentally important that these preferred periods of feed intake are determined, and appropriate amounts of feed are delivered in a manner that allows satiation of all the fish.

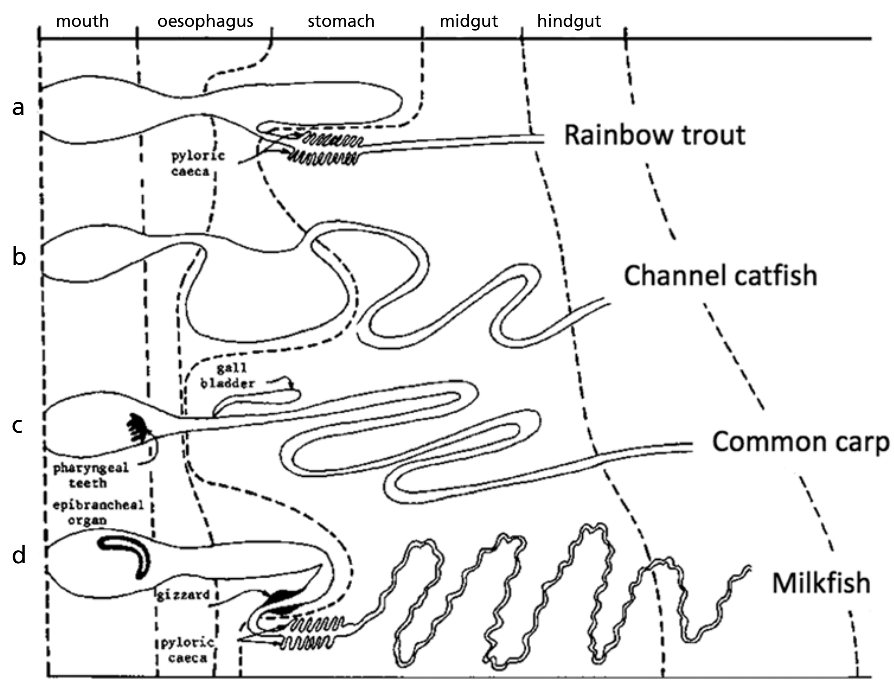
In most cases the effect on feeding is temporary, until circumstances return to normal. If feeding behaviour is affected for more than a few days or mortalities increase, further investigations should be carried out to investigate the cause, testing for suspected disease and the feeding schedule should be altered and closely monitored until that investigation is complete.

4.11 Feeding frequency and ration size

Feeding frequency is the number of times fish in a pond or cage are fed per day. It is critical to know the species being grown and to optimize the frequency, given it affects the efficiency of feed utilization, which impacts the amount of food used to grow the fish (i.e. the FCR). It also affects aggression and feeding hierarchy, so it is important to establish the optimal frequency of feeding to attain the best possible (optimal) FCR and uniform size of fish.

The amount of feed that can be consumed in one time is related to stomach capacity, and the frequency of feeding is related to the time taken for food to be digested in the stomach, and in the mid- and hindgut before the excess is evacuated as waste. Different species of fish have different stomach and gut anatomy (Figure 8) that affect feeding frequency. Piscivorous fish tend to have larger stomachs so can consume a larger ration at one time, and relatively short mid- and hindgut, so food is passed through relatively quickly; whereas omnivorous/herbivorous species tend to have small stomach but a long mid- and hingut, so need to feed continuously, but it takes a long time to pass through.

FIGURE 8
Diagrammatic representation of the digestive anatomy of different types of fish



a. Rainbow trout (carnivore).
b. Catfish (omnivore, with an emphasis on animal food sources).
c. Carp (omnivore, with an emphasis on plant food sources).
d. Milkfish (microphagous planktivore).

Source: ADCP (1980).

The return of appetite depends on stomach fullness, and when the previous meal has been partly digested and food passed from the stomach to the mid- and hindgut, appetite slowly returns and fish can be fed again. The speed with which food is digested depends on water temperature and is faster at higher temperatures, and on body size, with smaller fish needing to be fed more often than larger fish. So, feeding frequency should change as the fish grow.

The following should be considered when deciding how frequently fish should be fed each day:

- It is expensive in terms of labour to feed continuously, or a large number (five or more) of times per day.
- Hatchery and fry production will require more frequent feeding because of the small fish size.
- In grow-out systems there may be an initial period, when fry is first delivered, the frequency of feeding will need to be higher, given fish will have been used to being

fed four or five times per day in the hatchery/nursery, but generally in grow-out ponds and cage systems, feeding 2 or 3 times a day is adequate.

- Juvenile fish need to be fed more frequently than adult fish because they have higher metabolic rates and their stomachs are too small to hold all the feed they require for a day.
- Larger fish (above 400 g) can be fed once per day because at this size the stomach can hold enough food to satisfy their energy requirements for the day. At this stage, feeding all the fish at the same time once a day results into more uniform growth rates.
- Correct feeding frequencies reduce starvation and result into more uniform sizes of fish at harvest. The feed given at a meal should generally be consumed within the first 15 to 20 minutes, depending on the size of pond or cage and ability to load sufficient food for the initial feeding frenzy. After this the feeding rate can be slowed, until the farmer is satisfied that no further feeding is taking place, when feeding can be stopped. If feeding takes longer than 15 to 20 minutes, provided there is no other obvious reason why the fish should not be eating, the rate of application of feed should be increased to help satisfy the demand in the fish. Equally if feed is shorter than this the rate of application of feed should be slowed to match the amount consumed.
- The rate at which feed is consumed can be best observed with floating pellets, but is possible, although more difficult to determine, with sinking feed.

Feeding little-and-often: Traditionally, fish have been provided with feed at a relatively low intensity over prolonged periods. The choice of a 'little-and-often' feeding regime has partly been the result of technical limitations in some of the feeding systems used in farming operations, and partly because many farmers have thought that intense feeding was associated with high feed waste. Feeding milkfish and Nile tilapia little and often does not follow the fishes' natural feeding habits, and should not be done for these species.

Distinct feeds: There is evidence that larger fish of several species feed intensively in distinct periods or 'meals'. One to four meals per day may be sufficient for most fish to achieve maximum feed intake and growth. The ideal number of meals is dependent on stomach capacity and evacuation rate, on the pellet size being fed, and on water temperature. In general, larger fish can be fed one to two meals per day, whereas smaller fish should be provided with three to four meals per day. The inclusion of longer non-feeding periods may be beneficial for the growth of fish since repeated feeding throughout long periods of the day increases swimming activity and energy expenditure. Repeated feeding also means fish will not digest meals efficiently, leading to slower growth, and increases the amount of undigested food passing through the stomach and gut system, increasing faecal waste.

As the number of meals is decreased for larger fish, the rate at which feed is supplied (i.e. number of pellets per fish per unit time) generally needs to be increased. This may influence feed waste, because the fish may not be able to capture all the pellets before they float out of the culture system, or to the sediment surface. This means that attempts should be made to adjust rates of feed supply to the feeding rate of the species, and the duration of meals should be adjusted according to the time required for all feeding individuals to become satiated.

Feeding practices are very important in maintaining optimum water quality and in obtaining efficient feed conversion. There are numerous benefits from the efficient application of feeds. Feed is one of the highest expenses for aquaculture farmers, and by feeding correctly feed expenses can be lowered and environmental impacts minimized.

Feeding rhythms: Most fish are active either during the day or at night, but not throughout 24 hours. Species have acquired these behavioural patterns to avoid predators, optimize feeding, dependence on vision for the capture of food, and so on. Thus, in most species, diurnal or nocturnal feeding behaviour has been fixed genetically.

Nile tilapia (Oreochromis niloticus) displays a predominantly diurnal rhythm of feeding activity, although some feeding activity may occur during the night. Salmonids – which are usually considered visual feeders – may feed diurnally with peaks in activity around dawn and dusk. When food is continuously available, most fish feed during a specific phase of the light-dark cycle.

However, for the convenience of feeding in farms, feeds are generally given during daylight. It has been suggested that the optimal feeding time to promote growth might correspond to the species' daily peak of feeding activity.

Feeding frequency: Based on the experience of milkfish and tilapia farmers in the Philippines, the recommended frequency of feeding per day is specified in Table 22.

TABLE 22
Recommended feeding frequency for tilapia and milkfish

Stage	Fish size (g)	Pond system	Cage system
Hatchery Fry	0.2 – 1.4	Natural food Supplemental feed: 2 times per day	4 to 5 times/day
Nursery Fingerling	14 – 10	Natural feed Supplemental feed: 2 times per day	3 to 4 times/day
Grow-out	10 to market size	Supplemental feed: 3 times per day	3 times/day

Time of feeding: Based on the experience of milkfish and tilapia farmers in the Philippines, it is recommended to feed as defined in Table 23.

TABLE 23
Recommended distribution of feed ration into three meals given at different times of day

Type	Morning	Noon	Afternoon
Cage	40% at 0800 hours	30% at 1300 hours	30% at 1600 hours
Pond	20% at 0600 hours	40% at 1200 hours	40% at 1700 hours

Feed pellet size: The size of the fish feed varies for different fish species and according to the age of the fish and size of the mouth (mouth gape). Feeding with pellets that are too small can result in insufficient feeding because more energy is needed to locate the pellets and fish need to eat more pellets to satisfy their needs. On the other hand, feeding with pellets that are too large will, at worst, prevent the fish from being able to grasp pellets so no feeding takes place; or can decrease feeding as fish struggle to grasp pellets, and may also cause choking.

Estimating the correct ration: The correct ration is calculated as the amount of feed to be fed (percent of feed as a function of body weight and temperature). Feed manufacturers usually print feeding charts, tables or advice on bags of feed or publish material on their company website. Feeding charts and tables, underpinned by research, have been developed for many cultured species, and for different sizes of fish within species. Feeding charts present the farmer with suggested feed ration sizes based on percentage body weight of feed to be given per day, itself based on the size of the fish and water temperature. Following established feeding recommendations and making on-site adjustments as needed, will reduce costs.

Many farmers waste feed by overfeeding, not feeding at the right time of day, or not observing feeding behaviour of fish. The behaviour of fish while feeding gives the farmer a good indication of the overall health of the stock.

It is recommended to:

1. Keep a record of the number of fish stocked per pond or cage, count fish mortalities, deducting this from the initial stock added, to keep a running total of the amount of fish present.
2. At initial stocking record the length (mm) and weight (g) of a number of fish (e.g. 50) and retain these records.
3. Use an appropriate feeding chart/table to estimate feed ration per day, based on the initial fish size, and water temperature.
4. Remove a number of fish (e.g. 50) from each pond or cage on a monthly basis and measure for weight (g), recording the information. Return the fish to the same pond or cage. Calculate the average weight of fish in each pond or cage.
5. Calculate the total biomass in the pond or cage (equals number of fish from the running total multiplied by the average weight). Use this new total weight to estimate the feed ration required per day using feed tables.
6. Repeat 4) and 5) and recalculate feed ration size on a monthly basis, based on measurement, and water temperature, and using available feed charts.
7. Select the correct pellet size for the size of fish in the pond or cage. When changing the feed size to a larger pellet size, it is usual to feed a mix of the two feed pellet sizes for a period of up to 10 days. After this time feed the new larger pellet size only. Mixing pellet sizes temporarily will ensure that any fish present in the stock that are below the average weight will gain sufficient nutrition, until they are large enough to consume the new pellet size.

4.12 Feeding response

It is extremely important for farmers to judge feeding response, because:

- It enables the farmer to feed the fish based on their actual needs at each meal. Therefore, the likelihood of overfeeding or underfeeding is reduced to a minimum.
- It enables the farmer to visually assess the number of fish, and their growth on a daily basis without having to physically handle the fish. The only time a farmer can see most of the fish in one mass is during feeding.
- It gives the farmer the chance to monitor water quality and fish condition. When water quality conditions in the pond or cage are poor, or fish are sick (diseased), their first response is to reduce or stop feeding. When fish are fed by response, it becomes easier to detect when they have lost their appetite. Problems can be detected sooner, and remedial measures enacted promptly, before issues gain traction and it becomes too late to put in place effective remedial action.

The fish's feeding response depends on:

- Suitability of the feed, where the feed's size, appearance, smell, texture and taste influence the fish's appetite. The more palatable the feed is, the better the feed response should be.
- Culture (water) environment, where the most important water quality parameters that affect feeding response are water temperature and dissolved oxygen concentration. The warmer the water (within given limits), the more active fish will be and the better their feed consumption will be, keeping FCR to a minimum.
- Other stressors, where pollutants in water, other water quality variables (notably ammonia and pH), handling and social interactions also affect the fish's appetite. When fish are stressed, their appetite drops quickly and the feeding response becomes poor.

The attention paid by the farmer/feed person is extremely important in assessing how much the fish need to be fed at each meal, or throughout the day. In order to make this assessment, the following should be noted by the farmer before and during feeding:

- The weather that day, and whether it is rainy, cold, hot, windy, and so on, with the potential for feeding adjustment made accordingly.
- Condition of the water (water quality) is also important. Consider whether fish are coming to the surface and gulping air, which may indicate low oxygen concentration.
- Take note of any mortality that may indicate a potential disease issue.
- At the initial feed input, how fast the fish moves towards the feed and how this reaction/behaviour compares with previous feedings, to indicate readiness for feeding.
- During feeding whether the fish remain interested in the feed and consume it quickly, which indicates hunger level and the need for feeding.
- Consider what proportion of the fish comes to the feed, and whether the entire stock is feeding normally.
- Towards the end of feeding, are the fish consuming less and more slowly, which indicates they are nearing satiation, and whether less feed should be added, or feeding stopped altogether.

Feed tables are (good) estimates, assuming the fish are fully healthy and water and other environmental conditions are "standard". Simply calculating the feed ration and feeding that amount regardless of the specific circumstances on the farm can result in feed wastage, higher FCRs and poorer water quality. The farmer must always observe the feeding process to watch how the fish are feeding each and every day, and make adjustments (less feeding, or perhaps slightly more feeding) based on their observations of the fish and condition present on the day.

4.12.1 Criteria for judging feeding response

Criteria for deciding the feed response are subjective. It is up to each farmer or the person feeding to study the fish and their feeding behaviour, and respond accordingly to adjust the amount and timing of feed added. As much as possible, the fish in any one pond or cage should be fed by the same person each day, so that person can by fully familiar with "their stock of fish", and that person should also be responsible for recording the daily feeding record.

Although subjective, the following criteria could be used to judge the feeding response of fish (Isyagi *et al.*, 2009):

E - **Excellent:** Fish are very active and come to feed immediately. The feed administered is all consumed by the fish within five to 10 minutes of feeding being started.

G - **Good:** Fish are generally less active and come to feed over a slightly longer duration. Feed gets consumed in about 15 to 20 minutes.

F - **Fair:** Fish are sluggish but do consume most (e.g. three-quarters) of the feed. However, they do so over a longer period (30 minutes).

P - **Poor:** When feed is applied, fish do not come to feed, or consume only very slowly. More than three-quarters of the feed administered is liable not to be consumed, if added.

When feeding response is "excellent" or "good", then most or all the feed allocated to that feed can be added to the pond or cage. If feeding response is "fair" then the farmer needs to be cautious so as not to add in more food than is necessary to satisfy those fish that are feeding. When feed response is "poor" the farmer should consider slowing the rate at which food is added, or to stop feeding.

4.12.2 Training fish to feed by response

Fish can be trained to come up, and eat their feed at the water surface. In large culture systems where fish are fed using the broadcasting technique, the following steps can be followed:

- Give the feed at the same spot in the pond or cage and at about the same time every day. This gets the fish into the habit of being in a certain area at feeding time. If the fish do not come to the area to feed initially, do not add any more feed until they learn to come to the assigned feeding area. It may take up to a week to train fish to come and feed from the same area and learn their feeding times.
- Broadcast a handful or a full scoop of feed once most of the fish have gathered at the feeding area. If the fish come out to get the feed and immediately consume the first feed, the rest of the feed may be given.

By training fish to feed in this way, it is deliberately creating competition for food. The fish soon realize that if they do not come to feed at meal time, they will not have food until the next mealtime. Therefore, the fish actively compete to get to the feed at meal times and eat as much as they can, as fast as they can. Because all the fish eat at the same time, growth rates become more uniform, and FCRs consequently improve.

4.12.3 Factors affecting feeding response

Feeding response is affected by fish health, water quality, climatic conditions, presence of predators, handling and a number of other factors. Based on the experience of milkfish and Nile tilapia farmers in the Philippines, several recommended adjustments to feeding rate are provided in Table 24.

TABLE 24
Adjustment to feed rations based on environmental conditions

Environmental condition	Feed adjustment
Rain during meal time	25 to 50% feed reduction
During and after heavy rainfall	50 to 75% feed reduction
Heavy plankton bloom	50 to 75% feed reduction for three days
Strong winds	Stop feeding until strong winds reduce
Plankton die-off	25 to 50% reduction until water back to normal conditions
High temperature	50 to 75% feed reduction
Daily fish mortality	Stop feeding until mortality reduces
Partial harvest	No feeding for 1 – 2 days
Cage transfer/net change	No feeding for 1 – 2 days
Water current speed is low (slack tide and low tidal fluctuation) for cages	25 to 50% feed reduction
Turbidity is high (for example after heavy rainfall)	25 to 50% feed reduction
Oxygen level are low - surfacing of fish, slow swimming behaviour	50 to 75% feed reduction until O_2 levels normalize

4.13 FEED USE DOCUMENTATION AND ASSESSMENT

4.13.1 Documenting evidence

Stock and feed control form the basis of good management practice. Knowing how many fish are present in the stock and the amount of feed being used to feed that stock are critical to gaining a better control over feed purchases, costs of production and improvement in feed conversion ratio, and to analyse what factors may be involved when production goes well and not so well.

It is critical to maintain written records. Previously, means to estimate the required ration were given, which included recording the number and weight of the initial stock, keeping records of mortalities and measuring fish regularly (monthly) to determine how much feed should be added using feeding tables. In addition, it is critical to keep daily records of feed fed, which then allows calculation of indices that will show how well the farm is being managed, and how well fish are feeding. Information should be recorded as it happens, and pre-prepared tables are a useful means of collecting such data. An example table for recording feed added to cages, along with notes on feeding performance is presented in Annex 3. In outline the table includes:

- The estimated feed ration per day, as a percentage of total body weight based on water temperature and fish size, which should be accurately weighed out for delivery to the fish.
- The actual amount of food added at each feeding point during the day, based on three feeds per day as outlined in Table 21. Any unused food should be re-weighed to gain an accurate measure of feed added. The time of each feed should be recorded.
- A calculation of the daily difference between feed estimated using the feed table and the actual amount added.
- The farmers view assessing feeding response, according to the criteria laid out above, along with notes on weather conditions, pond or cage condition, and any other information that may help the farmer understand the feeding response that day. This is particularly important when the feeding response has only been recorded as "fair" or "poor".

Recording this information at the time, will save the farmer trying to recollect later in the day or in the following days. By doing this for each feed, each day it will help the farmer to:

- Maintain records of daily feed application, to then assess FCR and other feed key performance indicators (KPIs) regularly.
- Keep a track of actual feeding times.
- Evaluate whether the feed tables, used to estimate feed input, are suitable. Regularly adding more food or less food than is proposed by the feed tables, will allow adjustment of the feeding regime.
- Maintain daily records of the behaviour of fish when fed, particularly looking for increases or drops or a variation in feed amount, which may provide an indication that the average weight of the fish is incorrect and will need to be re-measured, or may provide an early indication of stress or a disease outbreak.
- Make sure the same staff are feeding the correct pond or cage each day.
- Will help support feed purchasing, by maintaining a regular inventory of feed purchased, feed used, current stock and turnover of feed. Will help support efficient and cost-effective purchases of feed materials.
- The keeping of records forms the basis for a farmers' feed and fish biomass inventory tracking system. Keeping farm management records helps farmers to control cost and select the right feed and management approach.

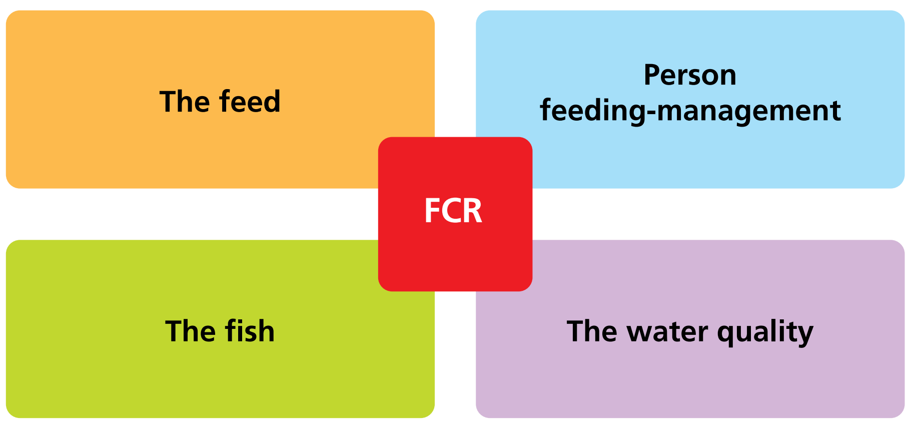
4.13.2 *Key performance indicators*

Key performance indicators, or KPIs, are a means to evaluate the performance of fish, feeding and management practices employed at the farm. The most well known of these is the feed conversion ratio (FCR), but there are other KPIs, which are detailed in the following pages.

FCR is a common indicator of feed usage in aquaculture that provides a simple and standard method to compare the feeding efficiency in different species, feeds and systems (Figure 9). FCR is a ratio, and has no units, and refers to the weight of feed in kilogrammes required to achieve an increase of one kilogramme in fish weight throughout the growth cycle, or can be calculated regularly at shorter intervals (daily, weekly, monthly etc.). Typically, FCR is an assessment of the:

- the performance of a feed;
- the performance of the person feeding the fish;
- the quality of water where fish live; and
- a broad indicator of the health of the fish.

FIGURE 9
Illustration of factors affecting feed conversion ratio



Source: Isyagi *et al.* (2009).

The formula to calculate FCR is as follows:

FCR = total amount of dry feed fed or given (kg)/total amount of fish produced in wet weight (kg)

For Nile tilapia and milkfish grow-out stages, in ponds and cages, the FCR would typically be around 1.2 (= 1.2 kilogrammes of feed added to gain 1 kilogramme of fish (wet weight)), thought it can be higher or lower than this, depending on the efficiency with which feed is fed, and the condition of the fish stock, and the quality of food used.

Economic Feed Conversion Rate (eFCR) is an extension of the FCR and used to evaluate the cost of feed as a ratio with the value of the fish grown. it is a measure of the cost-effectiveness of a particular feed. FCR and eFCR should be taken into account simultaneously and not independently of each other. Using the cheapest feed available, more often than not, does not translate into the lowest cost to produce a kilogramme of fish, because the feed is likely to be deficient in required nutrients and therefore less useful to fish growth and FCR may be higher.

The eFCR allows the farmer to compare the cost of different feeds and assess the most cost-effective feeds to use. eFCR gives a value of the feed cost to produce 1 kg of fish.

eFCR = total cost feed fed (e.g. in US$) / total wet weight gain (kg)

The lower the FCR, the lower the amount of feed used to produce a kilogramme of fish, and the proportionately lower cost to produce that fish, even though the feed itself may be more expensive to purchase.

Daily feed consumption (percent body weight per day) is the amount of feed fed per day, as a percentage body weight compared to weight of the fish. The formula to calculate daily feed consumption rate is as follows;

Feed consumption (percent body weight/day) = (cg/wt) x 100

where cg (consumption in gramme) is the mean daily feed consumption, and wt is the mean fish weight at time t (days).

Weight gain is the percentage increase in fish weight between two time intervals (e.g. day or month). The formula to calculate percentage weight gain is as follows:

Weight gain (%) = (final weight – initial weight) x 100/initial weight

Specific growth rate (SGR) is the equalized daily percentage weight gain between two time intervals. The formula to calculate SGR is as follows:

SGR (%/day) = ((ln FW – ln IW) x 100)/day

where FW is the final body weight (in g) and IW is the initial body weight (g). (Note: ln refers to natural log at base 10).

Survival rate is the percentage of fish surviving between two time points (e.g. input and harvest). The formula to calculate percentage survival rate is as follows:

Survival rate (%) = 100 x (final fish number/initial fish number)

Mortality is the percentage of fish that die (irrespective of reason for death) between two time points (e.g. input and harvest), and is calculated as follows:

Mortality (%) = 100 – survival rate

4.13.3 The economics of feed management

The lower the FCR, the lower the amount of feed used to produce a kilogramme of fish. Therefore, the feed, which gives the lowest FCR, even though it might be costlier to purchase, is, nonetheless, often the one that gives the overall lowest cost of production.

The implications of feed type, formulation and feed management practices on the economics of the farming operation are important considerations when planning farming activities. While these economic interrelationships are often difficult to assess, they can have a profound effect on the profitability of the farming operation (FAO, 2010; Hasan and New, 2013; Shipton and Hecht, 2013). These relationships are most evident in highly competitive sectors where feed costs represent a high percentage of the production cost, farm-gate prices are low, and profitability is marginal.

In some sectors, credit schemes between feed manufacturers, dealers and the farmers have been developed. These micro-lending models need to be encouraged, and new ways to fund feed purchases tried such as bulk buying schemes led by a farmers' association, the involvement of banks and micro-lending institutions, and public-private partnerships.

4.14 Managing the components that affect FCR

Figure 9 illustrates that FCR reflects a complex interaction between the feed used, the fish present, the person feeding and the overall feed management strategy at a farm, and the water quality conditions that can affect fish health and welfare.

The following sub-sections provide a summary of what can go wrong with each of these components and actions that can be taken to put that right, and to improve FCR and thus reduce the environmental impacts of the aquaculture activity.

4.14.1 the feed component

The quality of feed embodies its formulation, digestibility of feed ingredients, freshness, quantity of fines, pellet integrity, appearance, texture, odour and other properties. Quality is reflective of both physical and nutritional attributes. Having a well-made pellet using good quality ingredients that is the correct size and has the right nutritional values for the size of fish being raised is extremely important.

What could go wrong?

- poor quality feed;
- feed not developed for the species being grown;
- old or spoiled feed.

Making it right

- purchase feed from reputable feed manufactures, who are willing to share information on ingredients and proximate composition;
- purchase feed developed for the species being grown;
- good storage and proper handling;
- FIFO: first in-first out, using oldest stock first;
- keep minimum inventory on site;
- ask for independent feed testing;
- request a benchmark of feed quality;
- check on performance in use to see if the feed gives the KPIs required, ensuring poor performance is not for any other reason;
- bulk purchase from an association or cluster of farmers can encourage dealers to maintain a relationship of trust with with farmers.

4.14.2 The fish component

The fish species, fish size, fish condition, and the means of transportation to site (e.g. water conditions, water temperature, other parameters) will have a large effect on the success of the subsequent grow-out phases. It is important to purchase fish from a reputable supplier, who will provide the correct size and quality of fish for on-growing.

What could go wrong?

- mixed size of fingerlings;
- infected with disease;
- stressed from handling, poor water quality or low oxygen in transportation.

Making it right

- practical training on assessment of seed quality;
- check regularly on the condition of the stock during transport;
- prior to stocking in ponds or cages ensure fish check fish for size variation;
- request transport mortality allowance from hatchery suppliers;
- insist on certified disease-free seed;
- proper transport and handling of seed;
- certification of hatcheries can help;
- bulk purchase of seed would encourage seed suppliers to keep a good relationship with the farmers;
- as a principle – quality is as important as cost.

4.14.3 The person component (management)

The knowledge of the person feeding the fish is important, and requires learned skills in calculating the correct quantity to feed, skill in judging fish appetite, ability to assess for disease and other issues that may affect feeding and in overall management of stock. The person feeding has a crucial role in the farm and must be trained to feed the fish based on the feeding response, knowing what type of feed to give, how much feed to give, whether or not to adjust or stop feeding, how best to administer the feed, what pond/water management details need adjusting; keep written records and keep track of and evaluate fish performance by observation and analysis of the information recorded (i.e. with quantitative as well as qualitative information); and keep track of fish numbers and sizes in the various production units during culture.

What could go wrong?

- lack of experience and/or training;
- unsure of the fish biomass in the cage or pond;
- ignoring feeding behaviour;
- lack of understanding in factors that affect appetite;
- feeding poorly or irresponsibly.

Making it right

- appropriately targeted training;
- incentive system – equitable, fair;
- minimum-maximum feed input, being flexible and using observation as a basis for feeding while being guided by feed tables;
- develop and use appropriate tables to record qualitative and quantitative information, daily;
- conduct periodic sampling of fish to assess size (length and weight);
- calculate KPIs regularly to assess performance;
- consider automatic feeders (reduces human error and extends the feeding time).

4.14.4 The water quality component

The water quality and local environmental conditions (rain, strong winds, birds and other predators, etc.) are important as these can affect the health and welfare of stock and affect appetite in the fish. The most critical water quality parameters within the production system include water temperature and the concentration of dissolved oxygen, but is also affected by levels of ammonia, pH and other pollutants in the water and the turbidity (particulate and algal concentration). Some of these factors cannot be controlled (e.g. wind, rain etc.) but it remains important that the person feeding knows how to respond when these occur.

What could go wrong?

- competitors in the pond;
- low dissolved oxygen (DO) in pond watrer;
- algal bloom in lakes;
- water turbidity;
- water pollution;
- high water temperature;
- low water level in ponds

Making it right or avoiding it

- WHEN IN DOUBT – DO NOT FEED. REMOVE SOURCES OF DOUBT;
- check water color, check for pests and other organisms;
- use water quality kit – request from feed companies (part of incentive) – to test water quality parameters;

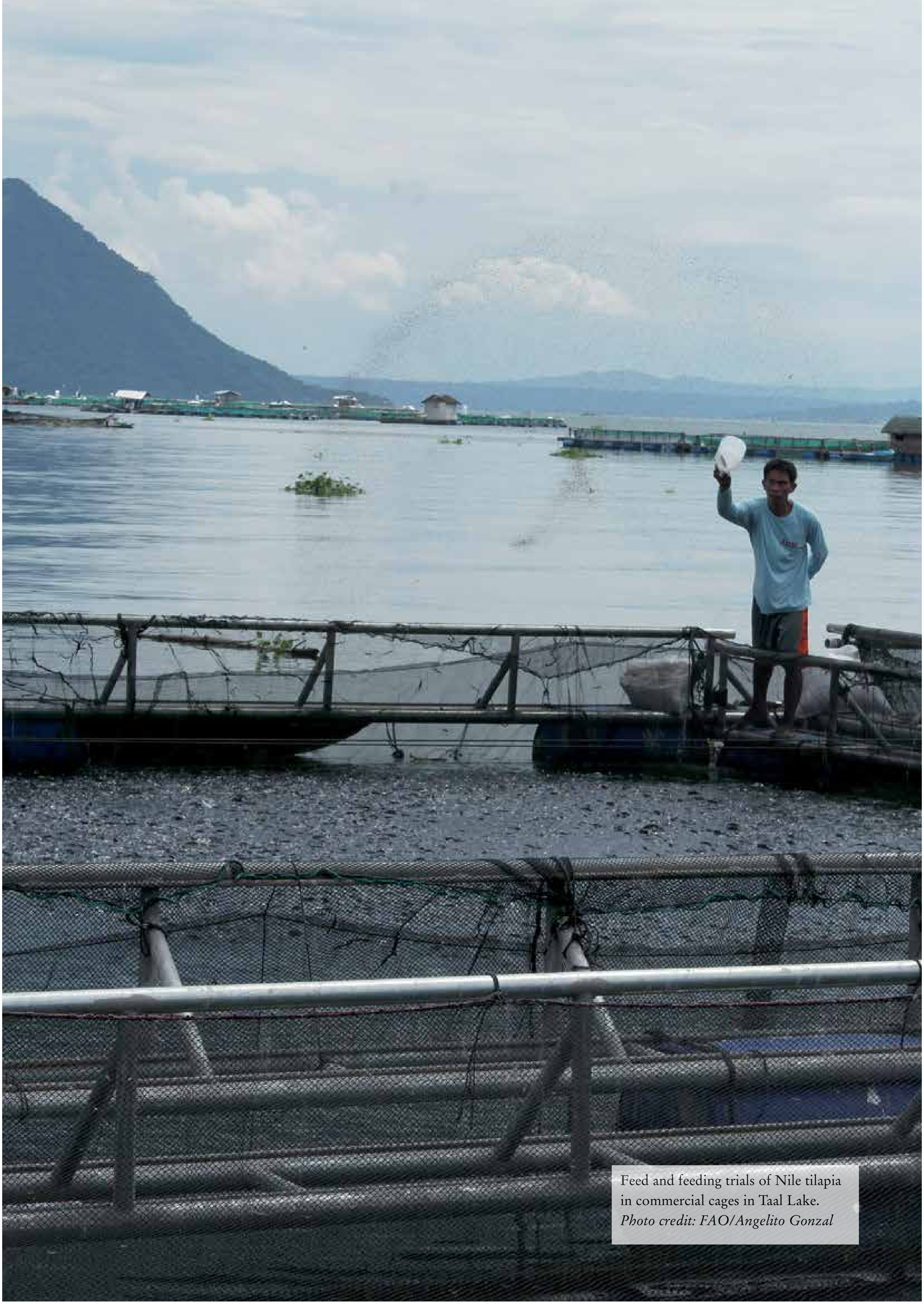
- measure water temperature and DO concentration;
- evaluate historical knowledge of fish kills, spots in growing area, causes;
- Undertake proper siting (of cages);
- time crop production to avoid periods of low water level, and/or use of bigger fingerlings for earlier harvest;
- if scale allows have a backup system for water quality enhancement, including aeration and pumps, and lime or zeolite (ponds);
- in pond design have intake provision for aerating the water (rocks, bamboo, net);
- correct feeding, quality feed, use of floating feed;
- consider water agitation (lakes) or water replenishment (ponds).

4.14.5 Effects of feed on water quality

Feed contains protein utilized by fish to build muscle but protein contains nitrogen that, in digestion, generates ammonia that is released to the environment as dissolved nitrogenous waste excreted through fish gills; and nitrogenous waste that is released in particulate form as faeces which can stay in the water column or settle onto the lake or pond bottom and seabed; and when overfeeding occurs protein (nitrogen)-rich feed settles on the lake or pond bottom and seabed. Particulate material on the lake/pond bottom and seabed is broken down by bacteria and this process can increase further concentrations of ammonia (as well as phosphorus and other nutrients) to the water column. Ammonia (NH3) is of specific concern because it can be extremely toxic to fish at low concentrations. Ammonia is naturally oxidized, or broken down, by bacteria to ammonium (NH4+) which less toxic, into nitrite (NO2-) which can be toxic, and eventually to relatively non-toxic nitrate (NO3-). In the process of breaking down particulates, or dissolved components like ammonia, bacteria consume large quantities of oxygen that can reduce the oxygen concentration available for fish. Unfortunately, lower oxygen also slows the process of ammonia oxidation, leading to increased concentrations of ammonia in the water in a potentially spiraling effect. It is therefore critical to have good control of feeding and feed use, and to limit feed waste.

To counter some of these potential effects:

- Under ideal conditions all feed added to ponds or cages should be consumed by fish, which requires dedication, vigilance and good assessment of appetite and feeding behaviour by the farmer;
- Good feed storage, handling and feed delivery will reduce the quantity of fines added to the water, which will not be consumed by the fish but will add to water quality degradation; and
- Good quality feed will have good pellet integrity, and holds together long enough to be consumed by fish, whereas poor quality feed is liable to disintegrate quickly, adding to water degradation.



Feed and feeding trials of Nile tilapia in commercial cages in Taal Lake.
Photo credit: FAO/Angelito Gonzal

5. Aquafeed governance

Aquafeed manufacturers and fish farmers have a common goal: to maintain viable enterprises that provide a fair return on their respective investments. Adequate governance seeks to enable both the feed miller and farmer to realize these objectives in a sustainable way that respects society and the environment. The goodwill within this general principle is apparent but is not self-executing, and it has to be made possible through appropriate governance policy. Such policy should include these four components:

- *Command and control, through regulatory instruments* such as the formulation, sanctioning and enforcement of farming, processing, and trading rules and regulations; site licencing; management plans for fish farming enterprises including for the water bodies and land areas used; other mechanisms such as bans on or specific limits in the use of certain drugs and chemicals, and licensing requirements for engaging in fish farming, manufacture or aquaculture trade.
- *Market-based instruments*, such as taxes, user fees, market incentives, and product certification and standards.
- *Voluntary or self-regulation mechanisms and instruments*, such as farmers' organizations, codes of conduct, best management practices, and co-management.
- *Provision of public goods and services* including infrastructure, scientific and technical information and services, and inputs that the private aquaculture sector cannot provide directly.

The policy overview in Annex 4 summarizes the current governance mechanisms applied, and recommendations for development, in relation to the two primary outcomes from project TCP/PHI/3404. These relate to:

- formulation of feed whose nutritional quality, safety and cost would be most suitable to milkfish and tilapia farming in the Philippines; and
- best management practices in feeding and feed management which contribute to the efficient utilization of feed (expressed in terms of FCR) and minimizing the impact of feed use on the environment.

Within this context there are several issues and concerns that impact government at a broad policy level, the local government, the aquafeed industry, the aquaculture zone, and the farm level.

5.1 Common issues

The common issues that are relevant to both feed manufacture and feed utilization are:

a. The low priority accorded to aquaculture compared to agriculture and capture fisheries, a corollary being the low priority given to aquaculture in freshwater allocation, which affects pond aquaculture particularly of tilapia.
b. The high cost of imported feed ingredients, which is one reason the cost of feed is high in the Philippines.
c. Philippine aquaculture feed standard provides maximum-minimum values for feed ingredient use in feeds but it is usually the minimum values that are used in order to reduce the cost of feed, which often reduces that feed's nutritional value for fish.
d. How to translate the higher quality but invariably more expensive feed to improve the overall cost-benefit to the farmer, through improved FCR for example.

5.2 Feed quality, safety and cost issues

Institutional issues pertain to the inspection functions of the two Government authorities, the BAI and the BFAR.

- The first issue relates to feed quality standards and feed safety standards inspection and compliance, where BAI is mandated to perform the former, and BFAR deputized to do the latter. This seems wasteful of Government resources but more critical is the difficulty of implementing the inspection/regulatory work among feed millers, despite the mandatory requirement to do so.
- Feed millers are required by law to be inspected for quality by BAI and for safety by BFAR. Confusion sometimes arises on the scope of such inspections, for example between the need for proximate analysis (by BAI) and detection of banned substances (by BFAR).

5.2.1 Feed standards

a. BAI standards are not in harmony with the Philippine National Standards on aquaculture feed (referred to as PNS Aquafeeds) (BPS, 2010) issued by the Bureau of Agriculture and Fishery Products Standards (BAFPS).
b. Feed millers are adopting BAI standards but at present the PNS Aquafeed is a voluntary standard and not implemented routinely. According to BAFPS, the PNS Aquafeeds should be translated into a BAI Administrative Order to enforce the necessary adoption of the PNS standards more widely.

These are anecdotal examples of the adverse impact of the lack of harmony between the two standards:

- Santeh Feeds Corporation, apparently unclear about the regulation, suffered rejection from BAI due to "non-compliance" with BAFPS standards, despite these being voluntary.
- CJ[3] Philippines is confused with brand labelling such as use of "Fish Grower" on feed, while they are required to put a specific label such as "Tilapia Grower".
- For feed registration certain details are supposed to be forthcoming (e.g. defining a feed for a specific species, the feed type and composition, and for which fish life stage the feed is for). However, some feed millers continue to sell their feeds using generic categories such as "Nutrifloat", without providing the necessary information. At the same time PNS standards are too generic, referring to a need to identify only a single category called "Herbivore/Omnivore" covering both tilapia and milkfish for example, despite the nutritional requirements of these fish being very different.

5.2.2 Feed costs

a. Farmers welcome and need better quality feed, which currently comes at a higher cost that farmers find a challenge to meet. On the other hand, the challenge to feed manufactures is not having to pass the additional cost of higher quality formulations to farmers. In feed manufacture, raw materials take up 80–85 percent of the cost of the finished product and this can vary dramatically depending on availability, in part due to the tax imposed on imported ingredients. Taxes vary by country of origin. For instance, the tariff on imported corn from Thailand is seven percent while it is 30 percent for corn from the United States of America. There are also issues of cost within the Philippines: corn from Isabela Province[4] of the Philippines costs PHP15.50–16.00/kg compared to PHP 14.50/kg for imported corn from Thailand.
b. The cost of compacted sinking pellet feed is usually 20 percent lower than that of extruded floating feed. The regulation to use only extruded (floating) feed in

[3] Cheil Jedang, the South Korean parent company.
[4] Isabela Province is the largest producer of corn in the Philippines.

Lake cage culture (e.g., Taal Lake), which has in part an environmental purpose, increases the cost of production for farmers. Meeting the ability to produce extruded feed is also difficult for small- and medium-scale feed millers who are unable to afford the cost of retrofitting their mills or acquiring new equipment. While floating feeds can reduce pollution, the application of relatively simple and improved feed management practice also reduces feed waste, without the need to introduce only floating feeds. The regulation to use floating feeds only brings with it some problems of suitability of floating feed to specific life stage of fish, particularly milkfish. As milkfish grow larger and heavier they tend to feed lower in the water column so that simply applying floating feeds means the fish may not get fed correctly and can result in large quantities of uneaten feed that contributes to water pollution.

5.3 Issues on encouraging adoption of better management practices (BMPs)

The application of better management practices in aquafeed manufacture and use attempts to define the best available choices in feed ingredients, methods of feed production, feed formulation, transport and handling, and in the best use of the feed by farmers to improve FCR, reduce wastage and minimize environmental damage. The issues that prevent or make it more difficult to encourage the adoption of BMPs for aquafeed manufacture and use include intersectoral issues, feed cost and quality, water quality and management of aquaculture areas.

5.3.1 Intersectoral issues

a. the low priority of water use accorded to aquaculture;
b. aquaculture receiving contaminated or polluted water from land-based sources.

5.3.2 Feed cost and quality

a. Size of bags and weights are not standardized, with different millers using different sizes and weights.
b. Higher prices of feed may not reflect the true price of the ingredients or the quality of the product.
c. Floating feeds not entirely floating – 40 percent float, 60 percent sink;
d. Poor nutritional value of feed;
e. No policy or programme of Government to bring down cost of imported raw materials such as soybean;
f. Adulterated feed (anectodal evidence of a significant amount of inert matter found mixed with the feed).

5.3.3 Water quality

a. Water quality is usually poor. In a survey of the production and marketing risks faced by farmers it was cited as the major factor for the poor growth of fish.
b. While the density of units is regulated, stocking density of fish is usually ignored, which means it is sometimes too high leading to the same problem of poor water quality.

5.3.4 Area management

a. Guidelines developed by the PHILMINAQ[5] project on Best Practice Guidelines for Local Government Units are available but not adequately implemented. These guidelines explain the laws and regulations for aquaculture and specify the roles and linkages of the agencies responsible for planning, management, monitoring and control of aquaculture.

[5] PHILMINAQ Project 2, "Mitigating impact from aquaculture in the Philippines". http://www.aquaculture.asia/pages/15.html (accessed 18 January 2017)

b. The limited implementation of the Protected Area Management Board under the National Integrated Protected Areas System Act (RA 7586 of 1992). The Protected Area Management Bureau (PAMB) that has been established for Taal Lake should be emulated in other lakes and reservoir bodies.
c. Mariculture Parks provide an opportunity for the application of good area and better farm management practices, which is not widely implemented at present.
d. The formation of farmer clusters or associations of farmers in the same watershed or geographical area, to improve area management and to better farm management of pond aquaculture areas, is very limited.

5.4 Interlinked policy and management constraints

The interlinked policy and management constraints are:

a. those faced by feed manufacturers in meeting the standards of feed quality, safety and cost to satisfy milkfish and tilapia farmers; and
b. those that make it difficult for farmers to comply with legally prescribed standards and to adhere to the standards required by the project's recommended and validated BMPs.

Constraints have been identified in the preceding sections. The measures proposed to address them and enable a cost-effective achievement of the standards are described in the following sections.

5.4.1 Feed safety and quality

The BAI registers feed ingredient manufacturers, feed importers, distributors of imported feed ingredient suppliers, feed manufacturers, and imported feeds (e.g. CP[6] , InVivo[7], Cargill). A survey carried out by project staff revealed that almost all protein sources are imported in large quantities, but no system is in place to inspect these materials within BAI. This strongly points to the need to review programmes, procedures and the resources needed to conduct inspections and tests. Feed millers, however, can and do perform a validation check on the quality of imported ingredients, but this may or may not be comprehensive. Small- to medium-scale operators, however, do not have that capability and are unable to carry out similar testing.

According to BAFPS, the Philippine National Standards on Aquafeeds will have to be translated into a BAI Administrative Order (AO) so that the PNS standards can be adopted formally, instead of being voluntarily as at present. This would require an amendment of the current administrative order. Additionally, this action would place the Philippines in step with the Association of Southeast Asian Nations (ASEAN) economic integration.

One issue is whether there is a need to have a more technically precise (e.g. higher crude protein and fat content) and separate species-specific standards. The downside is that the higher cost of doing so is typically passed on to farmers. The upside is species-specific standards would likely improve FCR and growth for a higher profitability and have less impact on the environment from improved FCRs. Thus, the recommended options are to produce high-density feeds (high specifications according to approved standards) alongside regular, low-density feeds (with minimum specifications according to the approved standard) and something in between. This would offer farmers a range of choice in feed selection, according to the differing nutritive qualities of each type of feeds.

It is also suggested to emulate the regulations being implemented in Taal Lake, namely:

- feed millers supplying the lake farmers undergo accreditation from the DENR-PAMB;
- accreditation is carried out by the PASU;
- labels on the bags should clearly indicate "floating pellets";

[6] Charoen Pokphand
[7] www.invivo-group.com/en/complete-feed/

- PAMB periodically convenes meetings with the feed millers;
- PAMB rules and regulations are disseminated to farmers.

BFAR was deputized by BAI in 2001 to monitor contaminants of export products and assist BAI in monitoring aquafeeds. The mandate for registration is BAI's, but BFAR's involvement was justified by the nature of the commodities, i.e. seafood and their remit to ensure food quality. BAI carries out nutrient analysis as part of the registration requirement while BFAR inspects for banned compounds, such as antibiotics, as a food safety measure. Reporting on antibiotic contamination monitoring had been challenging, but BAI has now the capacity with its high-performance liquid chromatography (HLPC). This being the case, the feed millers suggest that BAI cover both proximate analysis and detection of banned substances.

It was also recommended that the Food and Drug Administration (FDA) perform registration and licensing and BAI conduct monitoring. The Department of Agriculture is requesting the amendment of the existing Joint Administrative Order (JAO) of FDA and BAI, to include BFAR since aquaculture is included in the JAO. With such an amendment probable, there is a move to create a Technical Working Group to settle administrative and operational concerns that such a change may raise; for example, mandates over inputs and products to be used in aquaculture, where BAI would handle inputs used in terrestrial animals while BFAR would do the same for aquatic animals but only for veterinary drugs and products.

5.4.2 Feed cost

Minimizing the additional costs associated with the recommendations on the nutritional improvements of fish feeds and the development of species-specific feeds is needed. Passing on the increased cost of feed to farmers should be avoided. It is recommended to bring down the input cost using one or a combination of a reduction in the tariff for imported raw materials, bulk buying, and an appropriate subsidy. A strong suggestion is for the sector to lobby Government to reduce or abolish import tariffs on raw materials and ingredients.

It was also suggested to conduct a benchmarking exercise on feed cost structures with those of other ASEAN countries. This would reveal how other (ASEAN) countries are structured in their feed manufacturing sector and what their feed manufacturers are doing differently from or better than the Philippines. The purpose is to better understand cost and price structures of feed within ASEAN to inform relevant policy and other measures on aquafeed in the Philippines.

It was further suggested that the National Economic Development Agency's Philippine Institute for Development Studies (PIDS) provide and explain the results of their studies on tariffs, subsidies, and other measures in the livestock and crop sectors. Results and lessons learned from the studies would provide a basis for policy recommendations for the aquaculture sector.

5.5 Compliance with regulations, Good Aquaculture Practice (GAP) and adherence to the BMPs developed with the project

Improved compliance on existing regulations, good aquaculture practices and the introduction and development of the better management practices developed through this project is likely to be best achieved by developing a comprehensive plan of action at local government level through Local Government Units (LGUs). Local governments are the most proximate to farmers, and this close proximity means their directives and actions can be directly linked to farmers. It is recommended that LGUs, in promoting compliance with regulations or adoption of GAPs and BMPs, should work through local farmer's associations or farmer clusters, as a means to implement actions to the widest possible group of fish farmers. The associations and farm clusters then ensure their members' compliance.

There are, however, recommendations addressed to different stakeholders:

- **Certification and registration of farmers:** The Good Aquaculture Practice prescribed by BFAR has been made mandatory and should also be promoted through extension and training to the small-scale operators. One means of assessing compliance with the GAP standards would be to "grade" operators, by setting an appropriate benchmark, say 70 percent pass mark, as a requirement for registration and certification. Similarly, the same structure could be adapted for the feed manufacturers with critical elements identified related to food safety (such as traceability of ingredients, feeds source, and so on) to qualify for registration with BAI and BFAR.
- **Local Government Unit and Farmer Groups:** It is recommended that BFAR train LGU officers in a number of actions, such as those related to area management, the BMPs developed by this project, and BFAR's Good Aquaculture Practice (BPS, 2014). In turn, trained LGU officers would provide training farmers in and promote the adoption of the BMPs developed by the project and other requirements. (The improved feeding tables developed by the project will be provided to BFAR and LGUs). The LGUs should be equipped with water quality testing kits to enable localized testing and improvement of water quality. They should also assist in the formation of farmers associations within their respective jurisdictions to engage and promote adoption.
- **Farmers Associations:** The Federation of Fish Growers will promote among its member associations the appropriate actions derived from the Comprehensive National Fisheries Industry Development Plan. It will also promote the adoption of production of higher value species to improve the return on feed investment, which for farmers represents the highest single cost of production. This will need the assistance of the Research and Development sector, particularly to overcome bottlenecks that still occur in broodstock and hatchery technology. To lower the cost of imported ingredients, the farmer associations could enter into public-private partnerships with Government in the bulk importation of ingredients and processing; especially for soybean, before these are sold to feed millers. Among other advantages, this does not require a subsidy.
- **Government:** Government should forge a partnership arrangement with farmer associations in bulk buying and trading of feed. It should also link fish producers with aquatic products processors and provide encouragement and technical assistance in developing the export market for Philippine aquatic products. The Government is urged to review its policy on aquaculture and the priority accorded to it. The Department of Environment and Natural Resources should also review its priorities on water allocation and impose the appropriate regulations on water treatment and discharge from other sectors, to provide the aquaculture sector with good quality water, which it then must maintain.
- **Financial services:** The recommendation is for the provision of credit on easy terms, particularly for the purchase of feed, so that farmers are not always dependent on the feed suppliers for advances (which invariably raises the cost). An appropriately developed insurance scheme could enable a farmer, at reasonable cost, to recover from a crop failure without heavy dependence on feed dealers.
- **Research and Development:** In line with the Comprehensive National Fisheries Industry Development Plan, the R&D sector needs to develop a better-coordinated national aquaculture research and development programme. Specific research should be undertaken to help lower FCR, which could be achieved through research on better nutrition for specific species, development of means to produce higher value species, which can provide better returns from high quality feed, and targeted research and promotion of lower-cost environmentally friendly production systems such as the biofloc technology.

References

ADCP. 1980. *Fish feed technology.* ADCP/REP/80/11. Rome, UNDP/FAO. 395 pp.

ADCP. 1987. *Feed and feeding of fish and shrimp.* ADCP/REP/87/26. Rome, UNDP/FAO. 275 pp

BPS (Bureau of Product Standards). 2010. *Aquaculture feeds.* Philippines National Standard, PNS/BAFPS 84:2010 ICS 67.120.30. Bureau of Product Standards. Manila, BFAR. 17 pp. (also available at www.chinaaseansps.com/upload/2012-07/12072017499945.pdf).

BPS (Bureau of Product Standards). 2014. *Code of good aquaculture practices (GAqP).* Philippines National Standard, PNS/BAFS 135: 2014 ICS 65.150. Manila, Bureau of Product Standards. 26 pp. (also available at www.bafps.da.gov.ph/images/Approved_Philippine_Standards/PNS-BAFS135-2014CodeofGoodAquaculturePractice.pdf).

Cruz, P.S. 1997. *Aquaculture feed and fertilizer resource atlas of the Philippines.* FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. 259 pp. (also available at ftp://ftp.fao.org/docrep/fao/field/009/ag176e/AG176E05.pdf).

de la Higuera. M. 2001. Effects of nutritional factors and feed characteristics on feed intake. *In* D. Houlihan, T. Boujard & M. Jobling, eds. *Food intake in fish,* pp. 250–268. Oxford, Blackwell Science Ltd. 418 pp.

FAO. 2010. *Report of the FAO Expert Workshop on On-farm feeding and feed management in aquaculture. Manila, the Philippines, 13–15 September 2010.* FAO Fisheries and Aquaculture Report. No. 949. Rome, FAO. 37 pp. (also available at www.fao.org/docrep/013/i1915e/i1915e00.pdf).

FAO. 2017. *FishStatJ version 3.03.2.* Rome. (available at www.fao.org/fishery/statistics/software/fishstatj/en).

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.). (also available at www.fao.org/docrep/019/i3481e/i3481e00.htm).

Hasan, M.R. & Soto, S. 2017. *Improving feed conversion ratio and its impact on reducing greenhouse gas emissions in aquaculture.* FAO Non-Serial Publication. Rome, FAO. 33 pp. (also available at www.fao.org/3/a-i7688e.pdf).

Isyagi, N.A., Veverica, K.L., Asiimwe, R. & Daniels, W.H. 2009. Manual for the commercial pond production of the African catfish in Uganda. Alabama, Auburn University. 222 pp. (also available at http://www.ag.auburn.edu/fish/international/uganda/docs/Catfish%20ManualEntire.pdf).

Kestemont, P. & Baras, E. 2001. Environmental factors and feed intake: mecahnisms and interactions. *In* D. Houlihan, T. Boujard & M. Jobling, eds. *Food intake in fish.* pp. 131–156. Oxford, Blackwell Science Ltd. 418 pp.

Nguyen, V.H., Lan, H.P., Manalac, L. & Manomaitis, L. 2015. Asian sea bass growth performance using a cage-in-pond production approach with soy-optimized diets in a fresh water environment in Vietnam. *World Aquaculture 2015 Meeting Abstract, World Aquaculture Society* (also available at www.was.org/meetings/ShowAbstract.aspx?Id=35262).

Shipton, T.A. & Hecht, T. 2013. Economic, regulatory and legal review of feed management practices. *In* M.R. Hasan & M.B. New, eds. *On-farm feeding and feed management in aquaculture*, pp. 565–585. FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. 585 pp.

Tacon, A.G.J., Metian, M., & Hasan, M.R. 2009. *Feed ingredients and fertilizers for farmed aquatic animals: Sources and composition.* FAO Fisheries and Aquaculture Technical Paper. No. 540. Rome, FAO. 209 pp. (also available at www.fao.org/docrep/012/i1142e/i1142e.pdf).

Harvest of milkfish from a brackishwater pond, Dagupan, Philippines.
Photo credit: FAO/Mohammad Hasan

ANNEX 1

Proximate composition (calculated and analyzed) and amino acid content (calculated) of the four Nile tilapia experimental and control feed formulations (dry matter basis)

Calculated values[1]	Formulation				
	FAO-TF1	FAO-TF2	FAO-TF3	FAO-TF4	Control feed (Tathe surfer grower)[2]
Crude protein	34.33	34.25	33.80	34.39	31.00
Crude lipid	7.94	7.92	7.24	7.42	6.00
Dry matter	93.22	93.10	92.61	92.47	88.00
Ash	10.63	9.29	8.35	8.64	6.00
Gross energy (MJ/kg)	17.96	18.00	17.42	17.28	-
Cost (US$/kg)	0.57	0.56	0.55	0.58	-
EAA[3] (r2)	0.76	0.59	0.52	0.64	-
Arginine	8.43	8.20	8.36	7.26	-
Histidine	2.35	2.40	2.51	2.68	-
Isoleucine	4.10	4.20	4.42	3.54	-
Leucine	7.52	8.44	9.53	7.75	-
Lysine	6.54	6.11	5.93	6.00	-
Methionine + cystine	3.42	3.25	3.26	3.75	-
Phenylalanine	4.52	4.81	5.18	4.75	-
Phenylalanine + tyrosine	8.36	9.07	10.03	7.94	-
Threonine	4.47	4.35	4.43	3.88	-
Tryptophan	1.90	1.99	2.40	1.08	-
Valine	5.05	5.07	5.39	5.13	-
Analyzed values (%)[4]					
Crude protein	34.66	35.07	35.11	34.24	32.72
Crude lipid	4.93	4.22	4.94	4.97	6.10
Crude fibre	0.82	0.50	1.17	1.85	4.39
Ash	12.50	12.57	12.02	10.65	7.59
Moisture	7.04	6.50	7.01	8.00	7.85
Analyzed values (%)[5]					
Crude protein	31.46	35.41	34.39	35.15	31.81
Crude lipid	2.78	3.55	3.09	4.39	4.01
Crude fibre	2.03	2.47	2.67	2.47	3.09
Ash	12.24	12.73	11.53	10.20	9.49
Moisture	8.82	7.88	8.74	8.31	9.75
Protein digestibity	90.25	88.91	84.05	88.30	91.92
Nitrogen free extract (NFE)	42.67	37.96	39.58	39.48	41.85

[1] All values are in percent unless otherwise indicated;
[2] Control feed used in farmer's trial;
[3] EAA = essential amino acid - the r2 is a correlation coefficient and is based on the EAA profile of the feed and the body composition of the animal and provides an indication of the balance of EAAs in the feed;
[4] analyzed at the laboratory of Santeh Feeds Corporation;
[5] analyzed at the laboratory of Lipa Quality Control Centre, Makati City Lipa Quality Control Centre, Makati City.

ANNEX 2

Proximate composition (calculated and analyzed) and amino acid content (calculated) of the four milkfish experimental and control feed formulations (dry matter basis)

Calculated values[1]	Formulation				
	FAO-MF1	FAO-MF2	FAO-MF3	FAO-MF4	Control feed (Tathe surfer grower)[2]
Crude protein	31.20	31.16	34.31	34.27	31.00
Crude lipid	5.64	10.64	6.20	11.20	6.00
Dry matter	92.27	92.89	92.94	93.56	88.00
Ash	9.76	9.06	10.54	9.83	6.00
Gross energy (MJ/kg)	17.42	18.63	17.81	19.01	-
Cost (US$/kg)	0.59	0.62	0.60	0.63	-
EAA3 (r2)	0.82	0.76	0.76	0.76	-
Arginine	7.44	7.45	7.82	7.83	-
Histidine	2.34	2.34	2.35	2.35	-
Isoleucine	4.14	4.15	4.25	4.25	-
Leucine	7.84	7.85	8.85	8.86	-
Lysine	6.23	6.24	6.17	6.18	-
Methionine + cystine	3.36	3.37	3.38	3.38	-
Phenylalanine	4.61	4.61	4.82	4.83	-
Phenylalanine + tyrosine	8.03	8.04	9.01	9.02	-
Threonine	4.17	4.17	4.39	4.40	-
Tryptophan	1.09	1.10	1.84	1.84	-
Valine	4.86	4.87	5.08	5.09	-
Analyzed values (%)[4]					
Crude protein	31.78	31.44	32.46	35.21	32.72
Crude lipid	4.11	7.99	4.04	8.38	6.10
Crude fibre	0.75	2.67	1.81	1.60	4.39
Ash	12.55	9.59	16.21	12.53	7.59
Moisture	7.49	7.00	7.07	6.65	7.85
Analyzed values (%)[5]					
Crude protein	31.46	32.70	33.61	35.94	31.81
Crude lipid	2.78	6.77	3.67	7.53	4.01
Crude fibre	2.03	1.89	2.01	1.96	3.09
Ash	12.24	9.62	12.69	12.85	9.49
Moisture	8.82	7.86	8.45	7.03	9.75
Protein digestibity	90.25	90.64	92.32	86.11	91.92
Nitrogen free extract (NFE)	42.67	41.16	39.57	34.69	41.85

[1] All values are in percent unless otherwise indicated;
[2] Control feed used in farmer's trial;
[3] EAA = essential amino acid - the r2 is a correlation coefficient and is based on the EAA profile of the feed and the body composition of the animal and provides an indication of the balance of EAAs in the feed;
[4] analyzed at the laboratory of Santeh Feeds Corporation;
[5] analyzed at the laboratory of Lipa Quality Control Centre, Makati City Lipa Quality Control Centre, Makati City.

ANNEX 3

Daily feed record example

Table A3.1 provides a recommended daily feeding table to be completed by the farmer or farm worker who feeds the fish. One table should be used per pond or cage.

Table A3.1: Recommended daily feeding record

Pond/ cage number		**Feed type**				**Mounth**			**Year**		**Name of feed staff** ....
Date	Calculated amount of feed to be fed (kg)[1]	Morning feed added[2] (kg)		Noon feed added[2] (kg)		Afternoon feed added[2] (kg)		Total feed added per day (kg)	Quantity over (+) or under (-) fed[3] (kg)	Feeding response (E, G, F, P)[4]	Notes[5]
		Time	Amount	Time	Amount	Time	Amount				
1st											
2nd											
3rd											
etc.											

[1] Feed to be fed is the estimate using feed tables or similar mechanisms, based on estimated biomass of fish present in cage or pond and the water temperature.
[2] At each feed record the time fed and the amount fed.
[3] Deduct the total feed added per day from the feed table calculation of how much feed should have been added to work out how much over or under the target figure was added that day.
[4] Feeding responses can be evaluated as excellent (E), good (G), fair (F) or poor (P). For description see main text.
[5] The notes column is used to record unusual weather or environmental conditions, or factors that may have affected feeding, such as presence of diseased fish, that might be used to explain fair or poor feeding response.

ANNEX 4

Policy instruments for quality, safe and cost-effective feed formulation and better feeding and feed management

This annex provides an overview of the current and recommended policy instruments to enable safe and cost-effective feed formulation (Table A4.1) and better feeding and feed management (Table A4.2), as outcomes of the TCP/PHI/3404 project. The tables show the gaps in governance, which become opportunities for introducing additional appropriate management measures. There are very few current and recommended market-based governance mechanisms. Specific recommendations are in italics.

Table A4.1: Formulation of feed with suitable nutritional quality, safety and cost

Objective	Command & control	Market-based	Voluntary	Institutional service
1. Quality	Translate PNS for aquafeed into BAI Administrative Order to enforce compliance with the PNS		Adoption of PNS on aquafeed.	Research and development on local sources of feed ingredients
	The BAI registers feed ingredient manufacturers, feed importers, imported feed ingredient suppliers		Feed millers perform validation check on the quality of imported ingredients.	Provide validation check service of imported to small- and medium-scale feed millers
	BAI proximate analysis of ingredients for quality	Certification of feed millers	Adoption by feed millers of the project developed feed formulations	Promote the feed formulations developed by the Project
2. Safety	BFAR inspection of manufactured feed for banned compounds	Certification of feed millers		
3. Cost	Reduce tariffs on imported feed ingredients	PPP with farmers for bulk buying of feed ingredients and processing		Public-private agency to handle bulk importation; processing of soybean
	Requirement for floating feed in lake cage culture (Note: this adds to manufacturing cost)			Promote the Project's feed formulations: improve growth by 10% at no additional cost.

Table A4.2: Better feed and feeding management

Objective	Command & control	Market-based	Voluntary	Institutional service
Efficiency and environmental sustainability	Regulate density of farming units	Suitable compensation for owners of dismantled cages	Farmer clusters or farmer associations adopt project developed BMPs and BFAR's GAPs	R and D on higher value species that use high quality feed more efficiently
	Regulation on water pollution from excessive feeding	Polluter-pays i.e. tax or fine on pollution; require on-farm pollution abatement facility	FCR-bonus to caretaker	Provide validation check service of imported to small- and medium-scale feed millers
	BAI proximate analysis of ingredients for quality	Certification of feed millers	Adoption by feed millers of the project developed feed formulations	Promote the feed formulations developed by the Project
Use of feed guide	Extension campaign to promote and train farmers on the use of the feed guide	Certification of feed millers		
	Regulation of water pollution from other sources: treatment of waste water discharge, fines, etc.	Fines on land-based polluters	Farmer associations negotiate with upstream users	Higher priority accorded to aquaculture on water use
	Zoning and area management	User pays, as applied to the use of irrigation water by tilapia pond farmers	Local governments implement Best Practice Guides of Philminaq project	BFAR trains LGUs on BMPs and GAP; and LGUs train farmers
Cost	Ordinance on use of floating feed in cage culture (Note: floating feed costs higher)		PPP: Government and farmer associations in bulk buying and trading	Also, promote the use of the feed guide
			Also adoption of project developed BMPs and BFAR's GAPs	Targeted R&D for low-cost production systems i.e. biofloc
				Institutional credit on favourable terms; crop insurance

In almost all fed systems, feed takes up the major share of the production cost. This basic economic issue faced by the milkfish and tilapia farmers of the Philippines became the key to the solutions embedded in the guidelines described in this publication. The guidelines that prescribe their application range from policy and regulations that provide an incentive for feed makers to produce feed that conform to safety and quality standards; better feeding and feed management practices for farmers to adopt; key support services for research and extension services to provide; and innovative linkages that government agencies, local government units, feed traders, and farmer groups can forge. All of these to pursue the core objectives of profitability for feed makers, traders and farmers, environmental sustainability, and a strong human resource, technological, and institutional support system for the feed value chain of the two most important aquaculture commodity industries of the Philippines. It was to these purposes that the FAO Technical Cooperation Programme (TCP) Project "Improvement of feeding and feed management efficiency in aquaculture production in the Philippines" implemented with the Bureau of Fisheries and Aquatic Resources (BFAR) of the Government of the Philippines was designed and carried out to achieve. The results and lessons from this project could be used, with appropriate adaptation, by other countries in the region.

ISBN 978-92-5-130485-3 ISSN 2070-7010

9 789251 304853
I9073EN/1/04.18