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

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ABSTRACT

The contribution of the Philippines to tilapia production in Asia has increased steadily in the past five years as it addresses hunger and poverty alleviation in the region. Commercial tilapia aquaculture in the Philippines has improved as farmers have become aware of the importance of adopting innovative husbandry technologies. These include the use of intensive culture, using novel feed ingredients, improving the quality of industrial aquafeeds, adopting cost-effective feeding strategies and efficient pond fertilization methods, and culturing improved genetic strains. A case study was conducted to: a) assess current tilapia feed management practices; b) determine recent nutrition-based innovations that include the use of alternative feed ingredients, the adoption of nutritionally complete commercial tilapia feeds, and improvements to feed management practices; and c) evaluate these factors in terms of improved production efficiencies. Thirty-two farmers from selected tilapia cage hatcheries, pond hatcheries, grow-out cages and ponds in Regions III and IV-A (known major tilapia producing regions in the Philippines) were interviewed. The issues addressed included their farm management practices, with particular focus on tilapia feed preferences; quality, procurement and storage methods; and feeding strategies. Their responses were collated and analysed in the context of information simultaneously gathered from the scientific literature, popular publications and relevant websites. The results from the case study highlight the importance of farmers being trained and remaining well-informed about recent improvements in feed technologies and the use of efficient cost-saving feeding strategies to optimize the production of seed and marketable tilapia. Recommendations on how to increase tilapia production through improved feed and feed management practices are described. Finally, recommendations for local regulatory agencies to implement aquafeed quality and nutrient standards are provided.

1. BACKGROUND

1.1 Nile tilapia farming in the Philippines

Although native to Africa and the Middle East, the tilapia is now a globally cultured freshwater fish that is currently produced and consumed in nearly 100 countries worldwide (Fitzsimmons, 2000). A large portion of world tilapia production comes from Asia. The first known Asian introduction of the species was in 1939 when the Mozambique tilapia (*Oreochromis mossambicus*) was introduced into Indonesia. In 1950, the species found its way to the Philippines, where it was promoted as a potential species for subsistence farming. However, when local culturists experienced problems in growing Mozambique tilapia due to its perceived inferior production traits, interest in commercial tilapia culture waned. Profitable tilapia farming in the Philippines began only in the 1970s, when Nile tilapia (*Oreochromis niloticus*) was introduced for pond and cage culture. Although production was initially in ponds, local cage farming techniques were readily developed, and the Philippines became a pioneer in Asia for Nile tilapia cage culture in lakes and reservoirs (Guerrero, 2002; BFAR-PHILMINAQ, 2007).

Since 1980, hybrid red tilapias (*Oreochromis* spp.) have also been farmed in the Philippines. However, the majority of Philippine tilapia production is still based on *Oreochromis niloticus.* Production is primarily restricted to: a) traditional extensive culture in earthen ponds; b) semi-intensive farming in cages, pens and ponds; and c) intensive culture in cages, ponds and tanks (Figures 1.1–1.4). The differences between the three production systems are the level of inputs and the intensity of production (PHILMINAQ, 2007; Eguia and Romana-Eguia, 2007; Lim and Webster, 2006). Under extensive culture, tilapia are stocked at low densities in fertilized ponds where the fish are not fed, and depend on the natural productivity of the system to supply their food and nutrition. Minimal labour inputs, little water exchange and no artificial aeration are applied, and thus low yields are attained. In semi-intensive systems, fish are stocked at higher densities and are dependent on natural feeds and supplemental feeds such as cereals, fishery by-products and/or formulated feeds. Water exchange under semi-intensive culture conditions is moderate, and aeration is provided partially or continuously. Finally, in intensive systems, tilapias are stocked at very high densities, and are totally dependent on formulated feeds to supply their nutritional requirements. Typically, water exchange rates are higher than in the semi-intensive and extensive systems; higher labour inputs and continuous aeration need to be provided. Table 1 provides a summary of the specific inputs that are required to operate each type of culture system, and outlines nutrition-related inputs (feeds and fertilizers) and the feed and water quality management systems that are required.

FIGURE 1.1
Earthen pond-based tilapia culture in the Philippines

COURTESY OF E. ROXAS.

FIGURE 1.2
Tilapia cages in Taal Lake, Batangas, Philippines

Source: http://pcij.org/blog/wp-content/uploads/2008/06/taal-lake.jpg

FIGURE 1.3
Tilapia pen culture in Laguna Lake, Philippines

Source: SEAFDEC/AQD (2009).

FIGURE 1.4
Concrete tanks for use in breeding and small-scale tilapia farming

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TABLE 1
Tilapia production systems in the Philippines

Parameters	Extensive		Semi-intensive		Intensive	
	Ponds	Cages	Ponds	Cages	Ponds	Tanks
Culture period (months)	4–5	4–6	4–6/7–8*	4–5	4–5	4–5
Size at stocking (g)	10–20	10–20	10–20/50*	10–20	10–20	10–20
Stocking density	3 000–5 000/ha	15–25/m^3	10 000–50 000/ ha/ 20 000/ha*	50–250/m^3	50 000–100 000/ ha	100–200/m^3
Water management	50% water exchange after 2 months	None	Frequent water change	None	5–10% water exchange daily	Flow-through
Fertilization	2 weeks after pond preparation	None	Applied in the first two months	None	Only at stocking	None
Feeding	None	Natural food + supplemental feed**	Natural food + supplemental feed**/ natural food + commercial feed	Commercial feed	Commercial feed	Commercial feed
Use of aerator	No	No	Optional	Optional	Yes	Yes
Size at harvest (g)	100–200	250–300	150–200/ 750–800*	150–250	250	>300
Survival rate (%)	80–100	70–90	60–85/60*	60	60	70–85
Yield	300–800 kg/ha	2.7–7.0 kg/m^3	1 000–3 000kg/ ha/1 000 kg/ha*	4–40 kg/m^3	7 000–15 000 kg/ha	20–50 kg/m^3

Notes: * Data from the San Antonio Aqua Fisheries Inc. (SAAFI), a local company engaged in the production and processing of exportable-size tilapia; **supplemental feed here refers to single feed ingredients, e.g. rice bran, bakery wastes (bread crumbs), kitchen scraps or formulated feeds.
Source: Sumagaysay-Chavoso (2007); Eguia and Romana-Eguia (2007); Guerrero (2002); Aldon (1998); Field survey (2010).

1.2 Production trends

In 2008, global production of Nile tilapia was 2.1 million tonnes – more than double that recorded in 2000 (FAO, 2012). This unprecedented increase in production may expand further, as more countries start to culture the species. In addition, tilapia producers have been intensifying their farming practices, thus contributing to higher farm yields (Lim, Webster and Li, 2006). The motivation to increase yields comes with increased consumer demand for inexpensive yet healthy sources of animal protein. In this regard, Nile tilapia, especially when organically farmed, provides a healthy, cheap product for health conscious consumers.

In 2008, Asian Nile tilapia production was recorded at 1 559 151 tonnes, equating to 76 percent of the world's tilapia production (2 061 816 tonnes). The largest producer country was China which produced 832 698 tonnes, followed by Indonesia at 291 038 tonnes, Thailand at 217 246 tonnes, and the Philippines at 188 103 tonnes (FAO, 2012). In 2008, local data from the Philippine Bureau of Fisheries and Aquatic Resources (BFAR) registered a total production of 257 133 tonnes of tilapia (Table 2; BFAR, 2008), representing a production volume that is approximately 69 000 tonnes more than that reported by the FAO. However, the BFAR report includes the production of all the known commercial tilapia species. Among the different regions of the Philippines, production ranged between 269 tonnes and 124 020 tonnes. Production was widely dispersed and derived from a range of culture environments and systems, including freshwater and brackishwater ponds, cages and pens, small farm reservoirs, rice-fish integrated systems and, although negligible, even marine fish cages (Table 2). Figure 2 shows the locations of the various regions.

TABLE 2

Aquaculture production (tonnes) of tilapias in the Philippines, 2008

Region	Total	Brackishwater			Freshwater			Small reservoir	Rice-fish culture	Brackishwater fish cage
		Fish pond	Fish cage	Fish pen	Fish pond	Fish cage	Fish pen			
NCR	501	132				369				
CAR	3 195				1 667	1 528				
I	6 915	1 183	52	58	5 543	49		30		
II	11 261	2 844	119		7 242	977		79		
III	124 020	6 801	2		117 124	6		87		
IV-A	81 255	44			1 577	67 637	11 997			
IV-B	575				575					
V	10 835	135			1 663	9 037				
VI	1 211	793			417					
VII	269	123			132	10		5		0.10
VIII	372	57		2	199	82	33			
IX	1 931	1 837			95					
X	1 454	401			1 053					
XI	913	169			721	3	20			
XII	8 236	232			579	1 765	5 659			
CARAGA	379	57	2	8	204	108				
ARMM	3 810	151			73	177	3 409			
TOTAL	**257 133**	**14 957**	**175**	**68**	**138 862**	**81 748**	**21 120**	**202**	**1**	**0.10**

Source: BFAR (2008).

FIGURE 2

Map of the Philippines showing the different regions

Source: http://mapsof.net/uploads/static-maps/philippines_regions_and provinces.png and http://en.wikipedia.org/wiki/Regions_of_the_Philippines

1.3 Technological developments in the Philippines

The increase in Nile tilapia production over the past decade (FAO, 2012), can be attributed to various technological interventions. These include hormonal/genetic manipulation and strain improvements, and refinements to feed, water and culture systems and their management. Since 1987, national and regional research institutions have been involved in selective breeding programmes to improve culture strains and, since 2000, these improved strains have been commercialized. These strains include the FaST (Freshwater Aquaculture Center Selected Tilapia), the SEAFDEC selected strain, the GIFT (Genetically Improved Farmed Tilapia) as well as other GIFT-derived strains such as the GST (Genomar Supreme Tilapia) of GenoMar and the GET-Excel tilapia being promoted by the BFAR (Eguia and Romana-Eguia, 2007; ADB, 2005a; Romana-Eguia *et al.*, 2004). A Tilapia Science Center was established in the Science City of Munoz, Nueva Ecija, where most of the tilapia selective breeding research projects and institutions are found. Realizing the importance of genetic improvement, one local feed company (B-MEG) has even developed its own improved strain (BEST 200) that they promote to fish farmer clients who use their commercial diets (B-MEG website: www.b-meg.com).

The rationale of using improved stocks is for the farmers to rear fish that have the genetic potential to: (a) grow and breed well; and (b) tolerate and/or survive sub-optimal culture conditions, environmental stressors (such as fluctuating salinity and water temperature levels due to climatic change), and diseases (Ponzoni, 2006; Eknath and Hulata, 2009). Although most of the improved stocks were primarily developed to promote better growth, farmers also require stocks to possess other production traits, including optimal fillet yield and carcass quality, late onset of sexual maturity, high fecundity, efficient feed utilization, and stress and disease tolerance (Siriwardena, 2007). Since the current trend to boost national production is to culture tilapia in brackishwater ponds that were originally devoted to milkfish and marine shrimp culture, two BFAR regional stations have produced and are currently field testing hybrids referred to as a) 'Molobicus' (Nile x Mozambique tilapia hybrids) and b) 'BEST' (Brackishwater Enhanced Selected Tilapia; no relation to the BEST 200 strain of B-MEG) strain tilapia, which are stocks suited for saline culture. Recently there were plans to develop improved Nile tilapia strains through genetic manipulation methods (e.g. transgenesis, triploidy); however the perceived risks associated with developing genetically manipulated organisms (GMO) make these approaches unacceptable in Philippine commercial aquaculture. Fortunately, the development of genetically manipulated tilapia has not been approved by local funding agencies and will not be pursued. Finally, it has been noted that the development of improved strains has been undertaken by agencies/groups that have access to technology and funds; consequently, the genetic strains they produce are mostly controlled by and benefit large businesses/private agencies, rather than marginalized farmers and smaller aquaculturists (Bartley *et al.*, 2009) Despite this, the initiatives to develop genetically improved strains continue, and in this regard, the WorldFish has transferred some of their GIFT broodstock from the Philippines to Penang, Malaysia to continue their selective breeding work.

In addition to the traditional stock selection techniques, sex reversal and advanced stock manipulation techniques (YY super male production; Mair, 2002) have also been developed for the production of mono-sex tilapia. Moreover, field-tested feeds, tilapia phase diets (feeds for the various tilapia growth stages), improved health management strategies, and a variety of hatchery and grow-out system innovations have also improved production characteristics.

1.4 Recent on-farm innovations

Traditionally, Nile tilapia has been cultured in freshwater. Production is divided between freshwater ponds, (54 percent), freshwater cages (32 percent), and freshwater pens (8 percent), with brackishwater ponds contributing just 6 percent of production (BFAR, 2008). Freshwater and brackishwater pond culture are practiced in Region III, while freshwater cage and pen farming is primarily restricted to Region IV-A (Asian Development Bank, 2005b; BFAR-PHILMINAQ, 2007). In addition, many of the tilapia hatcheries are also concentrated in Regions III and IV-A, and these areas are now the major production areas. The Tilapia Science Center, comprising the GIFT Foundation International Inc., FAC-CLSU, PhilFishgen, BFAR-NFFTC and Genomar, is located in Region III.

Improved seed stocks are sold at premium prices and are presumed to require lower feed inputs than conventional strains. Despite the higher seed stock costs, the use of genetically improved tilapia strains increases farm profitability. Based on local farm interviews, 56.3 percent of the farmers, the majority from Region III, use genetically improved seed stock for grow-out, and 62.5 percent use improved broodstock.

A recent innovation is the culture of saline-acclimated Nile tilapia in brackishwater ponds that were originally designed for milkfish and shrimp farming. As a euryhaline species, sea cage farming has also been considered however, to date this technology remains to be proven. In the event that tilapia mariculture is developed, it will most likely be confined to the culture of Nile tilapia hybrids crossed with more salt-tolerant species such as the Mozambique (*O. mossambicus*) and Zanzibar (*O. urolepis hornorum*) tilapias. Brackishwater tilapia culture was initiated when the shrimp industry encountered disease problems that significantly affected marine shrimp production. Currently, farmers are using ordinary Nile tilapia seed stock acclimatized to 17 ppt; however, once saline tolerant strains from BFAR are disseminated commercially, it is likely that production from brackishwater ponds will increase (Tayamen *et al.*, 2004).

In recent years many farmers have started to intensify their farming operations. The rationale for intensifying the farming systems comes with the realization that the water and land resources that are available for aquaculture development are finite, and therefore their use has to be maximized (Rana, Siriwardena and Hasan, 2009). In this regard, some farmers have shifted production from extensive and semi-intensive culture to intensive culture. This shift in intensification requires increased feed inputs. Intensive culture technologies are primarily applied to pond operations in Pampanga, and cage operations in Taal Lake, Batangas. In intensive cage culture operations, farmers use supplemental feeds (agricultural by-products, rice bran, bakery wastes etc.) and/or commercial diets. In contrast, commercially produced aquafeeds are used in intensive pond culture operations. Credit schemes have made the shift to commercial feeds possible. Of particular importance are those schemes that are provided by local feed companies, as they provide credit to farmers that would otherwise have limited access to finance.

In contrast, some farmers have started organic farming operations in which the use of sex-reversed seed stock is avoided, and environmentally friendly practices, such as integrating tilapia farming with pig production or poultry farming is practiced. In these systems effluents/wastes from the terrestrial farming activities are utilized as a source of organic fertilization for the tilapia ponds.

Finally, the demand for tilapia in international markets has led to the development of farms that are designed to produce export sized tilapia (750–800 g). This production method normally requires stocking larger tilapia fingerlings (~50 g), which are produced through conventional means and the use of commercially formulated aquafeeds.

2. METHODOLOGY

An assessment of the current feed management practices in the Philippines was made. Primary data were obtained through personal interviews with selected farmers and technical staff in research agencies. The respondents were selected from hatchery and grow-out farms in Bulacan, Pampanga and Nueva Ecija (Region III) and in Rizal, Laguna and Batangas (Region IV-A) (Table 3). The survey comprised seven tilapia cage hatchery operators, nine pond hatchery operators, five cage grow-out operators, and eleven pond grow-out operators. The farms were selected to provide a representative sample of small-scale (<2 tonnes per hectare per crop), medium-scale (2–5 tonnes per hectare per crop) and large-scale (>5 tonnes per hectare per crop) operations. Two questionnaires were prepared, *viz.* one for the hatchery operations and another for the grow-out operations.

TABLE 3
Details of the farms surveyed for the case study

Type/Location	Number of farms	Total farm area (ha) or number and size of cages
Cage hatcheries		
Region IV-A – Rizal	7	0.25–2 ha
Pond Hatcheries		
Region IV-A – Rizal	1	0.15 ha
Region IV-A – Laguna	1	5 ha
Region III – Nueva Ecija	5	1.65–10 ha
Region III – Pampanga	2	10–18 ha
Grow-out cages		
Region IV – Batangas	5 (intensive)	1–21 units of 10 x 10 x 20 m cages
Grow-out ponds		
Region III – Nueva Ecija	4 (semi-intensive)	0.6–40 ha
Region III – Pampanga	6 (1 semi-intensive and 5 intensive)	1.7–29 ha
Region III – Bulacan	1 (semi-intensive)	3 ha

Source: Field survey (2010).

3. RESULTS AND DISCUSSSION

3.1 Feeds and feed utilization

In aquaculture, feeds generally account for more than 50 percent of farm operational costs (Rana, Siriwardena and Hasan, 2009). Specifically, between 60–80 percent of the operational costs in intensive production systems are due to feeds, and in semi-intensive systems and between 30–60 percent of operational costs are attributed to feed and fertilizer costs (PHILMINAQ, 2007). In extensive and semi-intensive pond culture systems, fertilizers are applied to promote primary productivity. In tilapia cages set in eutrophic lakes, such as Laguna de Bay – the largest Philippine freshwater lake, feeding is minimal, and the tilapia rely on the natural productivity of the system for nutrients. In these systems, the unnecessary or excessive use of feeds, or the use of poor quality feeds, may negatively affect the environment (BFAR-PHILMINAQ, 2007).

3.2 Commercially produced complete feeds

Of the 426 registered commercial feed millers in the Philippines, 78 produce aquafeeds (Sumagaysay-Chavoso, 2007; PHILMINAQ, 2007). In recent years, there has been an increase in the number of local animal feed companies producing and distributing commercial tilapia feeds. Several of these companies produce phase diets (diets for the different growth stages) for tilapia. In contrast, a number of manufacturers (HocPo, Vitarich, B-meg and Santeh) produce 'generic' diets, meaning non-specific aquafeeds

(feeds meant for any fish species) – in this case either for milkfish or tilapia. Over time, feed manufacturers have diversified their products and increased production to supply the growing need for tilapia feeds. In 2006, the Bureau of Animal Industry (BAI) reported that the largest producers of aquaculture feeds in the Philippines were found in Region III (n = 32 feed companies), followed by Region IV (18) and the NCR (10) (PHILMINAQ, 2007).

The proximate composition of many of the commercially available tilapia feeds conform to the gross nutrient composition as outlined by Hasan (2007). Typically, the protein content is between 30 and 56 percent in fry feeds, 30–40 percent in the juvenile feeds, and 22–32 percent in the adult feeds. Lipid contents range between 5 and 12 percent, carbohydrates between 30 and 40 percent, and crude fibre between 4 and 20 percent. With respect to the feed costs, between 2005 and 2010 the average price of commercial tilapia fry feeds increased by 64 percent from US$0.47/kg to US$0.77/kg. During this period, fingerling and grow-out diets increased by 36 percent from an average of US$0.42/kg to US$0.57/kg (Hasan *et al.*, 2007 and this survey).

Farmers assessed the importance of various factors affecting their use and choice of feeds (Table 4). The farmers rated these factors between 1 and 10, with 10 being the most important. It was evident that farmers had little knowledge on how to assess feed quality, and simply relied on visual observations. In terms of water stability, the farmers do not test the feed at all. With respect to palatability, visual observation, and checking whether fish immediately ingested the diet after they had been administered, were the only criteria that farmers used. None of the surveyed farmers took note of the taste of the tilapia feed but deemed this criterion important, together with nutrient composition. Tilapia cage grow-out farmers rated feed quality at 9.8, suggesting that this factor was an extremely important consideration in their purchasing decisions. In contrast, tilapia cage hatchery operators rated feed quality at 7.5, indicating that feed quality was of less importance to them. This low score was due to the cage hatchery operators locating their spawning and larval rearing cages in a eutrophic lake with good primary productivity where, due to the natural productivity of the system, artificial diets are not so necessary.

TABLE 4

Evaluation scores of farmers on the importance of feed quality as a factor perceived to influence farm production and the associated costs

Criterion	Grow-out farms				Hatchery farms			
	Cages	Ponds			Cages	Ponds		
	Reg IV-A Batangas farms	Reg III Nueva Ecija farms	Reg III Bulacan farms	Reg III Pampanga farms	Reg IV-A Rizal f arms	Reg IV-A Rizal, Laguna farms	Reg III Nueva Ecija farms	Reg III Pampanga farms
Palatability	10.0	8.8	7.0	7.3	6.2	7.5	8.6	9.0
Water stability	10.0	9.3	7.0	8.6	7.6	9.0	8.8	8.5
Nutrient composition	9.4	9.3	10.0	7.5	8.7	9.5	9.8	8.0
Feed quality	9.8	9.2	8.0	7.8	7.5	8.7	9.1	8.8
Feed price	–	9.5	10.0	9.6	9.0	8.5	10.0	8.0
Regularity of supply	10.0	9.3	10.0	10.0	8.4	8.5	9.8	8.0
Brand used	10.0	10.0	10.0	8.4	8.4	9.0	8.0	8.5
Freshness	10.0	10.0	10.0	9.0	8.7	9.5	9.2	10.0
Reliability of feed labelling information	8.8	9.5	7.0	8.8	7.1	7.5	9.0	8.5

Source: Field survey (2010).

The perception of farmers with respect to feed costs, their availability and information on the ingredients and the quality used in commercial diet formulation was also recorded (Table 4); each was asked to assess the impact of these factors on their production costs. The respondent farmers considered price as an important factor in their farm operations. Supply or feed availability is as important but generally the farmers do not have any major problems with feed availability, since those who require feeds in bulk have their own feed storage facilities, or have the feeds readily delivered to them. On the other hand, those with minimal feed requirements are able to purchase them from small feed distributors or outlets. The feed brand is also important, although some farmers – especially those engaged in cage hatchery operations in Laguna Lake – administer any animal feed that is available at the time of purchase. For farmers that have access to technical information, feed brand and information on the ingredients used by the manufacturer are important factors that influence their decision on which commercial feeds to purchase. Feed freshness is also an important criterion as the farmers take note of sensory indicators – especially if they notice that the feeds are rancid and have an off-odour. The survey questionnaire originally included digestibility and the importance that farmers place on this as a criterion for feed quality and its influence on production costs. However, this criterion proved difficult for farmers to quantify, much less comprehend. It entails the measurement of a specific nutrient (e.g. protein) in the feed and faeces (Feed Development Section, 1994). Results of this part of the survey were not included because the respondents did not have a clear technical understanding of what digestibility meant.

In terms of evaluating the efficacy of commercial feeds, the farmers depend solely on the information that is presented on the feed packaging. As for the reliability of the information found therein, the only way for the farmer to validate the feed specification is to have a proximate analysis undertaken. However, the farmers do not have the means to do this. Generally, the farmers find the commercial feed manufacturers reputable, even though they do not have the nutrient composition of their feeds counterchecked; they believe that all the information on nutrient composition is credible – their scores on this factor were between seven and ten. Only when they find the fish to be growing poorly, when following the optimal feeding management schemes, will they doubt the veracity of the claims of the feed companies. In the Philippines, the BAI, the Bureau of Agriculture and Fisheries Products Standards (BAFPS) and the Fish Health Section of the Bureau of Fisheries and Aquatic Resources (FHS-BFAR) are the three agencies involved in feed regulation. Their roles are to ensure that the industrially-made aquafeeds meet the regulatory standards set. These agencies are mandated to perform the following specific functions (PHILMINAQ, 2007):

- BAI – regulates animal feeds, ingredients, veterinary drugs and products under the Livestock and Poultry Feeds Act (Republic Act 1556), which covers aquafeeds.
- BAFPS – under the Republic Act 8435 it sets and implements quality standards for preservation, packaging, labelling, importation, exportation, distribution and advertising of processed agricultural and fishery products standards for efficient trade; this agency has drafted standards for both commercial aquafeeds and Best Aquaculture Practices.
- FHS-BFAR – undertakes activities that ensure compliance to aquafeed quality and farm practices.

3.3 Farm-made feeds

Farm-made feeds are normally produced when the cost of commercial feeds is deemed prohibitive, and farmers believe that their use will be more cost effective. The advantage of producing farm-made feeds is that the farmers are assured of the freshness, quality and contents of the formulation. The key element in successfully producing farm-made feeds is the technical capacity of the producer. In the current survey, only one farm used farm-made feeds. The owner of this farm operated a milling facility to produce pig and tilapia feeds, and used a consultant to advise on formulations. A major constraint to the production of farm-made feeds is access to necessary equipment and, regardless of the cost, many farmers find it more convenient to use readily available commercial feeds. In this regard, the survey revealed that only 6.25 percent of the farms regularly use farm-made feeds. In addition, one pond hatchery operator (GET farm) occasionally prepared farm-made feeds with duckweed (whenever this plant was available) (Figure 3). The ingredients that are available for inclusion in farm-made feeds are presented in Table 5. Typical formulations for practical tilapia diets are presented in Table 6.

FIGURE 3
A tilapia pond hatchery operator growing duckweed in his farm to utilize it in his farm-made feeds

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TABLE 5
List of ingredients used in the production of farm-made feeds for a tilapia farm in Pampanga

Fry and pre-starter	Grower and finisher
Biscuit meal/wheat meal	Biscuit meal
Cassava meal	Cassava meal
Soybean meal	Soybean meal
Rice bran	Rice bran
Copra	Copra meal
Blood meal	Blood meal
Fishmeal	Fishmeal
Coconut oil	Coconut oil
DL-methionine	DL-methionine
Vitamin premix	Vitamin premix
Mineral remix	Mineral premix
Luctanox	Luctanox
Luctamold	Luctamold
Choline chloride	Choline chloride
Vitamin C	Vitamin C (coated)
Anti-salmonella	Yeast
T5X (toxin binder)	T5X (toxin binder)
Salt	Common salt
	Monodicalcium phosphate (MDCP)

Source: Jane Caras, Harvest Moon Farm, personal communication, 2010.

TABLE 6

Practical diet formulations (g/kg dry diet) for tilapia at various stages of culture

Ingredient	Broodstock diet 1	Larvae/fry diet	Grow-out diet
Fishmeal	362	301.7	182.5
Maize gluten meal	204	–	–
Soybean meal	177	259.5	250.0
Copra meal	118	114.8	100.0
Leucaena (ipil ipil) meal	–	81.0	–
Cassava flour	–	–	364.2
Rice bran	75	149.7	60.0
Starch	32	30	–
Cod liver oil	5	10	–
Vegetable oil	5	10	–
Vitamin & mineral premix	22	43.3	43.3
Proximate composition (% dry matter)			
Crude protein	44.0	38.1	28.1
Crude fat	5.5	8.7	3.8
Crude fibre	9.1	5.6	3.6
Nitrogen free extract	29.6	30.8	54.6
Ash	11.8	16.8	9.9

Source: Santiago, Aldaba and Reyes (1987); Santiago *et al*. (1985; 1986).

The feedstuffs presented in Table 6, and the other components of the farm-made feeds (Table 5, Sumagaysay-Chavoso, 2007) are sourced locally. With the exception of fishmeal, which is either locally available or imported, most of the ingredients used in the farm-made feeds are affordable, and thus farm-made feed formulations remain economical feed options.

The major ingredients used in tilapia aquafeeds, both commercial and farm-made, are maize and maize by-products, soybean, copra meal and fishmeal (e.g. Table 6). Farm-made aquafeeds may incorporate aquatic and land-based plant materials (duckweeds, *Azolla*, water hyacinth), animal materials (snails, clams, silkworm larvae, maggots), plant processing by-products (de-oiled cakes and meals, beans, grains and brans) and animal processing by-products (blood and feather meal, bone meal) (Rana, Siriwardena and Hasan, 2009). Table 7 provides information on the cost of selected feed ingredients.

TABLE 7

2010 prices of commonly used feed ingredients for tilapia diets

Ingredient	Cost (US$/kg)
Maize and maize by-products	
Yellow maize – grains	0.31
Yellow maize – grits	0.31
Copra	
Copra cake	0.18
Copra meal	0.19
Soybean meal	
Soybean meal (United States of America)	0.53
Soybean meal 46% (Argentine Hi-pro)	0.50
Fishmeal	
Fishmeal 60% (United States of America)	1.06
Fishmeal 60% (Thailand)	1.23

US$1.00 = PhP 46.00 as of July 2010.

Source: Philippine Superfeeds Corporation, Navotas, Metro Manila, Philippines, 2010.

Of the ingredients listed, imported fishmeal is the most expensive, and at US$1.23/kg it is more than twice as costly as imported soybean meal (US$ 0.53/kg). In addition to the expense, fishmeal has become difficult to source, and this has affected both the availability of commercial aquafeeds and the production of farm-made aquafeeds. The high cost and availability problem associated with fishmeal use has led researchers to focus on the identification of alternative protein sources. Fishmeal replacement studies have been undertaken on soybean meal, soy protein concentrate, pea protein concentrate, cottonseed cake, maize gluten, poultry by-product meal, and feather meal (Li, Lim and Webster, 2006).

3.4 Supplemental feeds

Supplemental feeds are often used when farmers increase the stocking density and standing crop of the production system and the natural foods become insufficient to support optimal growth. Supplemental feeds used include rice bran, maize meal, copra meal, coffee pulp, brewery wastes or by-products, and chicken feed, bread crumbs (Alava, 2002). Although these are normally high-energy feed sources, they are low in terms of protein levels and micronutrients (Feed Development Section, 1994). Though nutritionally incomplete when administered singly, the use of supplemental feeds are more economical as they are cheap nutrient sources. Of the surveyed farmers, two out of the seven practicing lake-based hatchery farming supplement their breeders and sometimes their seed stock with bread crumbs or rice bran. Many of the lake-based hatchery operators, particularly in the Rizal province, are subsistence fish farmers and are unable to afford commercial aquafeeds; instead they use cheaper supplemental feeds. Production expenses are primarily confined to the purchase of broodstock, cage/module fabrication and maintenance, and transportation. If they can afford commercial aquafeeds, they are usually used as broodstock feeds, with feeding normally being restricted to alternate days. Only one of the seven surveyed lake-based hatcheries used commercial aquafeeds on a continuous basis to feed their breeders and seed stock.

3.5 Feed additives

The main additives used in tilapia feeds are vitamin C and α-methyl testosterone. Both are used in hatchery feeds. Two out of the 16 hatcheries surveyed use vitamin C in their broodstock diets to improve egg quality and enhance disease resistance. Three of the 16 hatcheries surveyed produced sex-reversed all-male tilapia seed stock by feeding newly hatched fry with diets containing α-methyl testosterone. Sixty percent of the surveyed commercial tilapia pond hatcheries in Nueva Ecija follow a standard protocol for sex-reversal through hormonal manipulation. These incorporate doses of 50–60 mg α-methyl testosterone per kilogram of feed. The feed is administered to the tilapia fry for 21 to 23 days to obtain a population of 90–95 percent males. One farm reported using the hormone treatment for 35 days. Alpha-methyl testosterone is imported from Germany and costs US$ 36.5 per 10 g. With the added cost for the hormone, sex-reversed seed stock are 20 percent more expensive than normal tilapia seed stock.

3.6 Fertilizers

Fertilizers are used in extensive and semi-intensive pond culture systems. The survey revealed that inorganic fertilizers, including mono-ammonium phosphate (16-20-0 or 16 percent N, 20 per cent phosphate), urea (46-0-0), ammonium sulphate (21-0-0), and 14-14-14 are used. The most commonly applied organic fertilizer was chicken manure. It has been reported that in 2000–2001, 50 percent of the inorganic fertilizers used in the aquaculture industry were imported (ADB, 2005b). A summary of the fertilizer application practices amongst the surveyed farmers is presented in Table 8.

TABLE 8

Mode of pond fertilization in the tilapia farms surveyed in different provinces

Parameters	Nueva Ecija	Pampanga	Bulacan
Type	**Inorganic**	**Inorganic and organic**	**Inorganic and organic**
Grow-out ponds			
Fertilizers	Urea (46-0-0) and Ammonium phosphate (16-20-0)	Farms use two, three or all of the following: Urea (46-0-0) Ammonium phosphate (16-20-0) Ammonium sulphate (21-0-0) Nitrogen-phosphorus-potassium (14-14-14) Chicken manure	Ammonium phosphate (16-20-0) and chicken manure
Fertilization rate/amount used	20 kg 46-0-0, 5–6 kg 16-20-0 (mixed/hectare/week)	20–80 kg 46-0-0/ha 20–200 kg 16-20-0/ha 30–80 kg 21-0-0/ha 20–40 kg 14-14-14/ha 30–50 bags chicken manure/ha	100 kg 16-20-0/ha 50 bags chicken manure/ha
Cost	16-20-0: US$17.6/50 kg Urea: US$17.8/50 kg	16-20-0: US$15.6/50kg to US$20/50 kg 46-0-0: US$19.6/50kg to US$21.3/50 kg 21-0-0: US$11.7 to IS$11.9/50 kg 14-14-14: US$18.7 to 19.6/50 kg Chicken manure: US$1.3/50 kg	16-20-0: US$17.8/50 kg Chicken manure: US$1.1/50 kg
Method of fertilization	Fertilizer dissolved in bucket and then dispersed on the pond surface; this is done 6 times during the entire culture period	Broadcasting (dispersed from one side of the pond) or hanging method	Broadcasting
Hatchery ponds			
	Laguna and Rizal	**Nueva Ecija**	**Pampanga**
Fertilizers	Farmers use either 16-20-0 and chicken manure or chicken manure alone	Farmers use either 46-0-0 and 16-20-0 or 16-20-0 and chicken manure	Farmers use any two or all of the following: 46-0-0 16-20-0 chicken manure
Fertilization rate/amount used	1 kg 16-20-0/pond 50–100 kg chicken manure/pond	50–100 kg 46-0-0/ha 30–100 kg 16-20-0/ha 50–200 kg chicken manure/ha	100 kg 16-20-0/ha 100 kg 46-0-0/ha 100 kg chicken manure/ha
Cost	16-20-0: US$17.6/50kg Chicken manure: US$0.54 to 0.87/50kg	16-20-0: US$17.4–26.1/50 kg 46-0-0: US$17.4–26.1/50 kg Chicken manure: US$0.98/50 kg	16-20-0: US$18.5–21.7/5 0 kg 46-0-0: US$18.5–21.7/50 kg
Method of fertilization	Broadcasting	Broadcasting	Broadcasting

Note: US$1.00 = PhP 46.00 as of July 2010.
Source: Field survey (2010).

Pond fertilization practices vary between farmers and the use of inorganic and organic fertilizers varies with the intensity of the culture operations (e.g. intensive tilapia pond farming, pond-based seed stock production). Fertilizers are usually spread by broadcasting, not the tea-bag or hanging method. The traditional tea-bag or hanging method allows the fertilizers to gradually leach out; this occurs in the area of the pond where they are hung, and hence fertilization is slow and inefficient. The tea bag method was practiced at a time when fertilizers were relatively inexpensive. The broadcast method allows the fertilizer to be spread or dispersed much faster and more evenly throughout the pond; hence, in the long term, it proves to be more economical. A summary of fertilizer costs in 2009 is presented in Table 9.

TABLE 9

Whole-sale prices of fertilizers available in the major tilapia producing regions in the Philippines (2009)

Fertilizer	Region	Price (US$/kg)
Ammonium phosphate (16-20-0)	Region III (Central Luzon)	22.38
	Region IV-A (Calabarzon)	26.45
Ammonium sulphate (21-0-0)	Region III (Central Luzon)	12.74
	Region IV-A (Calabarzon)	15.98
Urea	Region III (Central Luzon)	19.69
	Region IV-A (Calabarzon)	22.82
Chicken manure*	Region III (Central Luzon)	0.97
	Region IV-A (Calabarzon)	1.09

Source: BAS (2010); *Field survey (2010).

US$1.00 = PhP 46.00 as of July 2010.

The retail prices for fertilizers varied between regions and, in contrast to Region III, are slightly higher in Region IV-A. The probable reason for the price difference is that these fertilizers are also used for agriculture in Region III, where crops such as rice are farmed – a region known as one of the major rice-producing areas in the Philippines. Region III (Central Luzon) therefore has more fertilizer brands and supplies in the market compared to Region IV-A, their costs in Region III less prohibitive. Organic fertilizers, such as chicken manure, are the cheapest fertilizers available. The cost of inorganic fertilizers is generally higher, with the most expensive being ammonium phosphate (16-20-0).

3.7 Current feed management schemes

3.7.1 Feed selection

The selection of feed by farmers is usually based on affordability and quality. Quality is primarily measured as a function of the growth performance and survival achieved; several respondents indicated that their choice was based on past feed performance using a particular feed. From a more technical perspective, one of the more important criteria for feed selection is their efficiency in terms of their feed conversion ratios (FCR). Unfortunately, with the exception of farms that are managed by academic research and government agencies, farmer-operators of private hatchery/grow-out facilities are not familiar with using FCR as a measure of feed efficiency. Many farms, particularly grow-out operations, have limited financial resources and have to procure feeds on credit. Under this scenario, the feed supplier is paid for the feed inputs once the tilapia have been harvested and sold. Using this financing paradigm, several pond-based grow-out farms, specifically those in the major tilapia producing province/region of Pampanga, use feed from companies that offer loan/financing schemes; they are more concerned with maintaining access to the feed, than its cost. An exception was one pond-based hatchery (GIFT Foundation International Inc or GFII), which utilizes the same brand for broodfish and seed stock because its manufacturer, Feedmix Specialists Inc., is supporting GIFT Foundation research and development activities. According to their operations manager, GFII is able to recoup its high cost of production on the price of the seed stock, which they sell at premium prices. This selection by GFII also supports its claim to having the experience of being able to produce better quality seed stock. When GIFT tilapia fingerlings are sold, the use of Feedmix feeds by the grow-out farmers is optional.

Another factor that influences the choice of feed/feed brand that farmers use is the aggressive marketing and promotional schemes of the manufacturers. Some feed companies form 'business clubs' for their loyal clients and encourage new clients to try their feed products. The 'incentive' for joining clubs would mainly be easier access to a credit scheme and to technical assistance. Locally-based feed companies employ research personnel/consultants to conduct aquafeed research, and undertake on-farm production trials to develop new feeding regimes that are then recommended to the farmers. However, under intensive marketing pressures, there is concern that the farmers are easily convinced to use excessive amounts of feed, and fail to follow optimal feed management strategies. In this regard, many of the farmers in the survey, notably the grow-out farmers, tend not to adopt optimal feed management practices, and in many cases overfeed their fish. Feed distributors also aggressively promote their products and have sales agents that visit farms to promote them. If purchases are made in bulk, the feeds will be delivered to the farm site. Moreover, as mentioned earlier, many of these feed companies have their manufacturing plants close to the tilapia production centres. Feeds are either delivered directly from the feed manufactures, or are readily available from small feed suppliers that are located close to the farms.

The majority of the farmers use a single brand, except when they intend to follow a scheme that would help to reduce feed costs. Some hatchery operators use high-cost commercial feeds and administer them alternately with low-cost commercial diets. High-cost commercial feeds, which normally have higher crude protein levels than low cost feeds, are fed to broodstock especially during the conditioning phase, with the assumption that the breeders will have better spawning performance and enhanced reproductive efficiency. Several farmers utilize a single brand and administer fry, fingerling, broodstock formulations, which have been introduced by the feed sales agent. Feed companies have now developed phase diets and now sell various feed types depending on the growth stage of the tilapia. The phase diets are formulated according to the nutrient requirements of each growth stage of the fish (Table 6).

Farmers who prefer to store feeds on their farms normally have storage facilities. Feeds are not kept long enough to allow them to spoil. A typical storeroom for feeds at a tilapia hatchery is presented in Figure 4. The results of the survey revealed that while all the grow-out farms have feed storage facilities, only 50 percent of the hatcheries store feeds on the farm. The survey revealed that only two out of 24 farms had optimal storage conditions. The storage facilities differed in size, with the smallest stock room holding 30 bags (25 kg feed/bag), and the largest having capacity for 2 000 to 7 000 bags per month. The surveyed hatcheries without feed storage facilities are mostly those that produce seed stock in lake-based cages. Under sub-optimal storage conditions, feeds spoil easily and become contaminated with moulds, mycotoxins (from fungi) and bacteria (Rana, Siriwardena and Hasan, 2009). In this regard, to prevent feed spoilage, the farmers need to be well informed on how to store feeds appropriately. Moreover, if feeds must be stored in bulk to save on feed, procurement and transportation costs, farmers need to ensure that the feed is rotated such that shelf lives are not exceeded, and the feed is used on a first-in: first-out basis. In this regard, the majority of the farmers in the survey were adopting appropriate storage periods, based on the capacity and condition of their storage facilities. Some respondents indicated that on occasion, feed spoilage was an issue in terms of the feed becoming wet and infested with insects. The respondents indicated that spoiled feeds are unfit for use, as they lead to an increase in the incidence of disease and mortality.

The following factors affect nutrient stability in feeds during storage: a) the moisture content of the feed; b) the relative humidity; c) elevated temperatures; d) air circulation; e) lipid peroxidation, which may cause feed rancidity; f) insect infestation; g) fungal proliferation; and h) bacterial contamination (Golez, 2002; Rana, Siriwardena and Hasan, 2009). Such factors can be avoided if the storage facility is clean, dry, well

FIGURE 4
Farm storage facility for aquaculture feeds at the GIFT Foundation International Inc., Nueva Ecija

COURTESY OF FAO/M.R.R. ROMANA-EGUIA.

ventilated, secure, and not directly exposed to sunlight. In addition, feeds should be properly labelled and stacked on a slightly elevated platform to allow air to circulate (Feed Development Section, 1994; Golez, 2002). Most of the farmers in the Philippines are not familiar with feed storage issues, and as a result tend to learn about them only when they experience specific problems.

The bulk storage of feeds saves transportation costs. Those farmers that do not have storage facilities, or for financial reasons are unable to buy feeds in bulk, are able to purchase feeds from the local feed dealers as and when they are required (either on a per kilo basis or in 25 kg bags); they then transport them from the dealership to the farm themselves. Alternately, for bulk purchases, the feed dealer may deliver, and charge transport costs. Some feed companies set quotas (e.g. 200 bags minimum) for purchases made in bulk, and this entitles the farmer to free feed delivery.

3.7.2 Feed management

Feeding management practices are species-, site- and input-specific. All the tilapia grow-out farms that were surveyed practiced monoculture. The only farms that practice freshwater polyculture using tilapia are the pen culture systems in Region IV-A, particularly those in Laguna de Bay where the primary culture species are either milkfish or bighead carp. In 2008, these culture systems contributed only 11 997 tonnes out of a total 257 133 tonnes, or 4.7 percent of the total tilapia production in the Philippines (Table 2; BFAR, 2008). In terms of national tilapia production, this level of production is minimal, and thus this sub-sector was not covered in the present survey.

Philippine tilapia production is primarily undertaken in intensive pond culture systems in Pampanga. The majority of the grow-out farms surveyed there prepare their ponds for stocking, using both inorganic and organic fertilizers (Table 8), followed by the feeding of commercially produced aquafeeds. Once natural productivity is established in the ponds, some of the farmers delay or restrict the use of aquafeeds for up to a month to take advantage of natural feeds; feeding is initiated if the farmers notice that the primary productivity has declined. Alternatively, Pampanga farmers (ponds size: 3 to 9 hectares) feed their stocks commercial diets twice daily. Initial feed rations are 15 percent of the total fish biomass per day for three months, gradually reducing to two percent as the fish grow; feed is given thrice daily in the final month prior to harvest. A final average harvest size of 250 g is obtained. Conversely, tilapia produced in Nueva Ecija are grown in semi-intensive pond culture systems where artificial feeds (or sometimes supplemental feeds) are used in occasionally fertilized ponds. Both intensive pond culture farms in Pampanga and semi-intensive pond culture systems in Nueva Ecija have access to the genetically improved and sex-reversed tilapia seed stock produced in those regions.

In Region IV-A, the majority of the tilapia production is derived from Batangas' Taal Lake, and is based on intensive cage culture systems that use commercially produced aquafeeds (Figure 5). Cages here typically measure 10 x 10 x 20 m^3 and are stocked at a rate of 100 000 to 300 000 mixed-sex tilapia fry per cage. With this high stocking density and lake primary productivity that is insufficient to provide sufficient natural food, the farmers have to use compound aquafeeds. Feeding is undertaken throughout the three to eight month culture period, at three to five percent of the total fish biomass per cage. Feed rations are dependent on the stocking density and prevailing weather conditions; this entails reducing rations when weather is cooler than usual. Dietary formulations (fry, fingerling and grower) are administered as stocks are reared from fry to marketable size. Marketable fish could either be of assorted sizes, or of four to five pieces to a kilogram (200 – 250g each) after five months. This means that some of the farmers do not sort the fish or do selective harvesting, as they are not particular about the size composition of the harvested tilapias.

FIGURE 5
Use of commercially produced aquafeeds in intensive cage farms in Taal Lake

COURTESY OF FAO/M.R.R. ROMANA-EGUIA.

The primary difference between intensive tilapia cage farming and pond farming is the percentage survival. The survey revealed that intensively farmed tilapias in ponds survive at higher rates (60 to 80 percent) compared to intensively farmed caged tilapias (50 percent). Cage grow-out operators particularly in Batangas do not own the farms themselves but are salaried farm technicians, who may not have an adequate technical background but learn the trade through experience. They do not mind if the harvested tilapia is half of the total stocked population as long as the yield is sufficient to allow the farm owners to earn a profit. The yields from cages are low because the farmer-operators intentionally overstock the cages. Their premise is that, even if half of the stock dies, they are still assured a harvest that will enable the owners to a earn profit; and at the same time provide the technicians with their salaries.

Finally, in intensive culture systems, and in particular in pond culture systems, farmers are increasingly using greenwater systems. Thus, in addition to managing feed, water and dissolved oxygen levels, primary productivity is also managed (which requires fertilizer inputs). The management of primary productivity results in improved growth and survival rates.

Although feed prices are high, the majority of farmers do not formulate or make farm-made feeds. Farm- made feeds are not difficult to prepare, and the production techniques can be easily learnt using low cost equipment that is readily available (Figure 6). These skills are taught in agencies such as SEAFDEC/AQD as well as in some stations of the local fisheries bureau. Despite the availability of these courses, many farmers elect to use the commercially available aquafeeds that are readily available in the market.

FIGURE 6
Basic equipment used for making farm feeds at SEAFDEC/AQD Binangonan Freshwater Station: feed mixer (left), meat grinder/pelletizer (middle) and fabricated feed dryer (right)

COURTESY OF FAO/M.R.R. ROMANA-EGUIA.

Farmers adopt feed management practices that optimize feed use and reduce operational costs. In this regard, local researchers have undertaken studies to determine whether feed management practices designed to reduce feed costs adversely affect tilapia growth. Bolivar, Jimenez and Brown (2006) demonstrated that feeding tilapia on alternate days did not significantly impact growth and survival. Additional feed management practices, including alternate feeding and delayed early feeding, have been tried; these show promising results. Some farmers have adopted these management practices and, as a consequence, have reduced their production costs. In addition, other researchers have undertaken exploratory work to determine the effect of variable feeding schedules and diets on the growth and fry production of Nile tilapia (Santiago and Laron, 2002). This research involved the use of high and low protein diets for both fingerlings and broodfish. The results demonstrated that the feeding schedules significantly influenced female body weight. Broodfish fed alternately with high-protein and low-protein diets produced the highest growth, fry production and feed cost savings.

3.7.3 Feeding strategies

In order to optimize growth rates and FCR, feeding strategies take into consideration ration size, feeding frequency and duration, appetite, feeding method, and feed monitoring. Feeding strategies need to take into consideration the nutritional requirements of the fish under different culture environments. Specific feeding strategies have been developed for tilapia broodstock, larvae and grow-out. Broadcasting feeding techniques are used, and the feed response is visually monitored so that feeding is ceased once the fish reach satiation.

3.8 Tilapia broodstock and hatchery operations

3.8.1 Cage-based hatcheries

Simple feeding methods are applied to cage-based hatchery facilities. These culture systems are common in Laguna Lake, Philippines (Figure 7), where the high natural productivity of the system supplies much of the nutritional requirements of the fish.

The need to supply additional nutrition through the application of compound aquafeeds is perceived as minimal, and therefore less than that administered in tank or pond based systems. Some of the tilapia hatchery operators in the lake employ techniques that are technically unsound or have no clear scientific basis. For instance, some of them have little knowledge about the adverse effects of: a) using broodstock from the wild which are of unknown ages and ancestry; b) pairing closely-related breeders; c) developing poorly selected potential broodstock from slow-growing unsold hatchery-bred fingerlings; and d) utilizing undernourished broodstock that are totally reliant on natural food in contrast to those fed with complete diets that enhance the their reproductive performance. Due to limited resources, broodstock are obtained from the wild, and are spawned at sex ratios of 1:5 or 1:10 (male:female). Sex ratios of 1:10 are high and considered sub-optimal. The usual sex ratios that are confirmed as effective and are adopted in tilapia pond hatcheries are between 1:1 to 1:4 or 1:5 (Bautista, 1988). Sex ratios beyond 1:5 (male:female) cause undue stress or spawning fatigue to the male stocks. Moreover, due to a poor understanding of the nutrient requirements of the broodstock that are spawned in cages, farmers do not always use supplemental broodstock feeds; this can result in suboptimal reproductive performance. In the absence of broodstock diets, lower seed yields can be expected. Instead of broodstock diets, some farmers use diets meant for other aquatic species, or even for poultry. These feeds are cheaper and do not contain the nutrients required for tilapia broodstock.

FIGURE 7
Hapa-based tilapia cage hatchery in Laguna Lake

COURTESY OF FAO/M.R.R. ROMANA-EGUIA.

3.8.2 Pond-based hatcheries

In comparison to cage-based hatcheries, the operation of pond or hapa-in-pond hatcheries (Figure 8) are both labour and input intensive. Pond hatcheries require more technically proficient operators than cage based hatcheries. With respect to yield, semi-intensive pond hatchery systems require more feed/fertilizer inputs than semi-intensive cage hatcheries. However, pond hatchery operations are more profitable (Table 10). The technology for tilapia seed stock production in ponds is more developed and cost-efficient than that applied to the cage systems. Feed management starts with the breeders used to produce the tilapia seed stock. Feeding is more frequent and the ration is defined at 1–2 percent of fish biomass. Except for one lake-based hatchery owner-operator, who has access to updated technical information from a nearby aquaculture research institution, most of the small-scale cage hatchery operators do not normally feed their broodstock artificial diets. Supplemental feeding is only undertaken if the farmer has extra funds to purchase feeds. The same is true for the feed management practices that are applied during the hatchery and nursery production phases. In comparison with pond culture operations, cage-reared tilapia fry are fed less frequently, as the farmers rely on the natural feeds in the water body. Conversely, the feeding strategies that are adopted in ponds (e.g. frequent feeding with formulated feeds) are well defined, and particularly so for the early larval stages. Early larval feed management strategies promote the production of strong fry/fingerlings with improved survivorship characteristics; even when commercial feeds are costly, the pond hatchery operators invest in them as they are assured better yields. A summary of the current hatchery rearing practices and accompanying feeding strategies is presented in Table 10, which includes an analysis of the gross returns (income from sale proceeds of fingerlings minus feed and fertilizer costs) from nursery feeding management.

FIGURE 8
Hapa-in-pond tilapia hatcheries in the Philippines

COURTESY OF A. LAZARTIGUE, SEAFDEC/AQD

TABLE 10
Management systems in small and large-scale tilapia hatcheries

Parameters	Cage hatcheries*	Pond hatcheries*
Broodstock management		
Size of broodstock enclosures	a) 5 x 12 x 1.5 m^3 b) 8 x 25 x 1.5 m^3	a) 100–1 000 m^2 b) 3 200 m^2
Total number of broodstock	a) 60 males and 600 females b) 2 000 males and 9 000 females	a) 6 000 b) 8 000–15 000
Type of incubators, if any	None	a) Recirculating system, jar type b) Downwelling incubators
Strain used	a) Wild (from Laguna lake) b) IDRC or FAST	a) GIFT G11 (GIFT Generation 11 2003) b) Genomar
Sex ratio for spawning	a) 1 Male: 10 Females b) 1 Male:5 Females	1 Male:3 Females
Initial broodstock size – final broodstock size	a) 100–300 g; b) 350–1 000 g (after 6 months to 1 year)	100–150 g females; 100–200 g males
Duration of use	a) 6 months b) 1 year	a) 2–3 years b) 1 year
Broodstock management	a) only males are replaced after 6 months b) both sexes totally replaced after 1 year	Total replacement
Average no. of eggs or fry/female	200–250	200–1 200
Broodstock feeding strategy		
Feeding frequency	a) Feeds given only as needed and when available b) once per day, alternate days	Twice per day
Time of feeding	a) No specific time b) 0900 hours	a) 0830 to 0900 hours, 1400 to 1500 hours b) 1000 hours, 1600 hours
Amount of feed	a) 1 kg ration for fish in 6 cages b) 2.5% of BW	a) 2% of BW; stocks sampled b) 1–2%, adjusted every 2 months
Feed brand/type used	a) Dry, sinking b) B-meg grower – dry, sinking pellets (28%CP); broodstock feed important, especially as it enhances the reproductive performance of the fish	a) Feedmix floating pellet b) Purina (high value)/Hoc Po (low value)
Feeding method	Manual, broadcasting	Manual, broadcasting
Feed monitoring	Regular	a) Regular b) Every two months
Growth performance of broodstock	Just right, controlled	a) Moderate from 200 g initial to 400 g final b) Moderate
Strategy to save on feed cost	a) Supplemental feeding practiced; very minimal feed inputs b) Skip feeding to supplement natural food already present in the lake	a) Skip feeding; reduction of amount from 3% to 2% daily b) Alternate feeding of fish with high-value then low-value feeds; high-value feeds given especially prior to conditioning

Parameters	Cage hatcheries*	Pond hatcheries*
Hatchery (fry) feeding management		
Feeding frequency	a) 3 times/week b) 6 times/day (to fry size 24)	a) 6 times/day b) 8–10 times/day with Tateh-brand commercial feeds for weeks 1–2 then 5–6 times/day for weeks 3 and 4
Time of feeding	a) No fixed time; mornings only b) 3 times in the morning and 3 times in the afternoon	a) 0800, 0900, 1000 hours/1400, 1500, 1600 hours b) Every hour
Amount of feed	a) 1 kg feed ration for 2 cages containing 70–80 tilapia/cage b) 5% of BW; adjusted weekly through regular sampling	a) Week 1 = 30%, 2 = 20%, 3 = 10% b) 100%; note that ponds lack natural food, as they are lined
Brand/type of feed	a) Any dry sinking b) B-meg fry mash/dry sinking	a) Feedmix floating SP1 and SP2 b) Tateh Fry booster
Feeding method	Manual	Manual
Average fry survival	a) 50% from fry to size 24 b) 90% from fry to size 24 (2 weeks under favourable conditions; 4 weeks if otherwise)	a) 70–85% (especially after MT treatment) b) 65–85%
Type of fry produced	Normal	a) Sex-reversed b) Sex-reversed
Reversal method	N/A	a) 50–60 mg alpha-methyltestosterone (MT)/kg used; 21–23 days treatment b) 50–60 mg MT/kg used; 21–23 days treatment
Nursery feeding management		
Feeding frequency	a) 3 times/week b) 3 times/day from size 24 to size 14	a) 3 times b) no nursery phase; seed stock sold easily
Time of feeding	a) Morning only b) 3 times/day	a) 0900 hours, 1100 hours, 1500 hours
Amount of feed	a) Ration divided among caged stocks b) 5% of BW	a) 5%
Feed brand and type	a) None in particular b) B-MEG fry mash, sinking dry	a) Feedmix, floating
Days of culture of seed stock	a) 14 days from fry to size 17/14 b) 30 to 45 days from size 24 to size 14	30 days from size 20–17
Production per run	a) 80 000 b) 1 million	a) 1 million/month b) 2 million/month
Estimated gross returns based on the feeds/fertilizers used	a) Very minimal feed inputs; US$870 value of 80 000 fingerlings; Return = US$870 b) US$4 891 cost of feed inputs; US$9 783 value of 1 million size 14 fingerlings; Return = US$4 892	a) US$1 574/month for feed inputs, US$522/month for fertilizer inputs; US$14 130 value of 1million/month of size 14 fingerlings; Return = US$12 034/month b) US$17 374/month for feed inputs, US$26 957 value of 2 million/month of size 14 fingerlings; return = US$9 583
Feed additives used	None	None vitamin C for broodstock
Seed stock transport	a) boat hull b) plastic bags, aerated boxes	plastic bags

**Source and key:* a) = low to medium input farms (cage hatchery data based on information provided by D. Santiago and pond hatchery data obtained from GIFT Hatchery); b) = high input farms (cage hatchery data based on information provided by East Cove Hatchery and pond hatchery data obtained from PhilNor Aqua Inc.); inputs refer to number of broodstock used and feed and better management inputs.

3.9 Tilapia grow-out operations

Tilapia grow-out farms in the Philippines are either based on semi-intensive or intensive pond culture technologies. These culture practices are widespread in the province of Pampanga and Nueva Ecija. This area is ideal as it is close to the seed stock sources based at Munoz, Nueva Ecija. In addition to the pond grow-out systems, cage culture systems are used in Batangas. The strategies for on-growing tilapia in ponds are well established and researched (Eguia and Romana-Eguia, 2007). Approximately 45 percent of the surveyed pond grow-out operators have benefited from technical support. In comparison, none of the cage grow-out farmers that were surveyed had received any formal technical training or support, and it is assumed that their technical knowledge was provided by the feed distribution companies. Table 11 provides an outline of the methods that are used for grow-out production, and includes an analysis of the gross returns (income minus feed and fertilizer costs) from grow-out feeding management. The feed consumption, yields and feed conversion ratios attained in the different culture systems is presented in Table 12.

TABLE 11
Management systems in small and large-scale tilapia grow-out farming systems

Parameters	Cages	Ponds
Size of culture enclosures	10 x 10 x 20 m^3	a) 20 000–60 000 m^2 b) 10 000–30 000 m^2
Total no of seed stock per cage	a) 100 000/cage (50/m^3) b) 260 000/cage (163/m^3)	a) 2/m^2 at 50g/piece a) 4/m^2 at size 14* (1.5 cm)
Strain used	Mixed-sex hatchery seed stocks from Laguna/Laurel, Batangas	a) GIFT-derived strain b) Hatchery bred, parental stock from SEAFDEC
Initial stocking size	Sizes 22 to 17* (1.00–1.25 cm)	a) Advanced fingerlings (50 g) b) size 14* (1.5 cm)
Culture method	Intensive	a) semi-intensive b) intensive (full feeding)
Days of culture	a) 8 months b) 3 months	a) 7–8 months (target size = 700–800 g) b) 3.0–3.5 months
Feeding frequency	a) 3–4 times/day for 2 months and 2 times/day from month 3 to month 8 b) 2 times/day	a) 2–3 times; 3 times for smaller fish b) 2 times/day for 2 months and 2–3 times for remaining month
Time of feeding	a) 08.00 hours, 12.00 hours and 16.00 hours; then 09.00 hours and 15.00 hours b) 09.00 hours and 15.00 hours	a) 09.00 hours and 15.00 hours b) 09.00 hours and 15.00 hours; then 09.00 hours, 12.00 hours and 16.00 hours
Amount of feed	a) 5 kg/day for months 1–2; 120 kg/day for months 3–8 b) 6 bags/day (150 kg/day) during good weather; 5 kg during bad weather	a) 2–3% BW; 400 bags/cropping b) size 14 (2 g); 15% BW; 3–5 g; 10%; 6–22 g: 7%; 22–39 g: 6%; 40–65 g: 5%; 66–75 g: 4%; 91–120 g: 3%; 121–200 g: 3%; 201–251g: 2%
Feed brand/type used	a) Feedmix SP1to GT35 (floating then sinking) b) B Meg floating pellets	a) Global-brand aquafeed b) Farm-made feed
Feeding method	Manual, broadcasting	Manual, broadcasting
Feed monitoring	Regular	Regular
Feed conversion ratio	No idea	a) 1.5:1–1.7:1 b) ~1:1
Growth performance	Good	a) Good, 50 g fish reach 700 g + in 7–8 months b) growth is faster when fed
Percentage yield or survival	a) 50% (Mar–Apr); 30% (Oct–Feb) b) Total yield = 20 tonnes	a) 60% b) 88%
Strategy to save on feed cost	Skip feeding if selling price of fish is low	a) none
Benefit-cost ratio estimate based mainly on feeds/ fertilizers used	a) 600 bags/cropping/cage used, hence US$9 130 cost of feed inputs; US$15 217 to US$19 022 value of harvestable tilapia at US$1.52/kg; Return = US$6 087 to US$9 891 (note: 50% survival) b) 250 bags/cropping/cage used, hence US$3 804 used for feed inputs; US$9 130value of harvestable tilapia; Return = US$5 326	a) 400 bags/cropping used, hence US$6 217 used for feed inputs; US$12 043 value of marketable sized tilapia (700 g each); Return: US$5 826 b) no data were given on feed cost for farm made feeds; according to the farm operator, they were able to break-even

Note: a) low to medium input farms (data from Pops Cage farm and SAAFI Inc.); b) high input farms (data from T. Dizago Cage farm and Harvest Moon Tilapia pond farm); inputs mean stocking density, feed and/or fertilizer inputs.
*tilapia fingerling size – the figure in brackets refers to the mesh size of the net used in sorting fish.

Source: Field survey (2010).

TABLE 12

Feed conversion ratios based on feed consumption and yield data of the surveyed farms

Location	Feed consumed (kg)	Fish yield (kg)	FCR
Cage-based, Region IV-A			
Pops Enterprises Agoncillo, Batangas (intensive)	16 500	15 000	1.1:1
G Desagun Farm Agoncillo, Batangas (intensive)	11 250	7 000	1.6:1
S Encarnacion Farm Agoncillo, Batangas (intensive)	~11 250	30 000	<1:1
T Dizago Farm Agoncillo, Batangas (intensive)	~6 000	26 000	<1:1
V Villanueva Farm Agoncillo, Batangas (intensive)	~15 000	24 937	<1:1
Pond-based, Region III			
FAC-CLSU Munoz, Nueva Ecija (semi-intensive)	–	–	1.2:1–1.5:1
PhilNor Aqua Inc San Miguel, Nueva Ecija (semi-intensive)	–	–	1.2:1
R Limos Farm Sto Domingo, Nueva Ecija (semi-intensive)	2 500	2 500	1:1
San Antonio Aqua Fisheries Inc. (SAAFI) San Antonio, Nueva Ecija (semi-intensive)	–	–	1.5:1–1.7:1
E Lulu Farm San Luis, Pampanga (intensive)	~1 000	4 000	<1:1
V Cruz Farm San Luis, Pampanga (intensive)	~5 000	5 000	1:1
J Marin Farm San Luis Pampanga (intensive)	8 750	8 500	~1:1
R Alfonso Farm San Luis, Pampanga (intensive)	8 750	5 000	1.75:1
Harvest Moon Farm Candaba, Pampanga (semi-intensive)	~10 000	35 200	<1:1
D Maglanque Farm San Luis, Pampanga (intensive)	~25 000	43 750	<1:1
R Sevilla Farm San Miguel, Bulacan (semi-intensive)	3 600	3 360	1.07:1

Note: feed consumption and yield cells with no information (–) mean that data were not shared by these respondents; in these cases FCR were estimated by the farmers.
Source: Field survey (2010).

The feed conversion ratios (Table 12) varied from <1 to 1.7. Many FCR values are less than 1, and may not provide a true reflection of the feed performance. The low FCR recorded may have been due to the natural productivity in the systems, which provided nutrition to the fish over and above that which they received from the feed. The low FCR may also be attributable to poor record keeping, or inappropriate FCR calculations.

4. OVERALL ASSESSMENT OF FEED MANAGEMENT AND UTILIZATION

4.1 Conclusions

Applying the estimated gross returns that are based on feed/fertilizer inputs and fish yield, it seems that tilapia the feed utilization and management of breeding and hatchery operations are more cost-efficient when in intensive conditions. In contrast, cost efficiencies in pond and cage-based tilapia grow-out systems are similar; however, profitability could be further increased with improvements to feed management strategies.

Feed use is responsible for approximately 50–60 percent of operational expenses. In this regard, the possibility of achieving higher returns on investment would be greater if farmers adopted cost-saving strategies to minimize feed costs. In future, feed ingredient costs will inevitably continue to rise as the demand, and particularly that for imported feedstuffs (e.g. fishmeal), increases. Therefore, research programmes need to be coordinated to improve feed technologies and provide farmer training to improve feed efficiencies. Existing technologies, ranging from the formulation of farm-based feeds to the use of efficient fertilization and feeding strategies (Thakur *et al.*, 2004) are currently available. However, research and development institutions – particularly those with the additional mandate to promote technologies as such – need to disseminate and commercialize these technologies to the fish farmers. Another concern is the need to educate the farmers on the adoption of sustainable farming practices. Notably, when using formulated feeds, farmers should adopt best management practices that not only increase earnings but also minimize environmental impacts. The gradual destruction of the environment brought about by the negative impacts associated with intensive tilapia farming may reduce productivity, ultimately affecting profits. An initiative to promote environmentally sustainable aquaculture also needs to include the fish feed manufacturers. This sector has the responsibility of developing products that are both cost-effective and minimize their negative environmental impacts. With respect to research institutions, it is hoped that they will continue to receive support from both the national government as well as the private sector to improve and refine culture technologies, including nutrition. The research institutions should not only disseminate science-based technologies to farmers but also provide backstopping support in terms technical inputs to legislators, particularly with respect to forming regulations related to feed quality.

Recently, farmers have started to report production problems perceived to be associated with natural calamities and climate change (sudden temperature fluctuations due to El Niño); these are reported to be negatively affecting both breeding and grow-out operations. Such problems are seriously affecting stocks bred and reared in land-based facilities, especially in earthen ponds, and researchers need to focus on addressing these issues.

Finally, the three government agencies involved in feed regulation, namely BAI, BAFPS and FHS-BFAR, should ensure that feed manufacturers strictly observe aquaculture feed quality standards, and that the aquaculture practitioners adopt suitable feed management strategies (BFAR-PHILMINAQ, 2007). When strictly implemented, the guidelines/policies as proposed by these agencies will benefit the farmers.

4.2 Recommendations

In summary, the following recommendations are made to promote increased tilapia production through improved feeds, feed management practices and aquafeed-related regulations:

4.2.1 For farmers:

- Keep good records of all the activities on the farm – especially in terms of the type of feed inputs, feeding management, breeding and farming practices, fish yields, and other information pertaining to the husbandry schemes that result in increased fish production. This is to allow the farmer to determine the viability of the farm (both from technical and financial perspectives) and implement improvements as necessary to further optimize tilapia production at a minimal cost.
- Seek advice and adopt feed management innovations from trained technical people, such as aquaculture researchers and extension workers.
- Apply good feed management and husbandry techniques to improve yields.
- Actively seek and try improved industrial aquafeed products, as well as inexpensive raw materials for use as ingredients for farm-made feeds.

4.2.2 For technology developers/aquaculture researchers/extension workers:

- Develop low pollution, cost-effective diets.
- Promote the importance of acquiring skills on the production and use of farm-made feeds.
- Evaluate raw materials for feed ingredients that can be used as substitutes for expensive and imported feed ingredients such as fishmeal and soybean meal.
- Develop cost-effective feeding strategies that would improve production efficiencies.
- Guide government agencies in the formulation of guidelines for feed regulations.

4.2.3. For regulatory bodies (BAI, BAFPS and FHS-BFAR):

- Define their individual mandates to avoid overlaps in their respective regulatory functions.
- Strictly enforce the nutrient standards for aquafeeds in the Philippines.
- Create and implement standards for feed quality, such as feed digestibility, diet stability and FCR.
- Develop and promote the use of simple feed quality assessment methods at the farm level.
- Promote good feeding management practices to the farmers.
- Effectively and regularly monitor feed supply, feed prices and feed product standards in the aquafeed markets.

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