

# On-farm feeding and feed management in tilapia aquaculture in Malaysia

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Ng, W.-K., Teh, S.-W., Chowdhury, K.M.A. and Bureau, D.P 2013. On-farm feeding and feed management in tilapia aquaculture in Malaysia. In M.R. Hasan and M.B. New, eds. *On-farm feeding and feed management in aquaculture*. FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. pp. 407–431.

## ABSTRACT

A field survey was conducted over a period of 10 months in 2007 to collect data on tilapia farming practices by small, medium and large producers in Malaysia, focusing on on-farm feed management practices and feed inputs. One hundred and four farms in both Peninsular and East Malaysia from the states of Negeri Sembilan, Pahang, Perak, Penang, Sabah, Sarawak, Selangor and Terengganu were surveyed. The major tilapia culture systems were found to be earthen ponds (46 percent), ex-tin mining pools (24 percent), and cage culture (21 percent). The dominant tilapia farmed is various red hybrid tilapia (*Oreochromis spp.*). The farm owners are predominantly male (age range between 41 and 60 years), and about 70 percent listed aquaculture as their major source of income. About 54 percent of the farmers own the land, but these are mainly small- and medium-scale producers. Large producers in certain states operate on temporary operation licences issued by the state land office. Tilapia production occupies a small percentage of the total land available on the farm, and other agricultural activities such as livestock and vegetable farming are sometimes carried out to supplement farm income; about 76 percent of farm land remains unused. Production function analysis suggested that cage culture was the best-performing system with the highest production yield. The average feeding costs of the surveyed farms were almost 63 percent of the production costs. High production cost was found to be caused by the use of commercial tilapia feeds in over 90 percent of the farms surveyed. The three major commercial aquafeed brands used by the tilapia farmers were Cargill (33 percent), Star Feeds (30 percent) and Dindings (21 percent). Analyzed proximate composition of various feed samples mostly tallied with the composition declared by feed manufacturers. Supplementary feed inputs, such as cattle and poultry pellet feeds, farm-made feeds, copra meal, palm kernel cake, poultry intestines, animal carcasses and kitchen waste, are used by small and medium producers to reduce feeding costs. Farm-made feeds varied greatly in their proximate composition depending on the ingredients used. Inorganic commercial fertilizers for pond

water fertilization are not commonly used in tilapia farms in Malaysia. In conclusion, technical aspects of tilapia farming such as the use of cost-effective feeds and better tilapia strains need to be given special emphasis in order to boost the production of tilapia with maximum profitability. Two industries identified as having the potential to supply much needed locally available alternative feed ingredients are the oil palm and poultry industries.

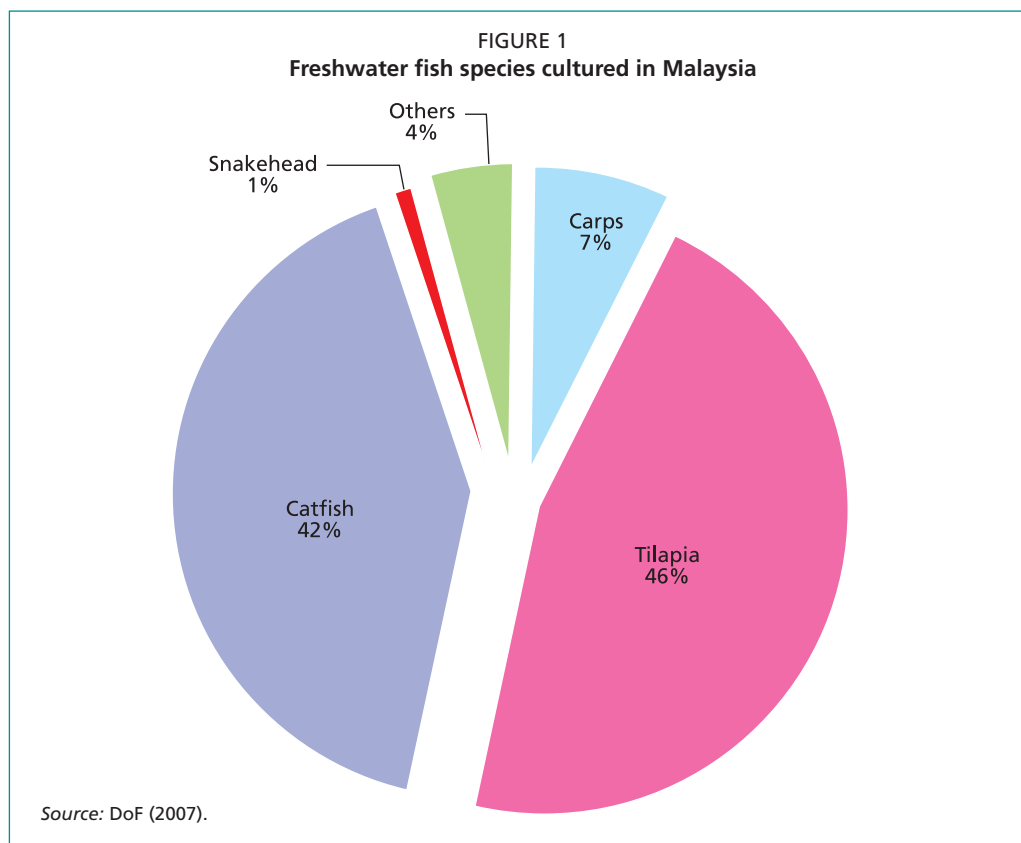
## 1. INTRODUCTION

In Malaysia, the fisheries sector contributed 1.42 million tonnes of seafood valued at MYR5.3 billion<sup>1</sup> (US\$1.66 billion) in 2007 (DOF, 2007). The sector can be divided into two main subsectors, namely the marine capture fisheries industry and the aquaculture industry. The marine capture fisheries subsector accounted for about 84 percent of total seafood supply. The inland capture fisheries subsector is very small, contributing less than 1 percent of the total seafood supply. The aquaculture industry contributed 268 500 tonnes (about 16 percent) to the seafood supply, valued at about US\$0.41 billion (DOF, 2007). Due to very favourable government policies (MOA, 1999), this subsector has great potential for further expansion (Ng 2009a,b). The local aquaculture industry recorded annual growth rates of about 10 percent from 1993 to 2007. The presence of vast bodies of inland freshwaters and the long coastlines of Peninsular Malaysia and East Malaysia augurs well for future aquaculture development. Malaysia is also a major global supplier of ornamental fish and aquatic plants.

Freshwater aquaculture contributed about 26 percent of the total aquaculture production in 2007 (DOF, 2007), with production of 70 064 tonnes arising from various culture systems such as ponds, ex-tin mining pools, cages and tanks/pens (18, 4, 3 and 1 percent, respectively). The use of ex-mining pools for freshwater fish farming is unique to Malaysia due to the many abandoned such sites that are now filled with water. Fish are either released into these pools of various sizes and shapes or are farmed in small cages suspended in the water. The three major freshwater species groups farmed are the tilapias, catfishes and carps, constituting 46, 42 and 7 percent of total freshwater aquaculture production (Figure 1). Other cultured freshwater species include snakeheads, marble gobies and freshwater prawns. About 32 023 tonnes of tilapia were produced in 2007. Unlike other countries where Nile tilapia is the major farmed species, the major tilapia species farmed in Malaysia is the red hybrid tilapia (*Oreochromis* spp.), which accounts for about 82 percent of total tilapia production; the remaining production consists of the 'black tilapias' [Nile tilapia (*O. niloticus*), Mozambique tilapia (*O. mossambicus*) and hybrids thereof]. Red hybrid tilapias are generally of unknown genetic status and are bred to enhance appearance and marketability. The original red hybrid tilapia introduced into Malaysia was probably a hybrid of *O. niloticus* with *O. mossambicus*. There is also a very pale-pink hybrid variety (sometimes called the Malaysian white hybrid tilapia) that is known for its fast growth rates. The major catfish species farmed are the African catfish (*Clarias gariepinus* or its hybrids), various *Pangasius* species and the bagrid catfish (*Mystus nemurus*). Total catfish production in 2007 was 28 875 tonnes. Various carps such as grass carp (*Ctenopharyngodon idella*), silver barb (*Barbonemus gonionotus*), common carp (*Cyprinus carpio*) and bighead carp (*Hypophthalmichthys nobilis*) are farmed, but production is relatively small, amounting to about 5 005 tonnes in 2007. Aquaculture production of the giant freshwater prawn (*Macrobrachium rosenbergii*) amounted to only about 246 tonnes in 2007.

The Malaysian Government targeted a production of 600 000 tonnes of seafood from aquaculture by 2010 (Ng, 2009a) under the Third National Agricultural Policy (NAP3). NAP3 is a guideline formulated by the Malaysian Government for the development of

<sup>1</sup> US\$1.0 = MYR3.2



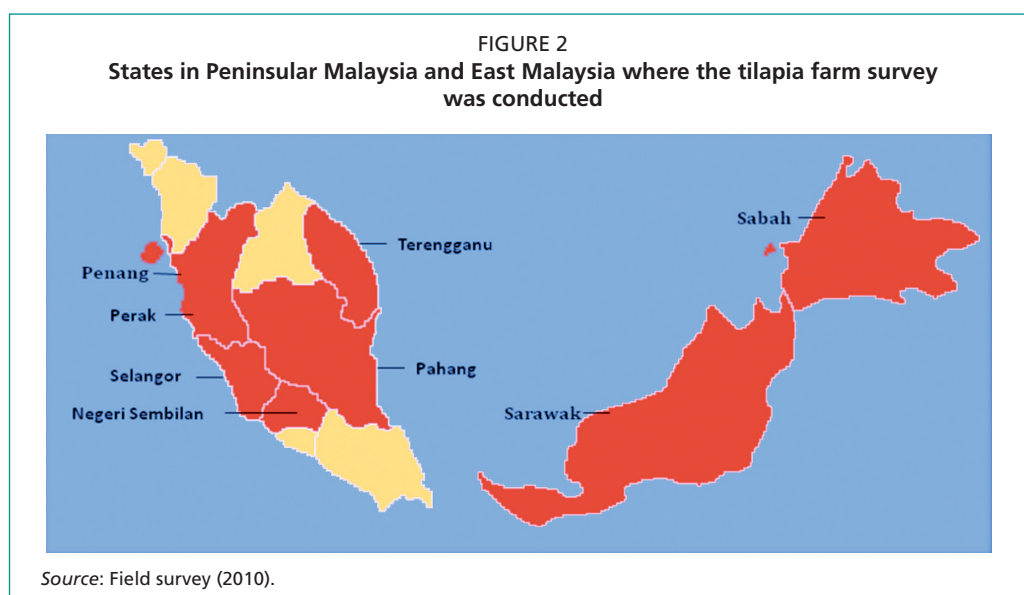
the agriculture sector, which includes fisheries. It emphasizes development towards a fully modern and commercialized capture fisheries and aquaculture industry through exploitation of available resources on a sustainable basis. NAP3 promotes commercial-scale aquaculture. The initial target was to have an estimated contribution of 123 500 tonnes from freshwater fish production by 2010, of which tilapia will be the major contributor (Ng, 2009a). Tilapia farming activities in Malaysia are therefore expected to undergo rapid development in the foreseeable future.

In view of this development, three organizations (Universiti Sains Malaysia, University of Guelph and the WorldFish Center) decided to conduct a comprehensive field survey of tilapia farming in Malaysia to collect baseline information about the industry. This was the first such study carried out on this industry in the country. It was hoped that the data collected could contribute to the formulation of appropriate policies and guidelines to expand tilapia farming on a sustainable basis. Data such as the socio-economics of farmer households, land status, water source, labour profile, support services availability, culture systems, access to tilapia fry for stocking, feed inputs, feeding practices, production costs, marketing of tilapia, and constraints faced by farmers were collected. Data were compiled based on on-farm interviews, farm measurements, photographs taken and the analysis of feed samples collected on the surveyed farms (WFC, 2009).

## 2. TILAPIA FARM CHARACTERISTICS

### 2.1 Number of farms and culture systems

A total of 104 farms was surveyed throughout Malaysia (Figure 2, Table 1). More farms were surveyed in Sabah, Perak, Selangor, Negeri Sembilan and Sarawak than in others due to the availability of farmers on the days the areas were visited. The overall distribution of farm culture systems surveyed is shown in Figure 3.



**TABLE 1**  
**Number of farms surveyed in each state**

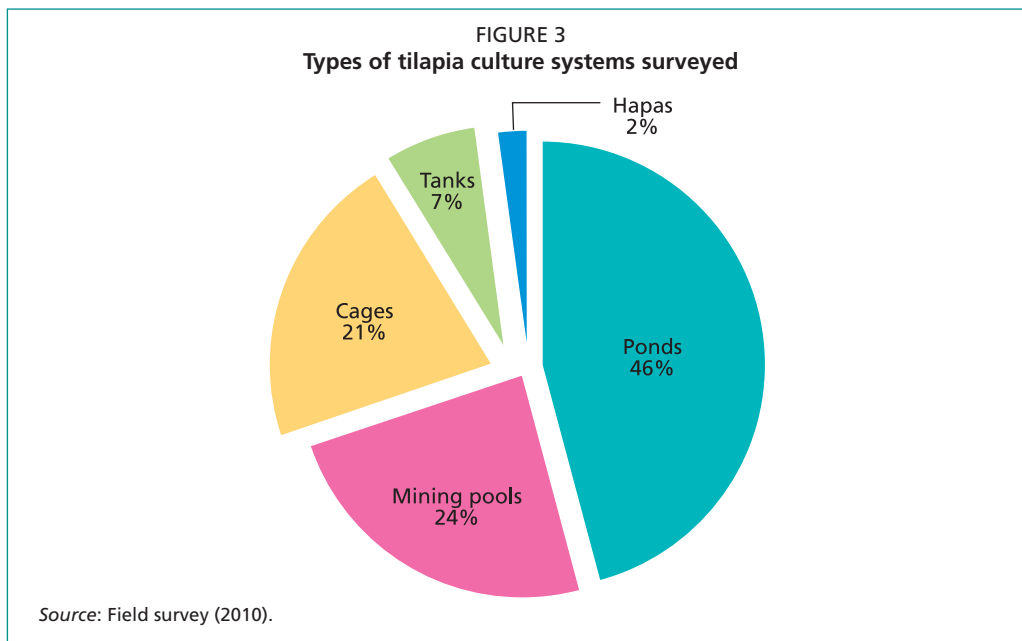
State	Number of Farms
Negeri Sembilan	22
Pahang	5
Perak	22
Pulau Pinang	4
Sabah	19
Sarawak	13
Selangor	17
Terengganu	2

Source: Field survey (2010).

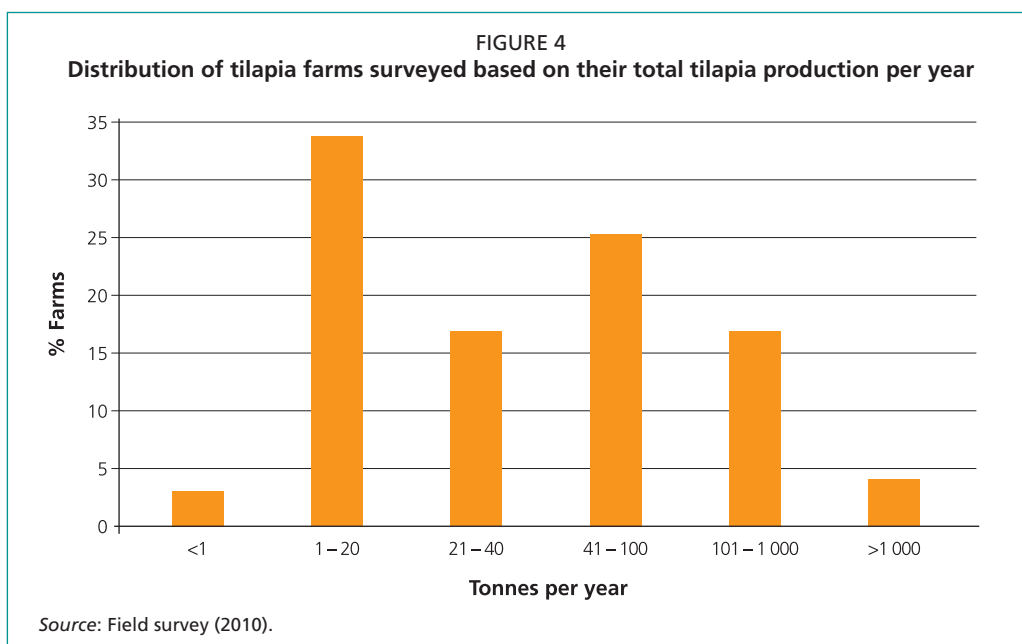
A majority of the farms surveyed is using earthen ponds, either man-made or ex-mining pools. Up to 78 percent of the culture systems surveyed in Sabah and 91 percent in Negeri Sembilan are constructed earthen ponds. In Perak and Selangor, 68 percent and 76 percent, respectively, of total farms surveyed are using ex-mining pools. In contrast, states with great rivers and reservoirs, such as Pahang, Terengganu and Sarawak, prefer to run their tilapia operations using floating cages. Despite the smaller number of tilapia cage farms surveyed, compared to pond systems, it should be noted that farming systems, feed inputs, stocking density and other farming practices are often standardized for all the tilapia cage farmers in a particular district or waterbody. Some of these cage farmers are set up as clusters or cooperatives by governmental or semi-governmental agencies. Data collected from surveyed farms were therefore considered representative of the many tilapia farms present in the specific localities in Pahang, Terengganu or Sarawak having a preponderance of these cage-culture systems.

## 2.2 Land ownership and scale of production

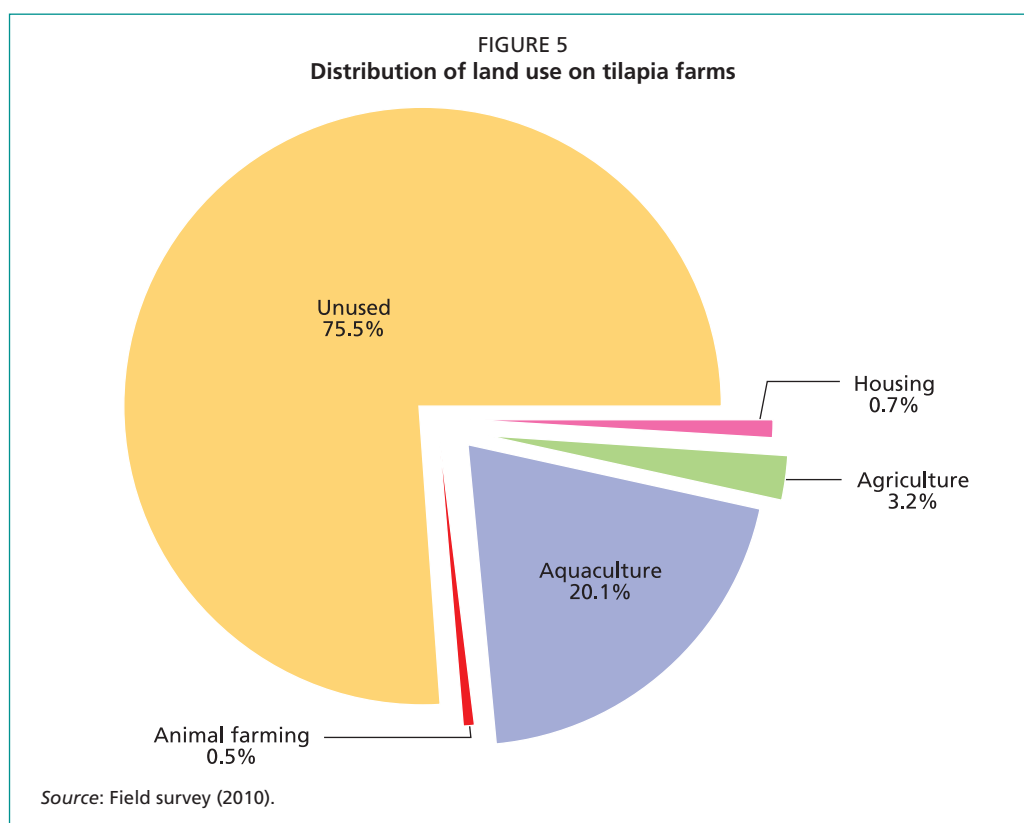
Many farmers in Malaysia do not own the land and/or waterbody from which tilapia is produced. The land status of farms surveyed can be classified into four categories, namely, land owners (54 percent); under temporary operation license (TOL) (22 percent);



state-owned (12 percent); or rented (12 percent). About half of the survey respondents own the land to their farms, but these are mainly small-scale producers and traditional backyard farmers. Medium-scale and large-scale tilapia producers, especially those in Perak, Selangor and Negeri Sembilan, are operating on TOL and rented land. The rates for license or rental fees are charged yearly based on land size and vary by state and also by district. The respective state governments have the authority to reclaim any land on TOL status for state or federal use at anytime. In contrast, farmers operating from state-owned farms are associated with government development projects implemented by the Federal Land Consolidation and Rehabilitation Authority (FELCRA), the Federal Land Development Authority (FELDA) or the local Department of Fisheries (DOF) and do not need to pay license fees or land tax. This is done through efforts by the Malaysian Government to improve the livelihoods of rural communities by creating employment and work opportunities. The distribution of surveyed farms according to their scale of tilapia production is shown in Figure 4.



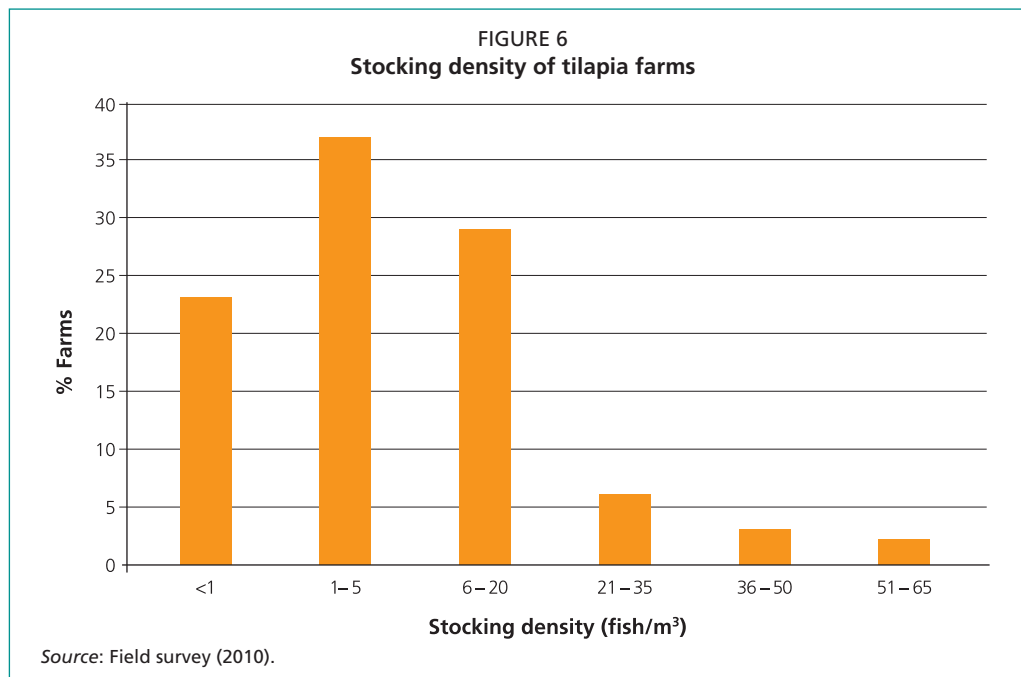
The ‘temporary’ and rented land status of many of the larger producers has somewhat dampened the desire of these tilapia farmers to expand their scale of production due to the perceived greater risk and loss in capital investment should the state government decide to take back the land. The lack of suitable funding was another factor given by the survey respondents as to their limited usage of this farm land for tilapia production. It is therefore not surprising that none of these farms were fully utilizing the land resources around them, including the most intensively managed farms. On average, tilapia production occupies about 20 percent of the total land available on the farm, and other agricultural activities, such as livestock and vegetable farming are sometimes carried out to supplement farm income. About 76 percent of farm land remains unused (Figure 5).



### 2.3 Farm management and labour profile

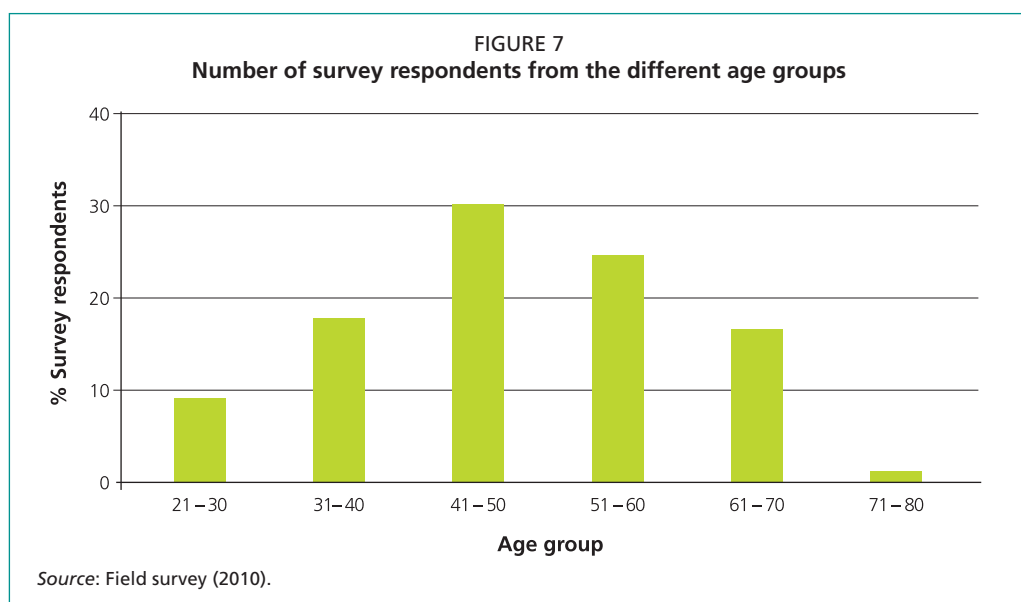
Tilapia stocking densities (Figure 6) varied depending on culture system, fish stocking size and the financial ability of the farmer to purchase seed. Most farms stock one to four cycles per year. The size of seed varied from 0.5 to 11.4 cm, with the majority of farmers using sizes below 5.1 cm. Seed are purchased from private or state hatcheries or are produced within the farm itself.

The stocking density and frequency of restocking often determined the amount of labour needed by the farmer. Labour cost is a major contributor to the total production costs. There are four categories of labour employed by the farms: foreign workers, tribal natives, locals and family members. The cost of hiring full-time foreign workers is slightly higher, ranging between US\$220 and US\$375 per month. The tribal natives are the cheapest labour force, being hired only on a daily basis (at about US\$14 per day for 4 to 5 hours of work) when extra hands are required. Local Malaysians (usually educated) and family members are paid the highest at around US\$375–625 per month. The wages are very much dependent on locality. However, workers in commercial farms



generally attained higher pay than those working in non-commercial farms. In addition, farm workers received relatively higher pay in West Malaysia than in East Malaysia.

Throughout the entire survey, only three female farmers were encountered. Their average age was 56 years, and only one of them was farming fish as her major occupation. Overall, 70 percent of the respondents practiced aquaculture as a major source of income. Of the 73 major farmers, 46 had no other source of income. The age range with the highest number of respondents was between 41 and 50 (Figure 7). Farmers from Sabah were relatively older men (mainly retirees) who run the operation out of interest and to generate extra income. The state governments of Perak, Pahang, Terengganu and Sarawak have introduced various incentive programmes to attract young and educated people to the aquaculture industry but, judging from the relatively small number of farmers below 40 years of age, the response seems lukewarm.

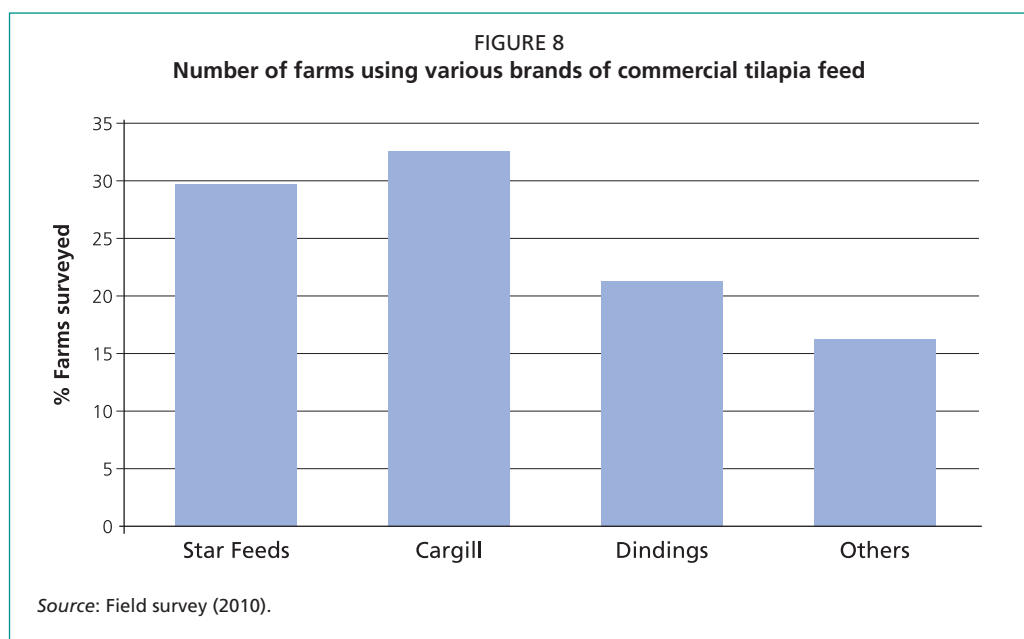


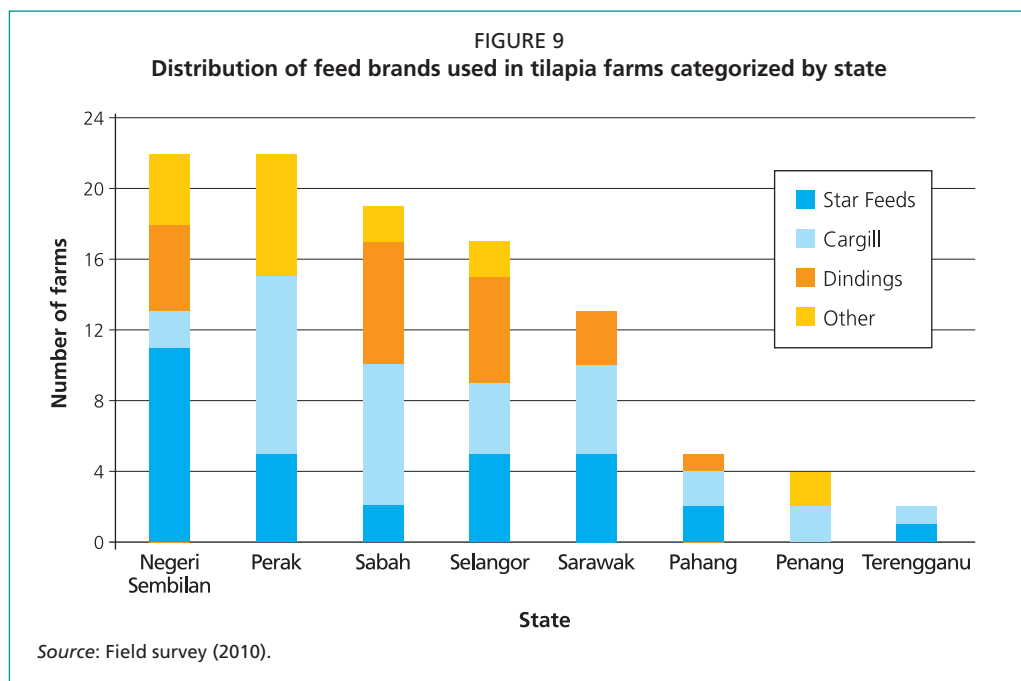
### 3. FEED INPUTS AND FEED MANAGEMENT PRACTICES

#### 3.1 Commercial feeds

Four main categories of commercial tilapia feeds are available in Malaysia. Pre-starter feeds for tilapia fry at the hatchery stage have about 34 percent crude protein and are priced at US\$880–1 100 per tonne. Starter feeds for the nursery and grow-out phase are formulated to contain 32–34 percent crude protein and are sold at US\$790–840 per tonne. Grower feeds cost between US\$730 and 800 per tonne and contain about 25–28 percent protein. Lastly, finisher feeds cost from US\$690 to 750 per tonne, with a crude protein content ranging from 18 to 25 percent. All tilapia feeds used in Malaysia are produced locally. Feed prices vary slightly among the different feed manufacturers and are also dependent on locality. Feed prices in East Malaysia are higher than in other parts of Malaysia due to the additional transportation costs across the South China Sea. Bulk purchases of feeds by the larger producers are usually given a discount by the feed manufacturers. Feeds are packaged in 20 kg bags when sold.

About 84 percent of the feed samples collected from the surveyed farms were commercial feeds, which included the three major brands: Cargill, Dindings and Star Feeds (Figures 8 and 9). Tilapia feeds from smaller local feed mills are also used by tilapia farmers. Farmers tended to practice brand loyalty and usually only one particular brand of tilapia feed can be found at an individual farm. Tilapia farms mainly used starter and grower feeds during the culture period. In an attempt to improve growth, some farmers used starter feeds from stocking to harvesting, despite their higher costs as compared to grower feeds. In one farm, the farmer mixed starter and finisher feeds for use in grow-out production. Pre-starter feeds are also used by some farmers, but these are restricted to nursery farms and hatcheries. The cheaper finisher feeds are often used towards the end of the culture period to reduce the cost of production in traditional or small-scale farms. Figure 8 shows the number of farmers using the various brands of commercial feed. Commercial chicken, duck and cattle feeds are also used by some small-scale producers in an effort to reduce feeding costs. These livestock feeds and other tilapia feeds produced by smaller feed mills, as well as the occasional catfish and marine fish feeds observed on farms, are categorized as ‘others’ in Figures 8 and 9.





The declared proximate composition of various commercial feeds as noted from the feed bags during the field survey is presented in Table 2. Some of these feeds were collected and taken back to the Fish Nutrition Laboratory at Universiti Sains Malaysia for chemical analysis. All proximate analysis was conducted using standard methods (AOAC, 1997). The analyzed proximate composition of feeds is generally within the stipulated values as declared by the feed companies (Tables 3 and 4). Crude protein content depends on whether the tilapia feed is pre-starter, starter, grower or finisher type, with analyzed values generally exceeding the minimum content declared by feed manufacturers. Analyzed crude lipid content is generally higher by 1 to 3 percent of the minimum content declared by the feed manufacturer. Ash and crude fibre content are not always revealed by feed producers but, when declared, generally do not exceed the maximum levels. The duck feed sampled had 21.5 percent protein, 10.2 percent lipid and low fibre content, but the chicken feed sampled contained low protein and high fibre and ash content and thus may not be suitable for smaller-sized tilapia (Table 4).

### 3.2 Feeding practices for commercial feeds

Feeding is carried out manually by scattering feed over the side of the ponds/cages or with the use of automatic feeders (Figure 10). In cage culture, feed bags are commonly placed near the cages under direct sun for ease of access to the feeds. Medium and large producers usually feed 3–5 percent of fish body weight per day, while traditional and small producers feed depending on the availability of feedstuffs. Since manual feeding is mostly carried out by hired farm workers, there is a tendency to overfeed, with the misconceived idea that fish given more feed will grow faster. On the farms of larger producers, farm workers are generally better trained, and more optimal feeding rates can be expected. With the exception of commercial large producers, estimation of feed conversion ratios (FCR) in smaller farms is difficult, due to unmonitored feeding of pelleted feeds, and is further complicated by the occasional use of supplementary feeds of various types (see section 3.3).

TABLE 2  
Declared proximate composition (%) of commercial feeds used by tilapia farmers

Feed sample	Feed type	Dry matter	Ash	Crude protein	Crude lipid	Crude fibre
<i>Star Feeds</i>						
TL 9991	Starter	min 88	NS <sup>1</sup>	min 32	min 4	NS
TL 9992	Grower	min 88	NS	min 28	min 4	NS
TL 9993	Finisher	min 88	NS	min 25	min 4	NS
TP-1	Starter	min 88	NS	min 32	min 4	NS
TP-2	Grower	min 88	NS	min 28	min 4	NS
TP-3	Finisher	min 88	NS	23–25	min 4	NS
9932	Fish Feed	min 88	NS	min 16	min 4	NS
9974	Marine Feed	min 88	NS	40–42	min 4	NS
9910	Catfish starter	min 88	NS	min 32	min 4	NS
<i>Dindings</i>						
92000C	Starter	min 89	NS	min 32	min 4	max 8
92000	Starter	min 90	max 10	min 32	min 5	max 5
92100	Grower	min 90	max 10	min 28	min 5	max 5
92900	Finisher	min 90	max 10	min 20	min 5	max 5
92300	Finisher	min 90	max 10	min 23	min 5	max 5
92500	Finisher	min 90	max 10	min 18	min 5	max 6
<i>Cargill</i>						
6103	Pre-starter	min 89	NS	min 34	min 4	max 5
6113-S	Starter	min 89	NS	min 32	min 6	max 6
6133-S	Finisher	min 89	NS	min 18	min 4	max 6
6113	Starter	min 89	NS	min 34	min 4	max 6
6123	Grower	min 89	NS	min 28	min 4	max 5
6083	Super	NS	NS	18–20	NS	NS
6353	Catfish feed	min 90	NS	min 32	min 4	NS
<i>Hong Lee</i>						
9922	Finisher	min 88	max 15	min 20	min 8	max 7

<sup>1</sup>NS = Not stated.

Source: Field survey (2010).

TABLE 3

Analyzed proximate composition (% dry matter basis) of the three major commercial tilapia feed brands (mean±SE for 3 analyses)

Sample	Feed type	Dry matter	Crude protein	Crude lipid	Crude fibre	Ash	NFE <sup>3</sup>
<b>Company A</b>							
n=3 <sup>1</sup>	Starter	92.1±0.6	37.7±0.6	5.6±0.5	2.1±0.2	9.0±0.3	45.6±0.6
n=2	Grower	91.4±0.2	32.6±0.1	6.2±0.2	2.2±0.2	8.9±0.1	50.0±0.2
n=1	Finisher <sup>2</sup>	90.4±0.1	32.8±0.0	6.9±0.1	3.3±0.1	9.3±0.0	47.8±0.0
<b>Company B</b>							
n=2	Starter	93.1±0.3	38.0±0.2	5.1±0.4	3.3±0.3	8.7±0.5	44.9±0.0
n=1	Grower	91.5±1.1	26.3±0.2	5.8±0.4	6.1±1.2	8.1±0.2	56.1±1.7
n=5	Finisher	90.9±0.0	21.7±0.1	5.9±0.3	4.6±0.3	8.3±0.0	59.6±0.2
n=1	Unknown	91.4±0.0	33.9±0.0	7.0±0.2	3.9±0.0	8.4±0.0	46.9±0.2
<b>Company C</b>							
n=1	Pre-starter	93.9±0.0	39.5±0.2	4.8±0.1	2.0±0.0	9.5±0.1	44.2±0.1
n=1	Starter	91.1±0.1	35.0±0.1	7.6±0.1	2.6±0.0	7.9±0.0	47.0±0.1
n=1	Grower	92.0±0.0	28.2±0.5	5.5±0.5	2.9±0.1	10.4±0.0	53.1±0.6
n=1	Finisher	90.8±0.0	24.4±0.1	5.1±0.0	3.2±0.4	9.4±0.1	57.9±0.0
n=1	Finisher	92.7±0.0	19.4±0.1	5.5±0.3	6.0±0.1	10.2±0.0	58.9±0.4
n=1	Unknown	89.3±0.0	39.6±0.1	5.7±0.7	3.3±0.5	8.7±0.0	42.7±0.7

<sup>1</sup>n = Number of farms from which the feed was collected. Samples were analyzed as 3 replicates for each farm

<sup>2</sup>According to the farmer

<sup>3</sup>NFE = Nitrogen-free extract = 100 – (% ash + % protein + % lipid + % fibre).

Source: Field survey (2010).

TABLE 4

Analyzed proximate composition (% dry matter basis) of other commercial pelleted feeds, farm-made feeds and feed inputs found at surveyed tilapia farms (mean±SE for 3 analyses)

Sample	Feed type/company	Dry matter	Crude protein	Crude lipid	Crude fibre	Ash	NFE <sup>2</sup>
n=1 <sup>1</sup>	Star Feeds catfish starter	91.3±0.0	38.8±0.8	5.3±0.0	2.8±0.1	8.1±0.0	45.0±0.7
n=1	Gold Coin fish feed	91.1±0.0	38.7±0.1	5.2±0.1	3.9±0.1	9.7±0.0	46.4±0.1
n=1	Hong Lee tilapia feed	91.8±0.0	22.3±0.1	8.6±0.1	11.1±0.2	10.0±0.1	48.0±0.1
n=1	Duck feed	88.4±0.1	21.5±0.4	10.2±0.2	3.6±0.0	8.5±0.2	56.2±0.7
n=1	Chicken feed	91.7±0.0	8.9±0.1	6.5±0.1	16.6±0.2	32.0±0.1	35.9±0.2
n=1	Palm kernel cake	89.5±0.0	11.1±0.1	3.7±0.1	22.2±0.3	12.5±0.0	50.5±0.1
n=1	Fishmeal	89.9±0.1	63.5±0.2	9.1±0.1	2.3±0.1	24.9±0.1	0.2±0.3
n=1	Starch	87.2±0.1	0.3±0.1	0.0±0.0	0.4±0.1	0.3±0.0	99.0±0.1
n=1	Farm-made feed (Sabah)	90.5±0.6	20.9±0.1	17.1±0.1	12.5±0.5	11.9±0.1	37.5±0.2
n=1	Farm-made feed (Penang)	54.5±0.3	27.9±0.4	4.8±0.2	12.5±0.6	19.5±0.3	35.3±0.6

<sup>1</sup>n = Number of farms from which the feed was collected. Samples were analyzed as 3 replicates for each farm

<sup>2</sup>NFE = Nitrogen-free extract = 100 – (% ash + % protein + % lipid + % fibre).

Source: Field survey (2010).

FIGURE 10  
Manual feeding (top left), auto feeder (top right) and feed bag placed near tilapia cages (bottom centre)



COURTESY OF W.-K. NG.

Commercial tilapia feeds are mostly extruded floating feeds, but some small- and medium-scale farms do use sinking pellets, which are cheaper. In order to monitor the feeding activity of fish fed these sinking pellets, some farmers resort to using feeding trays, which are suspended close to the water surface (Figure 11). The feeding activity and amount of feed needed by the fish can therefore be monitored more closely. In very large ponds and in ex-mining pools, a feeding platform and a feeding enclosure made of polyvinyl chloride (PVC) pipes can sometimes be seen (Figure 11, bottom). This designated feeding area allows the farmer to monitor the condition of the fish and their feeding activity. Fish are trained to congregate in this feeding area during meal times, and the large feeding enclosure prevents floating feeds from being dispersed over the pond surface by the wind. Any unfinished feeds can therefore be observed by the farmer and the feeding rate adjusted accordingly to the actual requirement of the fish.

### 3.3 Supplemental and farm-made feeds

Farm-made feeds are not a major feed input in tilapia farms in Malaysia. Nevertheless, these feeds are made and used by some small- and medium-scale producers as a supplement to commercial feeds. Due to the wet/moist nature of these farm-made feeds and the logistical problems for cold storage during the survey, we only managed to bring back two samples to the laboratory for proximate analysis. The proximate composition of the feed from a farm in Sabah contained about 21 percent crude protein but had a very high lipid level of 17 percent (Table 4). The farm-made feed collected in Penang had good protein and lipid levels but was high in ash content. The formulations of these two feeds are not known. Farmers tend to change the ingredients used depending on the availability of feedstuffs and by-products and their relative costs. It can therefore be expected that the proximate

FIGURE 11  
Feeding trays used in floating cages when sinking pellets are used (top photos)  
and feeding enclosure and platform constructed in a large ex-mining pool  
to congregate the tilapia during meal time (bottom centre)



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composition of these feeds will vary depending on season and locality. Feeds made on-farm are sun-dried if not immediately used (Figure 12). Other than these more ‘advanced’ farm-made feeds, where there is an attempt to mix various ingredients to get an intended nutrient composition suitable for tilapia culture, some farmers merely ferment, grind or mix one or two agricultural wastes or by-products and feed these to tilapia. These can therefore be classified as simple farm-made feeds or supplementary feeds. During the field survey, we noticed farmers using fermented palm oil mill effluent (POME) and a corn-based feed derived from discarded corn kernels (Figure 13).

Supplementary feed inputs used by smaller producers included copra meal, palm kernel cake (PKC), poultry intestines and kitchen wastes (Figure 13). Malaysia has a very extensive oil palm industry where PKC is a by-product from palm oil production. Research into the use of PKC has reported successful incorporation of low levels in diets formulated for tilapia (Ng and Chong, 2002; Ng *et al.*, 2002; Ng, 2004). However, on its own, PKC is not a suitable complete feed for tilapia, due to its low protein and high fibre content (Table 4). Nevertheless, it is readily available. Occasionally, aquatic macrophytes, terrestrial plant leaves and wild berries are also placed in tilapia ponds and cages, especially in small traditional farms (Figure 14).

In some farms, tilapia is farmed alongside African catfish but in separate ponds. In these farms, we noticed various cooking equipment, such as large woks, containers and boilers at the farm site (Figure 15). These apparatus are used to cook poultry and fish carcasses, which are later ground up in a meat grinder, sometimes mixed with flour or rice bran and fed to the catfish. It is possible that some of these cooked poultry and fish carcasses are also used to feed tilapia, as we noticed some large cooking woks along the pond dikes of tilapia ponds.



None of the commercial large producers use any farm-made or supplementary feed inputs or animal carcasses to feed tilapia. In these farms, tilapia are fed only with manufactured pelleted feed under very hygienic conditions. However, in the farms of a few medium-scale producers and especially in small-scale producers, supplementary feeds are used to reduce feeding costs.

### 3.4 Feed cost contribution to production

The mean feeding cost of the surveyed farms worked out to be almost 63 percent of the total production cost. Feed costs as a percentage of the production costs ranges from ~50 percent in Negeri Sembilan to ~72 percent in Pahang (Table 5). Feed costs are therefore the highest contributor to the cost of tilapia production in Malaysia. Mean labour and fingerling costs are also major contributors to the overall production cost (both ~13 percent). However, though never as high as feed costs, these costs were much more variable among the surveyed farms. Fry costs ranged between extremes of ~2 percent (Perak) and nearly 24 percent (Pahang); labour costs varied between <4 percent (Penang) and >24 percent (Selangor). The cost for fertilizers is very low, as only organic fertilizers (cow or chicken manure) are used in farms with earthen ponds to condition the pond before each fish stocking. There is no further use of organic fertilizers during the cultivation period, and inorganic fertilizers were not observed to be used in the farms surveyed in this study. Fixed costs include electricity, fuel, rental, land taxes, etc. Miscellaneous costs include maintenance and repairs. A breakdown of the average cost contribution of various parameters to tilapia production costs is shown in Figure 16. A more detailed breakdown in production costs organized by state is given in Table 5.

FIGURE 13  
Examples of farm-made and supplementary feeds (clockwise from top left):  
fermented palm oil mill effluent (POME), copra cake, kitchen wastes,  
cooked poultry offal, palm kernel cake (PKC) and a corn-based feed



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TABLE 5  
Aquaculture production costs by item and state presented as percentage (%) of total costs

Cost items	Sabah	Perak	Penang	Selangor	N. Sembilan	Pahang	Terengganu	Sarawak	Mean
Labour	15.95	15.33	3.79	24.29	21.55	4.55	10.74	8.66	13.11
Fertilizers	1.88	0.42	0.11	0.73	0.19	0.01	0.00	0.08	0.43
Fry/fingerlings	7.05	2.30	20.00	3.27	13.10	23.66	21.88	15.08	13.29
Feeds	56.37	68.08	52.51	65.02	50.46	71.77	66.68	70.24	62.64
Miscellaneous <sup>1</sup>	11.43	6.66	18.43	2.70	0.92	0.00	0.00	0.50	5.08
Subtotal	92.68	92.78	94.83	96.01	86.23	99.99	99.30	94.57	94.55
Fixed costs <sup>2</sup>	7.32	7.22	5.17	3.99	13.77	0.01	0.70	5.43	5.45
<b>Total</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>

<sup>1</sup>Miscellaneous costs are *ad hoc* costs such as one-time farm equipment maintenance/repair costs, losses caused by natural disasters, etc., where the amount is not fixed and is incurred irregularly.

<sup>2</sup>Fixed costs include monthly electricity expenses, transportation fuel charges, rental, tax and any fixed expenses due monthly or yearly, regardless of farming activity.

Source: Field survey (2010).

FIGURE 14  
Terrestrial plant leaves (top left), aquatic plants (top right) and wild berries (bottom centre) are used by small-scale tilapia farmers as supplementary feed inputs

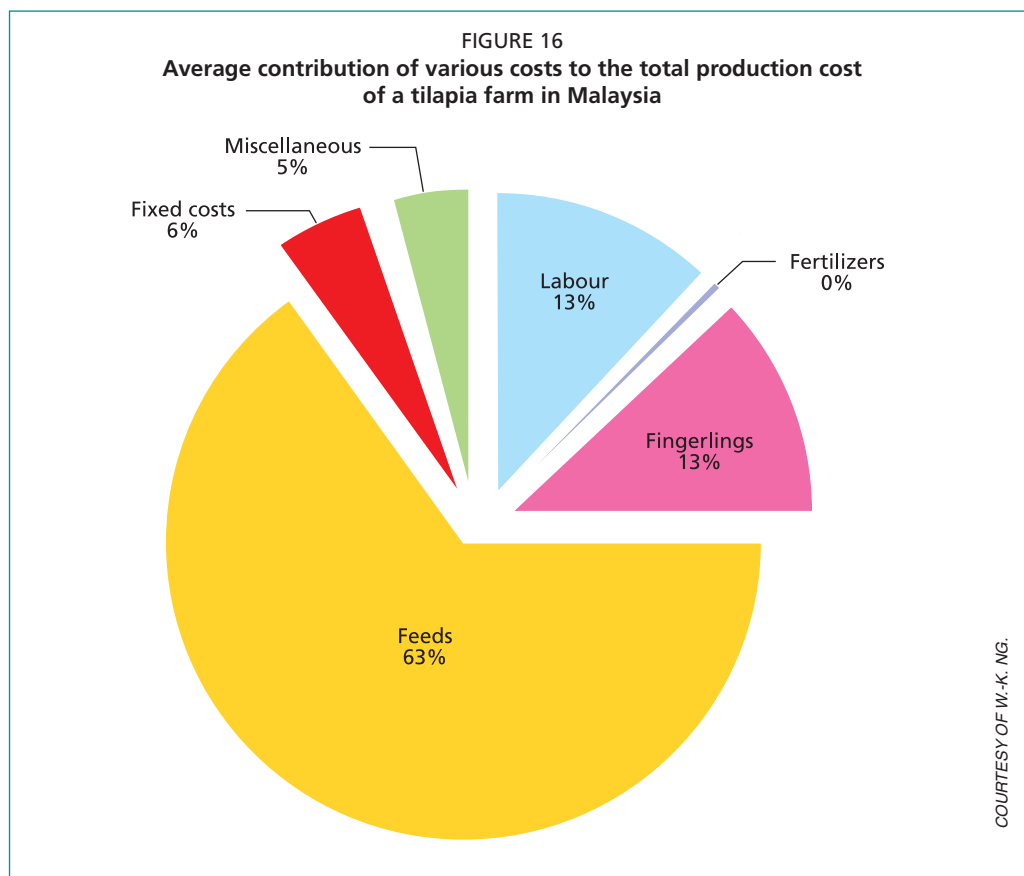


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FIGURE 15  
Examples of cooking apparatus used to cook animal carcasses to be fed to farmed freshwater fish



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#### 4. TILAPIA HARVEST AND SALES

Although pricing differs according to locality, the harvesting and grading processes are usually similar (Figure 17). The tilapia farmer and the buyer are usually present throughout the harvesting process. Both parties have to agree on the grade and price for each batch of fish on the weighing machine. Fish are graded by size and overall appearance. Once the price satisfies both parties, the fish are transferred to aerated tanks and transported to designated places. Live fish are transported to the market or to restaurants. Tilapia are mainly sold live or freshly chilled in Malaysia, with some being exported to nearby Singapore. There are currently very limited local processing facilities for tilapia. In one medium-sized processing plant that we visited in Sarawak, freshly harvested fish were degutted, cleaned and frozen before being sent to fast food and ‘economy rice’ restaurants within the vicinity of the town in that district. However, with the entry of several new large tilapia producers in the country that target the export market, this scenario will probably change in the near future.

Farm-gate pricing for tilapia can be classified under three categories: Grade A, Grade B and Grade C, based on the size of the fish. Prices for each grade differ not only by state but also by farm within the same district. Generally, Grade A includes fish larger than 750 g and can be sold at prices ranging from US\$1.63–3.13 per kg depending on negotiations between the buyer and the farmer. Fish ranging in size from 550 to 750 g are Grade B and are sold at US\$1.00–1.50 per kg, while those under 550 g (Grade C) are sold at US\$0.63–1.09 per kg.

FIGURE 17

Harvesting process at a community-based farm in Terengganu. Clockwise from top left; harvesting fish (farmer and buyer are seen in the background); grading; batch weighing; live fish ready to be transported to restaurant using aerated trucks



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## 5. FUTURE PROSPECTS AND CHALLENGES

The Malaysian government has aggressively embarked on various programmes to promote the national aquaculture industry. Several 'High Impact Projects' have been launched over the last several years, and the development of supporting infrastructure for the local aquaculture industry is robust, particularly in designated areas known as 'Aquaculture Industrial Zones' that are located throughout the country. In part, these coordinated programmes have resulted in aquaculture production increasing to about 355 000 tonnes in 2008, and production is expected to continue to increase, including that of tilapia.

About the same time that this field survey was being conducted, a Norwegian company, GenoMar, established – together with a local partner company – a major tilapia production company named Trapia Malaysia Sdn Bhd. Using state-of-the-art production facilities located at Temenggor Lake in Perak, this company is expected to be a major player in the tilapia industry, producing up to 20 000 tonnes per year of tilapia in a fully integrated operation. According to the company, the bulk of the production will be for the export market. Unlike most of the present tilapia farmers, Trapia Malaysia will be farming the strain of Nile tilapia developed by their parent company in Norway, instead of the red hybrid tilapia. Similarly, a major cage-culture project for tilapia is currently being established by the Department of Fisheries in another man-made lake, Kenyir Lake, in Terengganu. Kenyir Lake is one of the largest man-made lakes in the region, with about 37 000 ha of water surface, 2 800 ha of which have been designated for the tilapia cage culture project under a 'High Impact Project' programme, which has three phases. The survey team visited tilapia cage farms located in Phase 1 of this massive project. Both these private investor and government-driven

tilapia projects, along with many others, are expected to contribute greatly to increased tilapia production in Malaysia in the near future. Nevertheless, there are some challenges and issues impeding the growth of the local aquaculture sector, and these have been discussed in detail by Ng (2009a,b). For this current review, we only discuss the issue of increasing feeding costs for tilapia farmers, and the solutions thereof.

Based on this field survey, it is obvious that the majority of tilapia farmers use commercial extruded feeds. Even small-scale farmers use these feeds, together with supplementary feed inputs and/or farm-made feeds. Self-sufficiency in tilapia feed production is therefore crucial for the local tilapia farming industry. According to industry sources, there were about 13 active aquafeed mills in Malaysia in 2007, with a total aquafeed production of about 100 000 tonnes. Extruded feeds are mainly targeted towards the tilapia farms, which currently have an estimated demand of 35 000 to 40 000 tonnes annually. Based on the gazetted extrusion production capacity of the eight major aquaculture feed mills, an annual potential production volume of 222 000 tonnes is possible (C.K. Ng, Intersea Pvt. Ltd., personal communication, 2010). The feed production capacity in the country is therefore more than enough to meet the increased demand for feeds from the anticipated expansion in tilapia farming. Several feed mills are currently producing below their potential capacity. Even in the event of shortfalls, increased tilapia feed production can be easily met by the purchase of additional extrusion equipment and expansion of feed mill production capacity.

The challenge for the tilapia feed producers is not the lack of production capacity, but the lack of locally available and cost-effective feed ingredients. Malaysia imports most of the major animal feed ingredients it requires for its livestock industry, which is dominated by the poultry industry. About 2.2 million tonnes of poultry feeds were produced in 2007 (Stanton, Emms and Sia, 2009). Compared to the poultry industry, other animal food production industries (e.g. pig, cattle and fish farming industries) are small. Table 6 shows the amounts of some of the major feed ingredients that were imported into the country in 2007 and used in the production of various commercial animal feeds.

TABLE 6  
Quantity and source of animal feed ingredients imported into Malaysia in 2007

Feed ingredient	Imports (tonnes)	Major supply countries
Soybean meal	850 671	Argentina, India, China
Rapeseed cake	24 355	India, Pakistan
Other vegetable oil cakes	7 319	Singapore, China, Thailand
Fishmeal	18 659	Taiwan Province of China, Pakistan, Myanmar, Spain, Viet Nam
Rendered animal products	19 571	Australia, New Zealand
Starch industry residues	17 415	United States of America, Thailand, China
Brewery-based residues	5 505	Singapore, Australia
Vegetable wastes	33 070	Thailand, China
Whey	48 302	United States of America, Poland, France, Netherlands
Wheat <sup>2</sup>	2 160 000	Australia, Canada, United States of America, Argentina
Corn (maize) <sup>1</sup>	2 700 000	Argentina, China, India, United States of America, Thailand

<sup>1</sup>Imports for both human food and animal feed usage.

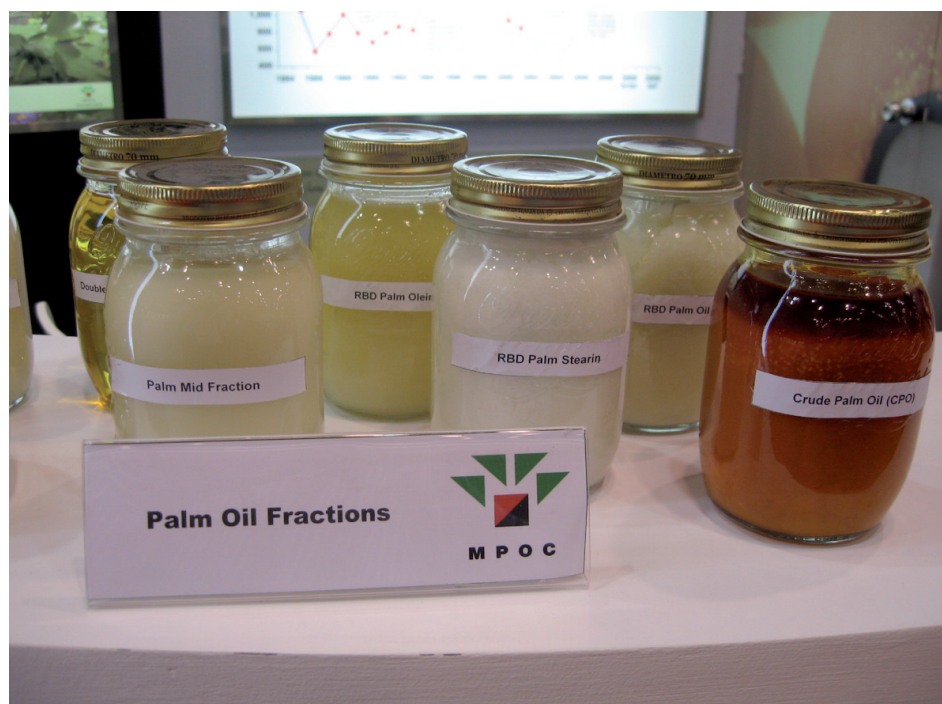
Source: based on data by Stanton, Emms and Sia (2009).

Despite having a long-standing policy of encouraging the use of locally available feed ingredients in the production of animal feeds, Malaysia is an agricultural resource-poor nation, with the exception of the oil palm industry. The major protein sources in tilapia feeds produced in Malaysia consist mainly of soybean meal and other oilseed meals. Wheat and corn flour and their by-products constitute the major carbohydrate sources. Soybeans, rapeseed and wheat are not cultivated in Malaysia, and local production of corn is very limited. These ingredients are therefore imported from various countries (Table 6) for the local production of tilapia feeds. Fishmeal and fish oil are also mainly imported, as are various feed additives. With increasing demand and rising global prices of these aquafeed ingredients (Rana, Siriwardena and Hasan, 2009), the local tilapia feed producers need to explore further the use of alternative locally available agricultural products and related waste materials in their feed formulations to remain competitive.

In view of the critical need to use alternative feed ingredients in tilapia feeds, the Fish Nutrition Laboratory of Universiti Sains Malaysia embarked on several research projects to evaluate the use of products and by-products from the oil palm industry (Ng and Gibon, 2010). The fruit of the palm tree, *Elaeis guineensis*, is the source of crude palm oil (CPO) and crude palm kernel oil (CPKO). CPO overtook soybean oil in 2005 as the most produced oil in the world, with its global production reaching 43.2 million tonnes in 2008 (MPOB, 2008). Malaysia is a major producer of CPO (about 17.7 million tonnes) from an estimated oil palm planted area of 2.4 million ha. Palm oil is comparatively one of the cheapest vegetable oils in the global market (Rana, Siriwardena and Hasan, 2009). As a perennial species, palm crops produce continuously for around 25 years, guaranteeing the reliability of palm oil supply (Figure 18).

FIGURE 18

**Palm oil is the most fractionated oil in the world, and various palm oil fractions have been successfully evaluated in fish feed formulations, including tilapia feeds**



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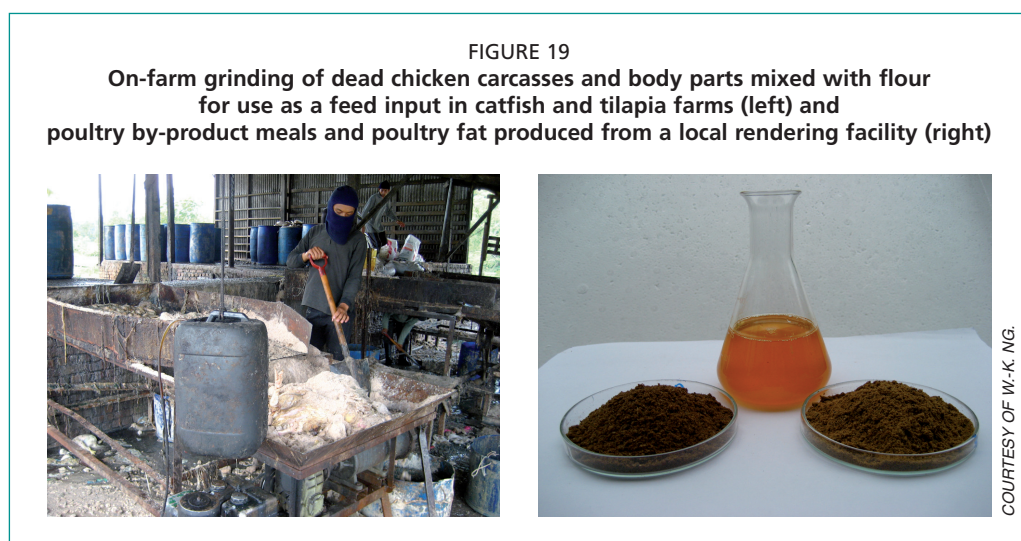
To date, research has indicated that CPO and CPKO can replace up to 100 percent of added fish oil in tilapia diets without any marked negative effects on fish growth, feed utilization efficiency or survival (Ng, Lim and Sidek, 2001; Bahurmiz and Ng, 2007). This is due in part to the very low omega-3 polyunsaturated fatty acid requirements of tilapia; this fact, coupled with the low lipid levels used in commercial feeds, means that tilapia is an excellent farmed species for the successful replacement of expensive dietary fish oil. CPO contains an abundant supply of saturated (48 percent) and mono-unsaturated (42 percent) fatty acids, which makes it a superior energy source for fish diets. The use of CPO in tilapia diets has also been shown to enhance tilapia fillet shelf-life under frozen storage (Ng and Bahurmiz, 2009) and to improve fillet nutritional quality (Wang, Yuen and Ng, 2006).

As previously mentioned, ~43 million tonnes of CPO were produced globally in 2008. In palm oil refining, bleaching clay is used to bleach the crude oil to the colour desired by consumers. Usually, bleaching clay is added at about 0.5 to 2.0 percent of the weight of CPO. This would therefore give rise to an estimated annual generation of 215 000 to 860 000 tonnes of spent bleaching clays (SBC) globally. After use, this SBC may contain 20 to 30 percent adsorbed oil that cannot be recovered economically and is discarded as a waste product in landfills. The use of farmed fish as biological agents to extract residual palm oil adsorbed onto SBC is a novel way of converting waste into wealth, and is expected to benefit the oil refining and aquaculture industries as well as the environment (Ng and Koh, 2011). Feeding trials conducted with tilapia have shown that high inclusion levels of SBC are possible without negative effects (Ng and Low, 2005; Ng, Koh and Zubir, 2006). This would represent the most economical way of incorporating palm oil into the diets of farmed tilapia. Clays are considered industrial minerals and are permitted as feed additives according to Annex 1 of Directive 70/524/EEC of the European Union. SBC are bentonite clays with residual vegetable oil or animal fat from edible oil refining and are considered as materials generally recognized as safe (GRAS) under the 'intended conditions of use' by the FDA of the United States of America. Nevertheless, being a by-product, SBC have a wide range of quality, and further research on the safety aspects of SBC from palm oil refining is needed. Some fish farmers are known to use SBC in the formulation of farm-made feeds, as it provides a good source of dietary lipid and energy. Palm oil refineries gladly provide the SBC to the fish farmers without charge; it is considered a cost-saving measure for these refineries, since they do not have to spend money for its disposal. More effort is needed to make this underutilized potential feed resource known to tilapia farmers and feed producers.

Palm kernel meal (PKM) is a by-product of palm kernel oil extraction, it therefore constitutes an oilseed meal/cake. About 2.4 million tonnes of PKM were produced in 2008 in Malaysia (MPOB, 2008). Currently, most of the PKM produced in Malaysia is exported at a low price to Europe for use as feed concentrates for dairy cows to increase milk fat. PKM is an established feed ingredient for ruminants, supplying valuable dietary sources of protein, energy and fibre. The use of PKM has been evaluated as an alternative to soybean meal in tilapia diets. Despite its high fibre content and the presence of indigestible non-starch polysaccharides, low amounts can be used in tilapia diets (Ng, 2004; Lim, Bai and Ng, 2005). Higher dietary inclusion of PKM in tilapia feeds may be possible if it is pre-treated (Ng and Chong, 2002; Ng *et al.*, 2002). Further research on the use of this cheap by-product from the palm oil industry in tilapia feeds is warranted. Small-scale tilapia farmers currently use PKM as one of their feed inputs, either alone, as a ground powder, or incorporated into simple farm-made feeds (Figure 13).

Apart from various palm oil fractions, by-products and waste-products from the palm oil industry, the only other known potential major source of local feed ingredient for use in tilapia feeds comes from the poultry industry. As mentioned earlier, Malaysia

has a large poultry farming industry with a sizeable number of integrated poultry farming operations. Some of the larger poultry farms have their own feed mills and processing plants. There is currently a great demand for dead chickens and their discarded body parts and offal by small- and medium-scale freshwater fish farmers. Agreements are usually brokered between fish farmers and nearby poultry processors to ensure a ready supply for the farm. As previously described, these chicken waste products are used as supplementary feed inputs (Figures 13 and 15). The dead poultry and their offal are often cooked before being fed directly to farmed fish. However, some farmers do not cook the carcasses but grind them with a meat mincer and, after mixing with flour, feed the processed meat to farmed fish (Figure 19).



The high demand for these poultry by-products has resulted in some enterprising larger poultry companies (such as Kentucky Fried Chicken/Ayamas) investing in basic equipment to process them into ground and dried or frozen forms, before packing and selling them to fish farmers at a higher price. A much more hygienic way to utilize these discarded poultry parts is to render them into useful protein meals. However, Malaysia currently does not have an established animal rendering industry. Nevertheless, one company, Dindings Soya & Multifeeds Sdn. Bhd., a subsidiary of Malayan Flour Mills with diversified interests in the feed ingredients, poultry and aquafeed industries, has a small rendering facility in Perak. Discarded poultry parts from their poultry farms are sent to this rendering facility to produce poultry by-product meal (PBM), which is then used in their own aquafeed formulations. They do not produce enough to sell to other aquafeed mills. PBM is known to be an excellent protein source for both fish and shrimp feeds (Bureau, 2006; Yu, 2008). A recent evaluation of locally produced PBM in feeds formulated for a carnivorous marine fish showed excellent growth performance that was equivalent to feeds formulated with PBM sourced from the United States of America or fishmeal (Shapawi, Ng and Mustafa, 2007); this indicates that local technology for rendering is available. Other potential feed ingredients from poultry rendering facilities would include feather meal and poultry fat, which would provide sources of dietary protein and lipid/energy, respectively. Significant quantities of blood meal can also be produced. It is hoped that a coordinated effort can be made by the relevant local authorities to centralize the collection of discarded poultry parts and to set up large rendering facilities to provide high-value feed ingredients for the thriving aquaculture sector. This can be patterned after organized rendering associations, such as those found in the United States of America, Canada and Australia. Currently, much of the rendered animal feed ingredients are imported into the country (Table 6).

These are indeed exciting but challenging times for the aquaculture industry in Malaysia. The rising costs of feed ingredients put aquafeed producers and tilapia farmers constantly at the mercy of market price fluctuations. Even though the global market for tilapia products continues to expand, the price of tilapia has remained stable. Increasing feeding costs and a stagnated market price of tilapia means reduced profit margins for tilapia producers. As indicated by the results of this survey, feeding costs account for about 63 percent of the total production costs of tilapia in Malaysia. Any savings in feeding costs would greatly benefit the tilapia farming industry. The use of locally sourced alternative protein and energy feed ingredients in both commercial and farm-made feeds would go far towards keeping the cost of production sustainable in the long term. Better on-farm feed management and feeding practices could also contribute towards cost savings. Small-scale tilapia farmers in Malaysia are especially vulnerable to rising feed costs and competitive tilapia markets (WFC, 2009). More extension services should be provided to enable these farmers to gain knowledge on producing nutrient-appropriate farm-made feeds using low-cost local feed ingredients. Farmers who use low-cost feed inputs often experience poorer tilapia growth performance; this illustrates the need for education on providing adequate nutrient input and proper feeding practices. It is hoped that this field survey will contribute to the current efforts, both by government and private-sector stakeholders, to make Malaysia a major global tilapia producer.

#### ACKNOWLEDGEMENTS

The authors would like to thank the CGIAR-Canada Linkage Fund, the Canadian International Development Agency (CIDA) and the Malaysian Agricultural Research and Development Institute (MARDI) for financially supporting the field survey. The logistical and technical inputs of Dr A.G. Ponniah, Dr Madan Dey, Ms O.L. Chen and Ms L.P. Ng (WorldFish Center, Malaysia) are gratefully acknowledged. The field survey would not have been possible without the help of Mr C.B. Koh, Universiti Sains Malaysia (USM) and officers from the various Departments of Fisheries (Perak, Selangor, Penang, Negeri Sembilan, Pahang, Terengganu) and Departments of Agriculture (Sabah and Sarawak). Lastly, we are grateful to all the tilapia farmers who provided us with valuable on-farm information about the industry.

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