Analysis of feeds and fertilizers for sustainable aquaculture development in Indonesia

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SUMMARY

Aquaculture production in Indonesia makes a significant contribution to export earnings, domestic food supply and conservation. Aquaculture production in 2003 was 1.22 million tonnes valued at US$1.72 billion and in 2004 had increased to 1.47 million tonnes valued at US$2.16 billion. In 2003 around 60 percent of total aquaculture production was from finfish culture, followed by seaweed (18.9 percent), crustaceans (16.2 percent), molluscs (0.3 percent) and others (4.7 percent). In terms of value, shrimp are the most important and during 2003 shrimp export earnings amounted to US$1.1 billion, which comprised almost 50 percent of total fisheries exports. Pacific white shrimp, *Litopenaeus vannamei* is now the most important shrimp aquaculture species in Indonesia.

Culture systems range from extensive pond culture to intensive culture of shrimp and fish in paddy fields, earthen and concrete ponds, raceways and cages. Extensive fish aquaculture is reliant on fertilization with organic and inorganic fertilizers and the use of supplementary feeds. The use of farm-made feeds in Indonesia is limited, though small-scale farmers are encouraged to use it and in particular to make better use of local ingredients. Because of transport and labour costs organic manures are more expensive to use than inorganic fertilizers. Semi-intensive milkfish culture is also dependent on organic manure for the production of natural foods. Organic fertilizer is also used in semi-intensive shrimp culture though inorganic fertilizers are now preferred to reduce the chances of disease transmission. Urea and triple super phosphate are the most widely used inorganic fertilizers in brackish-water aquaculture. In 2003, some 19 600 tonnes of organic and 7 600 tonnes of inorganic fertilizer were used in brackish-water and freshwater pond aquaculture.

Shrimp are fed on formulated, industrially manufactured pellets, as are tilapia and other freshwater fish species under semi-intensive and intensive culture conditions. Farm-made feeds are used mainly for low value species and consist mainly of trash fish, sun-dried fish or locally produced fishmeal as the primary protein source that is mixed with rice bran, corn meal, molasses, tapioca and other seasonally available ingredients. The availability of trash fish is decreasing and this is a major constraint facing the small-scale aquaculture sector, as well as intensive cage and pond culture of grouper. A moist pellet for grouper aquaculture has recently been developed. Seven million tonnes of animal feed was produced in 2005, of which 595 000 tonnes consisted of aquafeeds. Indonesia is highly dependent on imported fishmeal and fish oil and this, as well as the competition from the poultry sector is considered as a future constraint for the aquafeed industry. The bulk of the soybean meal, squid meal and wheat gluten used in aquafeeds is also imported. Local fishmeal processing technology must be improved to reduce the country's dependence on imports and further research is required to make better use of alternative, locally available, ingredients in aquafeeds.

Indonesia uses a relatively small proportion of the area that is available and or suitable for aquaculture and this together with the intensification of culture practices provides opportunity for rapid growth of the sector. Aquaculture is expected to grow at over 17 percent per annum and it is projected that aquaculture production will increase to over 4 million tonnes by 2009 and it is expected that there will be a higher dependency on commercial aquafeeds. To meet the demand the aquafeed industry needs to gear it appropriately and find alternatives to minimize the fishmeal content in aquafeeds. The high feed demand of *L.vannamei* needs urgent attention. A more cost effective feed needs to be developed to improve efficiency and to reduce environmental impacts. Greater consumer awareness of food safety issues requires the feed industry to pay greater attention to traceability of feed materials and feed processing technology.

1. GENERAL OVERVIEW OF AQUACULTURE PRACTICES AND FARMING SYSTEMS

1.1 Introduction

Aquaculture has a long history in Indonesia and began with the brackish-water pond culture of milkfish (*Chanos chanos*) on the island of Java. Subsequently, wild caught shrimp larvae were introduced into the ponds and grown extensively either in monoculture or polyculture with milkfish (Poernomo, 2004). The animals were not fed and relied entirely on natural food (algae, plankton and diverse benthic organisms) which grow prolifically in warm, shallow, brackish-water ponds. Initial production levels were low (200–250 kg/ha/crop), but under favourable conditions two crops could be harvested per year (Goddard, 1996). Extensive shrimp culture was initiated in eastern Indonesia (South Sulawesi) in the mid 1960s and from there spread to other islands with suitable environments. The first shrimp hatchery in Indonesia was commissioned in the early 1970s in Makassar (South Sulawesi) followed by another in Jepara (Central Java) (Poernomo, 2004).

During the last decade the area under culture has increased significantly (Table 1) and farming practices have been intensified and this has led to substantial increases in production. The expansion was driven largely by export and local consumer demand, consumer awareness and the ability to grow aquatic organisms year round. Moreover, capture fisheries have declined and this gave further impetus for the growth of the aquaculture sector.

The government revitalization programme promotes the culture of tuna, shrimp and seaweed, primarily for export. Other species are cultured mainly for domestic consumption as well as for conservation purposes. Approximately 2.4 million people are employed in the aquaculture sector (Ditjenkan Budidaya, 2005).

Aquaculture practices in Indonesia range from extensive to intensive farming of fish and shrimp. Black tiger shrimp, *Penaeus monodon* and in particular Pacific white shrimp, *Litopenaeus vannamei* are the two most important species grown for the export market. *L. vannamei* has been farmed in East Java since 2001 and from there has distributed throughout the country (Taw, 2005a). Shrimp aquaculture production has increased significantly within the last few years. Awareness of best management practices (proper pond design and construction, stocking of high quality seed, water quality management, and good feed and best feed management practices) and market forces have contributed to shrimp aquaculture development in Indonesia.

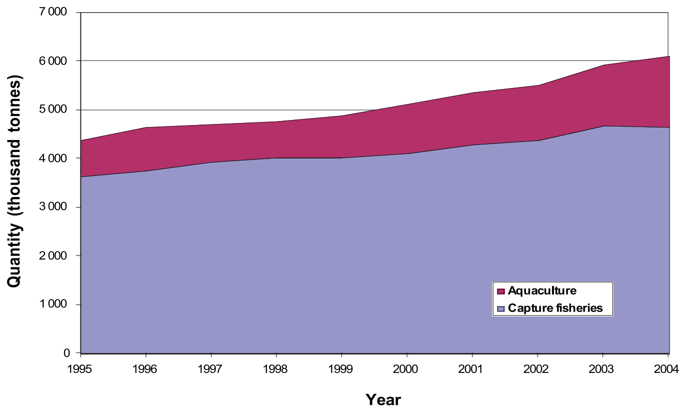
Giant freshwater prawn, *Macrobrachium rosenbergii*, is a high value species and is currently produced primarily for domestic consumption. The species has been domesticated and a new variety caleed "GI-Macro" (Genetic Improvement of *Macrobrachium*) is now used to produce high quality broodstock and seed. Several freshwater fish such as common carp, tilapia, giant gouramy, snakeskin gouramy, kissing

TABLE 1
Area under aquaculture in Indonesia during 2000–2003

Aquaculture area (ha)	2000	2001	2002	2003	Average increase per year (%)
Mariculture [1, 2]	601	699	932	961	19.97
Brackish-water pond	325 530	351 655	360 239	370 824	4.63
Freshwater pond	77 647	85 900	94 240	97 821	8.66
Cage[3]	76	80	86	93	7.46
Floating net cage [2,3]	183	354	356	373	34.60
Rice field	157 346	150 680	148 909	151 414	-1.26
Total (ha)	**561 383**	**589 368**	**604 762**	**621 486**	

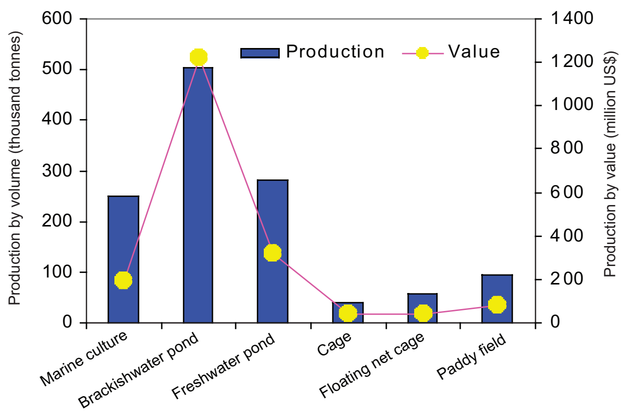
[1] Mariculture include only marine cage culture and excludes area used for seaweed culture;
[2] Data converted into hectare from the information available on the number of units of marine fish cage and floating net cage;
[3] Cage and floating net cage include only freshwater cage culture
Source: Ditjenkan Budidaya (2005)

FIGURE 1
Capture fisheries and aquaculture production in Indonesia during 1995–2004



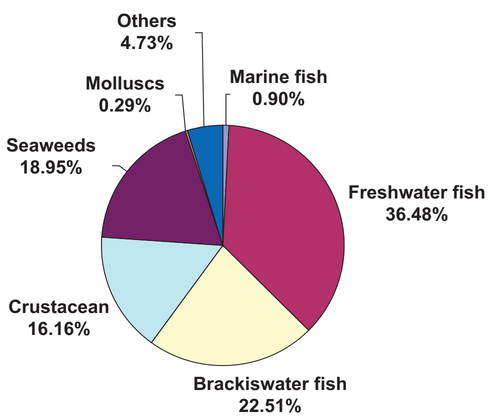
Source: FAO (2006)

FIGURE 2
Aquaculture production by volume and value in different culture environment in Indonesia, 2003



Source: Ditjenkan Budidaya (2004)

FIGURE 3
Aquaculture production in Indonesia by major species groups in 2003



Source: Ditjenkan Budidaya (2004)

gouramy, catfish, snake head, java barb, river eel, sand gobies, and hows carp are also farmed and production of these species has increased yearly. Fish are farmed for export as well as for domestic consumption. Brackish-water fish aquaculture is dominated by milkfish, which is now also grown in offshore marine cages. Other brackish-water fish species include mullet, seabass and tilapia. Mud crab is also produced in brackish-water systems. Seaweed, grouper, lobsters, colour shells and pearls are produced in the marine environment. Seaweed culture has recently been revitalized due to the rapid growth rates, low capital investment and simple culture technologies.

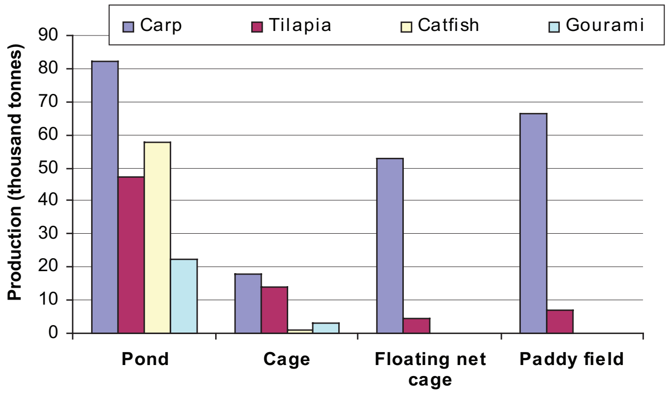
1.2 Production

In 2004 Indonesia was estimated to have produced about 6.12 million tonnes of aquatic products from capture fisheries and aquaculture (FAO, 2006). Capture fisheries contributed about 76.0 percent of total production while the remaining 24.0 percent was from aquaculture. Over the last ten years aquaculture production has almost doubled increasing from 0.74 million tonnes in 1995 to 1.47 million tonnes in 2004 (Figure 1). Aquaculture production in 2003 was 1.22 million tonnes valued at US$1.72 billion and in 2004 had increased to 1.47 million tonnes valued at US$2.16 billion (FAO, 2006). Aquaculture production by volume and value in different culture environment in 2003 are shown in Figure 2. Mariculture, brackish-water pond, freshwater pond, cage culture, floating net cages and paddy field culture accounted for 20.0, 41.0, 22.9, 3.3, 4.7 and 7.7 percent respectively of the total aquaculture production. The contribution of the different species groups in aquaculture is shown in Figure 3.

Marine aquaculture is dominated by grouper and seaweeds, which accounted for 0.7 percent and

18.9 percent, respectively, of the total aquaculture production. Milkfish (18.6 percent) and shrimp (15.7 percent) are the main species produced in brackish-water ponds while carp, tilapia, catfish, and gouramy are the major species produced in different freshwater aquaculture systems (Figure 4).

FIGURE 4
Aquaculture production of the four major freshwater fish species in different aquaculture systems in 2003

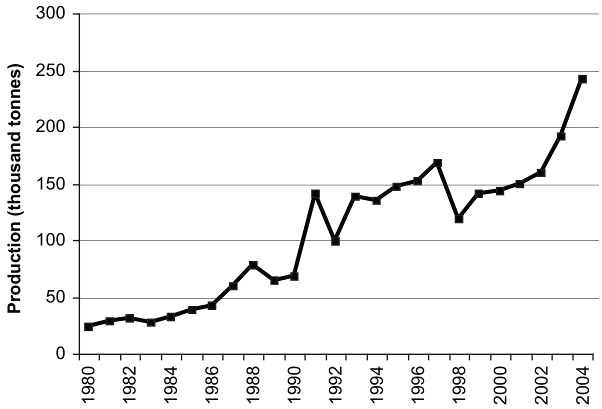


Source: Ditjenkan Budidaya (2004)

In terms of value, shrimp dominate aquaculture exports. In 2004, approximately 143 550 tonnes of shrimp (headless), valued of US$1.1 billion were exported, which accounted for about 50 percent of the total fisheries export (Ditjenkan Budidaya, 2005).

In terms of area (Table 1), marine aquaculture (19.97 percent/year) and floating net cage culture (34.6 percent/year) have grown substantially faster than other systems. This is mainly because of the increasing interest in grouper, seaweed, common carp, tilapia, catfish and gouramy aquaculture. The area under brackish-water ponds has decreased by 4.6 percent/year, particularly in South Sulawesi, East Java, West Java, Aceh, Lampung, East Kalimantan, North Sumatera and West Nusa Tenggara. However, the introduction of *L. vannamei* in 2001 (Briggs *et al*., 2004) ensured that shrimp production did not decline as well. The introduction of *L. vannamei* has, in fact, made a significant impact on shrimp production in Indonesia (Table 2; Figure 5). This species was initially cultured in East Java and the first successful pond yields were 7–10 tonnes/ha, with animals reaching 15 g in 90 days at survival rates of 75–90 percent and FCRs of 1.1–1.4:1. However, major losses were recorded in 2002 as a result of white spot syndrome virus (WSSV). At present with a better understanding of the species and the production of specific pathogen free (SPF) post larvae (PLs), *L. vannamei* is once again widely farmed in Indonesia (Kopot and Taw, 2004)

FIGURE 5
Indonesian shrimp aquaculture production during 1980–2004



Source: Ditjenkan Budidaya (2004)

L. vannamei has several advantages over *P. monodon*, such as faster growth, a wider salinity tolerance, tolerance to higher densities and a lower protein demand (Briggs *et al*., 2004). High density culture of *L. vannamei* is commonly practised, but lower stocking

TABLE 2
Shrimp aquaculture production (tonnes) in Indonesia during 2000–2004

Shrimp	2000	2001	2002	2003	2004
P. monodon	94 000	104 000	113 000	90 000	80 000
L. vannamei	0	2 000	7 000	43 000	80 000
Others*	50 000	43 000	44 000	45 000	45 000
Total	**144 000**	**149 000**	**164 000**	**178 000**	**205 000**

* Others include lobster, local white shrimp, Metapenaeus shrimp, and mysid

Source: Akiyama (2004)

FIGURE 6
High density (200 PL/m²) culture of Pacific white shrimp (*Litopenaeus vannamei*) in concrete ponds

densities of 20 animals/m² have recently been reported from East Java. Production after 2–3 months ranges from 800–2 000 kg/ha (CP Shrimp News, 2004, 2005).

The sharp increase in shrimp production over the last few years (Figure 5) is mainly due to higher stocking rates as well as the higher production capacity of *L. vannamei*. In intensive culture, *L. vannamei* are commonly stocked at over 100 PLs/m² and production normally ranges from 10.0–15.0 tonnes/ha/year (Taw, 2005a).

For example, a farm in Banyuwangi-East Java (Figure 6) using 0.4 ha of concrete ponds (stocked at 200 PLs/m²) produces 8 tonnes of shrimp (80 shrimps/kg) after 100 days (Nur, Arifin and Latief, 2004). Shrimp farming practices vary somewhat from region to region depending on the local conditions and financial conditions. Shrimp production also varies according to the culture technology applied (Table 3). In general, however, the introduction of SPF *L. vannamei* to Indonesia has prompted a move towards low water exchange, greater bio-security and the use of concrete or polyethylene lined ponds for high density culture (Taw, 2005b).

In 2004, a total of 5.3 billion PLs (or 65 percent of production capacity) were produced from about 13 hatchery enterprises (Ditjenkan Budidaya, 2005). Efforts to domesticate the broodstock of *P. monodon*, *P. stilyrostris* and *L.vannamei* have been initiated at Centre for Brackishwater Aquaculture Development (CBAD), Jepara since 2003 to support and provide high quality broodstock for hatcheries in Indonesia.

The higher pond production capacity of *L.vannamei* has resulted in higher feed inputs into the systems. Excretory products and uneaten feed have potential to accumulate in the sediment and ultimately may have an adverse affect on internal pond and or surrounding waters. Fortunately the dietary protein requirement of *L.vannamei* is lower than that of *P. monodon* (Tacon, 2002; Briggs *et al*., 2004; Cuzon *et al*., 2004; Akiyama, 2004). The protein content of *L.vannamei* feeds range from 28–42 percent. Field experience has shown that growth is impaired under

TABLE 3
Characteristics of various shrimp culture technologies in Indonesia

System and species	Stocking density (PL/m²)	Yield (tonnes/ha)	Average size (g)
Monoculture of *L. vannamei*			
Normal stocking density	60–80	8–10	16–20
High stocking density	130–150	14–30	14–18
Monoculture (partial harvest)	130–150	23–25	12–20
Bacterial floc (zero water exchange)	130–150 280	20–24 49.7	16–20
Polyculture with *P. monodon*			
P. monodon	40–50	7.5	
L.vannamei	20–30	3.5	-

Source: Taw (2005b)

high stocking densities (200 PL/m^2) at a protein content of less than 35 percent (Widyatmoko, pers. comm., 2005). While current on-farm stocking densities are 50–125 PL/m^2 the 35 percent protein diet is still the most widely used feed and this is affecting pond ecosystems and the environment. It is, therefore, important that further research be undertaken on the economics and nutrient budget of *L.vannamei* aquaculture to evaluate its sustainability in the future.

2. REVIEW AND ANALYSIS OF AQUACULTURE FEED AND FEEDING

2.1 Fertilizer, feed ingredients and aquafeeds

The bulk of fish and shrimp production occurs in extensive and semi-intensive farming systems. In extensive pond culture, production is based on the use of organic and inorganic fertilizer to promote the growth of simple plants which form the base of the pond food chain (Goddard, 1996). In semi-intensive or intensive farming systems, fertilizer is used to stimulate phytoplankton growth as a water conditioner and to create a favourable environment for optimal growth and survival of fish and shrimp.

In Indonesia, the most commonly used inorganic fertilizers are urea and triple super phosphate (TSP). Other fertilizers used in aquaculture are super phosphate (SP36) (36 percent P_2O_5 and 5 percent Sulphur) and NPKS[1] (15:15:15:10). The types of fertilizers used and their application rates vary widely. Commonly used organic fertilizers are poultry and cattle manure. In 2003, some 19 600 tonnes of organic and 7 600 tonnes of inorganic fertilizer were used in brackish-water and freshwater pond aquaculture.

Organic fertilizer is often more expensive than inorganic fertilizers because of higher labour and transport costs. The current price of urea and TSP is US$0.13/kg and US$0.15/kg, respectively compared to chicken or cow manure at US$21.97/tonne (Sulistyo, pers. comm., 2005). Because of increasing concerns on bio-security on shrimp farms, the use of organic fertilizer is being restricted to protect the shrimp from potential disease transmissions. However, organic manure is preferred for freshwater pond and paddy field aquaculture. Milkfish production in brackish-water ponds is also largely dependent on organic fertilizers.

2.1.1 Feed ingredients and feeds

Feed ingredients for aquaculture are sourced locally and from abroad. Ingredient choice depends on nutrient content, digestibility and bioavailability, the cost of destroying anti-nutritional factors and toxic substances, availability and cost. Animal and plant materials are the most common feed ingredients, though some wastes and by-products of the food industry are also used.

Currently, around 70–80 percent of feedstuffs for shrimp and fish feeds are imported (Yanuartin, 2004; Sukria, 2004). Production of aquafeeds, particularly for carnivorous finfish species and marine shrimp, has so far been dependent upon the use of fishmeal and fish oil as cost-efficient sources of dietary protein and fat (Coutteau *et al.*, 2002). Fishmeal typically constitutes between 25 and 40 percent of formulated feeds for carnivorous fish and shrimp (Lee and Kim, 2001). Locally available feed ingredients are less used for shrimp diets due to inferior quality, competition for human consumption and inconsistent supplies. For instance, imported fishmeal (crude protein >65 percent is preferred over local fishmeal with protein content ranging from 33–55 percent. Moreover, the ash and lipid content of the local fishmeal were higher than the standards recommended for shrimp (Yanuartin, 2004).

In accordance with the projected growth of the aquaculture industry, and an increased demand for and possibly shortage of marine raw materials in the coming decade, there is a need to identify alternative protein sources for aquafeeds (Lee and Kim, 2001;

[1] Nitrogen, phosphorus, potassium and sulphur

Coutteau *et al.*, 2002). Research on alternatives in Indonesia is on-going and in the recent past has focused on lupin meal (Sudaryono *et al.*, 1999), corn meal (Nur, Latief and Kuntiyo, 2000), golden snail (Utomo, Suryana and Jusadi, 2003), shrimp head meal (Anon., 2004; Laining *et al.*, 2004), fish and blood silage (Jusadi, Probosasongko and Mokoginta, 2004; Laining *et al.*, 2004), soybean meal cake (Suprayudi, Mokoginta and Naim, 2004), golden snail (Utomo, Suryana and Jusadi, 2003) and *Spirulina platensis* (Panji and Suharyanto, 2003). The potential of alternative ingredients is determined by their proximate composition, availability and cost.

2.1.2 Feeding practices

By far the most common feeding practice in extensive and some semi-intensive aquaculture operations involves the use of organic and inorganic fertilizers and the provision of supplementary feeds. Supplementary feeds can include live or fresh natural food items, kitchen waste, and single processed feedstuff, farm-made feeds to factory manufactured pelleted aquafeeds (Tacon and De Silva, 1997). Semi-intensive and intensive culture systems in particular, are entirely dependent on commercial feeds.

The inappropriate use of feeds may have adverse effects both on the environment and the animals being farmed. Funge-Smith and Briggs (1998) reported that a high proportion of nutrients in waterways adjacent to intensive shrimp farms originate from commercial feeds due to low nitrogen retention by shrimp (see Table 4). However, information on the environmental impact of shrimp farming in Indonesia is limited. The low nitrogen retention by shrimp is caused by several factors such as, suboptimal feed formulation or quality of feed ingredients, overfeeding and poor water stability of feeds. Hence, there is considerable scope to reduce nutrient discharge from shrimp farming, by better feed management and improved feed formulation (Burford and Williams, 2001). Feeding rates should be related to the estimated pond biomass and adjusted accordingly especially during cooler periods. Moreover, an average feeding rate of 2–4 percent of shrimp biomass for *P. monodon* stocked

TABLE 4

Percent nitrogen in pond sediments (S) and discharge into the environment (DE) from shrimp ponds

Shrimp species	Percentage nitrogen in		Country
	S	DE	
Penaeus monodon[1]	57		Australia
P. stylirostris[2]	Up to 38.4		New Caledonia
P. monodon[3]	24	27	Thailand
Penaeus sp.[4]	26		-
P. monodon[5]	14–53		Thailand

Source: [1]Jackson et al. (2003); [2]Martin *et al.* (1998); [3]Funge-Smith and Briggs (1998); [4]Lin and Nash (1996) cited in Avnimelech and Ritvo (2003); [5]Thakur and Lin (2003)

TABLE 5

Nutritional composition (minimum and/or maximum levels) of commercial diets available in Indonesia for various aquaculture species

Cultured species	Percentage				
	Crude protein (min)	Crude lipid (min)	Crude fibre (min)	Crude fibre (max)	Moisture (max)
Shrimp					
Black tiger shrimp	39–42	5	3		11
Pacific white shrimp	28–42	5		3–4	11
Finfish					
Grouper	50	10		2.5	10
Milkfish	23–26	4–6		4	11
Tilapia	24–30	4–6		3–4	11
Gouramy	25–28	4–6		4	11
Catfish (*Clarias* sp)	28–32	5–7		4	11
Carp	27–30	4–6		4	11
Catfishes (*Pangasius* sp)	28–30	4–6		4	11

Source: Information obtained from different commercial feed companies (2005)

15 animals/m^2 may significantly reduce feed cost without affecting growth and production (Allan, Moriarty and Maguire, 1995).

Shrimp and fish aquafeeds are produced locally in several feed mills and are readily available in the market. The nutritional composition of some of the available shrimp and fish feeds is shown in Table 5 and Tables 6 and 7 illustrate factory recommended feeding rates.

Shrimp feeding

Shrimp eat slowly on the pond bottom; consequently feed should be distributed evenly and often. Hand feeding is commonly practised by walking along the pond dyke, while floating mechanical devices are used to distribute feed in the middle of the pond. Feeding trays are commonly used to monitor feeding response and shrimp health and to adjust the ration and feeding frequency. The number of feeding trays depends on pond size and is around 4–6 per hectare (Akiyama, 1989).

Shrimp feed manufacturers recommend 3–6 meals a day. However, Smith *et al.* (2002) concluded that there is no benefit in feeding *P. monodon* more than 3 times a day when using a feed that is nutritionally complete and adequately water stable.

TABLE 6

Recommended feeding rates for *P. monodon* at a stocking density of >6 PLs/m^2 at an assumed feed FCR of 1.7–1.8 and water stability of 2–3 hours

Culture duration (days)	Weight (g)	Feed code	Quantity of feed/day (g)	Feeding frequency (times/day)	Survival (%)	Initial feed
1–10	Pl 15–0.1	01	200	2	100	1 kg for 100 000 PLs
11–20	0.1–1	02	400	3	90	
21–30	1–3	03	600	3	80	
Culture duration (days)	**Weight (g)**	**Feed code**	**Feeding rate (%)**	**Feeding frequency (times/day)**	**% feed on tray**	**TC (hours)***
30–40	3–5	03-03SP	5.8–5.0	4	0.6	2.5
40–60	5–9	03SP	5.0–4.2	4	0.8	2.0
60–80	9–14	04S	4.2–3.6	4	0.9	2.0–1.5
80–100	14–20	04S-04	3.6–3.0	5	1.0	1.5
100–110	20–25	04	3.0–2.7	5–6	1.1	1.5
110–120	25–30	04	2.7–2.5	5–6	1.2	1.5–1.0
>120	>30	04	<2.5	5–6	1.3	1.0

* TC = time to check feed trays

Source: Information obtained from commercial feed companies (2005)

TABLE 7

Recommended feeding rates for *L.vannamei* at a stocking density of 80–120 PLs/m^2 at an assumed FCR of 1.4–1.6 and water stability of 2–3 hours

Culture duration (days)	Weight (g)	Feed code	Feed added/day (g)	Feeding frequency (times/day)	Survival (%)	Initial feed
1–10	Pl 8–0.1	01-02	200	3	100	1 kg for
11–20	0.1–1.5	02	400	3	90	100 000
21–30	1.5–3.3	03	600	4	80	PLs
Culture duration (days)	**Weight (g)**	**Feed code**	**Feeding rate (%)**	**Feeding frequency (times/day)**	**% feed on tray**	**TC (hrs)***
30–40	2. 5–3.5	03	5.8–4.8	4	0.6	2.30
40–60	3.5–8.0	03SP	4.8–3.2	4–5	0.8	2.0
60–80	8.0–12.5	03SP-04S	3.2–2.6	5	1.0	1.45
80–100	12.5–17.5	04S-04	2.6–2.2	5	1.2	1.0
100–120	17.5–22.0	04S-04	2.2–1.8	5–6	1.4	1.30
>120	>22.0	04	<1.8	6	1.6	1.0

* TC = time to check feed trays

Source: Information obtained from commercial feed companies (2005)

Milkfish feeding

The demand for milkfish from the domestic market and as tuna bait is increasing. The species is highly suitable for aquaculture because of its efficient use of natural food (Figure 7) and rapid growth (Boonyaratpalin, 1997). Milkfish is farmed under extensive culture conditions in organically fertilized brackish-water ponds and is often produced without the use of supplementary feeds. Under these conditions the fish feed on lab-lab (klekap), plankton and lumut (*filamentous green algae*). With adequate organic fertilization, natural food production levels range from 2 000–3 000 kg/ha/crop. Urea and TSP can be used instead of organic manure at a rate of 100 kg and 50 kg per ha during pond preparation and there after at a rate of 25 kg and 15 kg, respectively, such that water transparency is maintained at 30–40 cm (Ahmad *et al*., 2005). There is no chemical treatment for pest eradication during pond preparation. Farmers simply rely on evaporation of sea water up to 100 ppt to sterilize their ponds.

In semi-intensive culture systems, commercial feeds are applied when fish reach 100 g (after ~ 3–4 months). From this size onwards and for about one month the fish are fed a commercial feed two times per day at a rate of 1–4 percent of biomass until

FIGURE 7
Natural food (lab–lab) (left) and commercial floating feed (right) for milkfish culture in brackish-water ponds

TABLE 8
Production parameters in extensive and semi-intensive milkfish culture systems in Indonesia

Culture condition	Extensive		Semi-intensive	
	I	II	I	II
Pond area (ha)	3	4	3	4
Number of fish stocked	10 000	30 000	10 000	30 000
Initial weight (g)	0.3	0.025	0.33	0.025
Stocking density (fish/m)	0.33	0.75	0.33	0.75
Amount of initial feeding (g)	-	-	50	100
Fertilizer (kg)	1 300	1 200	300	400
Culture period (days)	240	195	152	165
FCR	-	-	1.33	1.23
Period of feeding (days)	-	-	75	75
Final weight (g)	160	150	225	285
Total harvest (kg/ha)	1 300	2 350	2 100	5 130
Survival (%)	70–90	40–70	70–90	40–70
Economic analysis				
Total cost (US$)	456	684	1 046	2 206
Cost/kg (US$)	0.35	0.29	0.50	0.43
Total income (US$)	857	1 549	1 615	4 369
Production cycle/year	1	1	2	2
Profit/year (US$)	401	865	1 138	4 326

Source: CP Fish News, special edition (2005) they reach an individual weight of 200–250 g. The fish are conditioned to sound to facilitate feeding and to improve feed utilization. A comparison between extensive and semi-intensive systems (Table 8) shows that semi-intensive milkfish culture is more profitable.

Milkfish production can be increased by using higher stocking densities and reducing the production cycle, though this practice is not economically viable for most farmers. Milkfish are often fed with "alternative" supplementary feeds such as expired bread (or industrial bakery rejects) or rice-based crackers to reduce the feed cost.

Intensive milkfish culture in offshore cages has many advantages, viz., high density 100–300 fish/m^3 high specific growth rate (1.6 percent/day); feed is used more efficiently (FCR 1.7–2.2), high productivity (350–400 kg per 6 m^3 per 6 months); easy to harvest and there is no requirement for water quality management as in brackish-water ponds (Anon., 2005).

Grouper feeding

Groupers are among the most valuable species and are cultured mainly for export. Seed production technology for various species of groupers (brown-marbled grouper *Epinephelus fuscogutatus,* greasy grouper *E. tauvina,* and humpback grouper *Cromileptes altivelis*) was established in 1995 (Murjani, Subyakto and Sitorus, 2004). Since then seed availability has become more predictable and consistent. Groupers are cultured in either brackish-water ponds or in marine floating cages. Farmers prefer to use trash fish as a feed for grouper, though there are several limitations to its use such as inconsistent supply, variable nutrient content, difficult to handle and store and the potential for disease transmission. Given the slow-growth of grouper the use of trash fish as a sole feed becomes problematic. For example, Akbar and Sudaryanto (2002) reported that *C. altivelis* in floating net cages (initial weight of 1.3 g) require 12–14 months to attain 400–500 g, while *E. fuscoguttatus* reared in ponds take 7.5 months to grow from 39 to 311 g (Komaruddin *et al*., 2005). Recent research has shown that grouper respond well to moist as well as dry formulated pellets (Martawati, 1995; Nur, Kuntiyo and Malistiyani, 2000) and prefer and perform better on a slow sinking feed (Anon., 2004). Formulated feeds are used to wean the larvae from *Artemia* at 15 days after hatching.

The results of a comparative study using a commercial dry feed and trash fish in floating net cages are shown in Table 9. The fish (1–3 g) were fed 3–5 times a day at 10 percent of biomass. For larger fish (>250 g) the feeding frequency and feeding rate was decreased to 0.5–1 times/day and 0.8 percent biomass, respectively. These results show the potential use of artificial diets, although the production costs were higher.

Common carp feeding

Common carp is one of the main freshwater fish cultured in ponds, cages, floating cages and paddy fields. Around seven strains of common carp are cultured for consumption, while another five strains are produced for the ornamental fish market. Production phases include a hatchery stage (1–3 cm), nursery phase (5–8 cm) and the grow-out phase (marketable size ca. 6–8 fish/kg). Natural food availability such as Daphnia, Moina and rotifers is important during fry and fingerling rearing and this is stimulated by using organic and inorganic fertilizers in ponds. Chicken manure at between 250–500 g/m^2 is commonly applied in combination with urea and TSP at 8–10 g/m^2 to enhance plankton production. Both floating and sinking pellets with a

TABLE 9

Survival rate (percent), daily growth rate (DGR, g/day) and food conversion ratio (FCR) of humpback grouper *Cromileptes altivelis* reared in floating net cages

Feed type	Survival rate	DGR	FCR
Dry feed -1	98.7	2.23	1.3
Dry feed -2	98.0	1.10	1.6
Trash fish	95.1	1.71	6.0

Source: Anon. (2004)

minimum protein content of 30 percent are commonly used and fish are fed at a rate of 3–5 percent of biomass per day divided into three meals (Khairuman, Suhenda and Gunadi, 2002).

Some reservoirs built for electricity generation, irrigation and flood control are now used for floating net cage culture of common carp, tilapia and gouramy. In Cirata, some 33 000 floating cage units were installed, with disastrous environmental and economic consequences (Radiarta, Prihadi and Sunarno, 2005; Trobos, 2005). In contrast, sustainable cage culture in reservoirs is conducted in Wonogori, Central Java for almost 18 years. There are a total of 400 floating net cage units and each unit (7 x 7 x 1 m^3) requires around 3 tonnes of commercial floating feed per annum for production of tilapia and carp (Krismono, 2005).

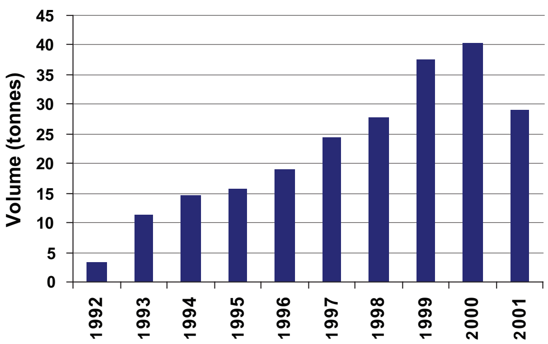
Tilapia feeding

Tilapia is an alien species and was introduced from Africa in the 1940s. There are four varieties of tilapia in Indonesia: Nile tilapia *Oreochromis niloticus*, GIFT[2] (a genetically improved Nile tilapia strain), red tilapia (a hybrid of *O. mossambicus*, *O. niloticus* and *O. aureus*) and blue tilapia *Oreochromis aureus*. The first three species/strains are more popular in Indonesia and are farmed throughout the country. Tilapia are farmed in freshwater (ponds, flow through systems, cages, floating net cages in reservoirs, lakes and rivers) and brackish-water ponds of up to 15 ppt salinity (Amri and Khairuman, 2003). Sucipto and Prihartono (2005) reported that Indonesia was the third largest tilapia producer after China and the Philippines. Tilapia is exported to the United States of America in the form of fresh and frozen fillets and whole frozen fish and the amount exported has continued to increase (Figure 8).

All male tilapia fingerlings are stocked into the production systems when they reach either 15–20 g or 30–50 g body weight. Marketable size for the domestic market is 250 g and 500–600 g for the export market, which is attained after 3 or 6 months, respectively. Culture methods are diverse and range from monoculture to polyculture with carp, java barb or catfish to integrated farming systems. Performance parameters of tilapia under different culture conditions are summarised in Table 10

A new strain of tilapia (JICA - *Jambi Initiative for Commercial Aquaculture*) was produced in 2004. In comparison to other tilapia this strain has a higher fecundity, growth rate and better FCRs than other strains.

FIGURE 8
Total volume (tonnes) of tilapia exported to the United States of America during 1992–2001



Data reported for 2001 was of seven months from January to July
Source: Ditjenkan Budidaya (2004)

Catfish feeding

Clariid catfish are mainly produced on Java Island in freshwater ponds, where it is popularly known as "*Pecel Lele*". Production has increased significantly from 28 991 tonnes in 2000 to 57 740 tonnes in 2003 (Ditjenkan Budidaya, 2004). The species responds well to various food types, is an air-breather and hence tolerant of poor water quality under high stocking densities and has a fast growth rate.

Genetic improvement through cross breeding programmes with the North African catfish, *Clarias gariepinus* has resulted in better performance of both broodstock and seed. In intensive pond culture, catfish are fed a floating or a sinking feed. Production

[2] Genetically improved farm tilapia

TABLE 10
Grow-out performance of tilapia in various farming systems in Indonesia

Performance	Ponds	Raceway (7 x 3 x 1.8 m)	Floating net cages (7 x 7 x 3.5 m)	Small cages (2 x 1 x 1 m)
Stocking				
Initial weight	15–20 g	15–20 g	15–20 g	50 g
Density	4–8 fish/m^2	300 kg/pond	200 kg/cage	5 kg/m^2
Feed and feeding				
Live food production		-	-	Natural food from the environment.
Urea	2.5 g/m^2/week			
TSP	1.25 g/m^2/ week			
Manure	250 kg/month			
Artificial feed				
Feeding rate	3–5% BW	5–6% BW	3% BW	2–3% BW
Feeding frequency	3 times/day	3 times/day	3 times/day	3–5 times/day
Crude protein	Min. 25%	Min.30%	Min. 20%	25–35%
Final weight	500–600 g	500–600 g	500–600 g	30–40 kg/m
Culture period	6 months	2–3 months	5 months	6–12 month
Survival rate	-	-	70%	-

is divided into two stages, viz. nursery and grow-out. The nursery phase starts from exogenous feeding larvae until the fish reach either 3–5 cm or 5–7 cm (1.0–2.6 g), where after they are stocked into ponds. During the nursery phase (28–38 days), commercial feeds are fed at a rate of 8–12 percent of biomass per day, divided into 4–7 meals. During the grow-out phase in ponds the feeding rate decreases from 6 percent at the beginning of grow-out to 2 percent of biomass per day at the end and feeding frequency is ultimately reduced to 2 meals a day. Catfish are low-value fish but there is a high local demand for the species. Plastic-lined ponds are used for intensive catfish production.

Gouramy feeding

Gouramy is the most expensive freshwater fish in Indonesia (US$2/kg) and is sold as a luxury food in many restaurants (Khairuman and Amri, 2003). Gouramy is cultured in extensive systems in freshwater ponds and paddy fields and intensively in floating net cages. In extensive culture systems gouramy are mainly fed on various leaves such as taro, papaya, and cassava. Floating net cages are used for intensive gouramy culture. Initial stocking size is 100 g at a stocking rate of 100 fish/m^3. Fish are fed a commercial diet *ad libitum* (4–5 times/day) with a dietary protein content of 25–28 percent. After 5 months the fish attain market size of 500 g.

2.2 On-farm pond and feed management strategies

2.2.1 Pond management techniques

Pond preparation

Pond preparation is a critical aspect of shrimp production systems. Avnimelech and Ritvo (2003) noted that nutrient accumulation in shrimp ponds result in the deterioration of the pond ecosystem. Pond sediments are therefore removed at the end of the production cycle and the ponds are allowed to dry out. Tea seed cake (10–12 ppm) and pesticides are commonly used to eliminate unwanted animals in the ponds. Lime is applied to regulate soil pH at 7.5–8.5. Recommended application rates are shown in Table 11. Liming is not recommended in areas where the soil has high pyrite content.

Ponds are filled with seawater and then sterilized with calcium hypochlorite (a.i 60 percent) at 25–30 ppm. During sterilization,

TABLE 11
Recommended lime application rate (tonnes/ha) for ponds

Soil pH	Agricultural lime	Hydrated lime
0.5–1.0	>6	1.0–2.0
5–6	2–3	1.0–1.5
<5	3–5	1.5–2.5

Source: ASEAN Cooperation in Food, Agriculture and Forestry (undated) the pond is oxygenated using a paddle wheel for 2–3 hours and then allowed to settle for 4–5 days, where after it is inoculated with *Chlorella*. Sun dried chicken manure at 300 kg/ha is sometime applied and urea and TSP are applied at a rate of 5–10 ppm. A few days after fertilization plankton blooms occur and the water becomes slightly green.

Stocking
High quality, uniformly sized, PCR negative seed (>PL_{15}) that have undergone a formalin test (200–300 ppm for 1 hour) are stocked into the ponds. *P. monodon* is commonly stocked at 10–20 PLs/m^2 and *P. merguensis* at 40 PLs/m^2, with a final survival rate after 150 days of 75 percent (Ariawan *et al*., 2004).

Feed and water quality management
Water and sediment quality are checked routinely such that they remain optimal (Chanratchakool *et al.*, 1995). Feeding regimes are adjusted routinely such that the shrimp are not overfed. Feeding trays are used to observe shrimp feeding response and growth is monitored every 10 to 30 days. Paddle wheels are used to maintain dissolved oxygen levels above 4 ppm. The number of paddlewheels depends on shrimp biomass and the general rule of thumb is that a one horse power paddle wheel can support 250 kg of *P. monodon* biomass (Taslihan, Supito and Callinan, 2004) or circa 500 kg *L.vannamei* (Tirta, pers. comm., 2005) During the production cycle of *P.monodon*, commercial feeds are applied at a decreasing rate from 20 percent at the beginning of the cycle to around 2 percent of biomass at the end of the cycle fed 2–5 times per day (Hardanu *et al*., 2004). The feeding rate for *L.vannamei* is about 50 percent of shrimp biomass at the beginning of the production cycle (Adiwidjaya *et al*., 2004).

Vibrio spp. and viruses have emerged as major constraints in shrimp aquaculture. In the past, antibiotics and other chemicals were commonly used. However, this practice has been phased out in favour of probiotics that are either incorporated into the feed or applied to the pond water (Decamp, 2004). The price of probiotics ranges from US$1.5–4.0/litre and the most commonly used brands are Super NB, Super PS and Bio-Bacter. Since 2001, probiotic application is widely used and research on the use of probiotics is on-going (Poernomo, 2004). In addition, the application of organic carbon rich substrates (glucose, cassava, sorghum meal or cellulose) to control the carbon/nitrogen ratio (C/N ratio) is one of the management measures applied in Indonesian shrimp ponds (Avnimelech, 1999; Hari *et al*., 2004).

2.2.2 On-farm feed formulation

Feed is the single most expensive item of the total production cost. The use of locally available ingredients (Table 12) for farm-made feeds must therefore be encouraged as well as appropriate fertilization regimens such that vitamins and minerals may be obtained through natural food (Brown *et al*., 1997; Trino and Sarroza, 1995).

Farm-made aquafeeds are normally manufactured using available raw material but without much regard for the composition of the ingredients and feeds are tested by trial and error. However, the number of farmers who produce their own feed is limited and most semi-intensive and intensive farmers now depend on commercial feeds. The escalating price of commercial feeds is a major constraint for farmers who produce low value fish.

2.2.3 Collection, transportation and storage of feed ingredients

Some feed ingredients such as soybean, corn, cassava, rice bran that are used in Indonesian aquaculture are readily available, though others such as *Nereis*, golden snail and *Azolla* are highly seasonal. Transportation of local ingredients is generally

TABLE 12
Proximate composition of locally available feed ingredients in Indonesia (percent dry matter basis except otherwise indicated)

Ingredients	Moisture	Crude protein	Crude lipid	Ash	Crude fibre	NFE**
Animal origin						
Fishmeal (local)[1]	8.70	55.17	4.46	19.33	1.98	18.06
Fishmeal (East Java)[2]	8.42	59.66	7.72	26.35	2.76	3.51
Fishmeal (SE Sulawesi)[2]	4.66	46.55	17.11	31.93	2.94	1.48
Fishmeal, sardine[1]	18.60	62.36	9.84	18.68	2.04	7.08
Fishmeal[1]	5.10	46.69	3.01	29.21	2.14	18.95
Krill meal[1]	11.90	60.89	1.91	29.42	1.43	6.35
Shrimp head meal[1]	11.80	41.99	1.30	37.15	2.58	16.98
Cow blood meal[1]	6.50	86.47	6.00	4.67	0.09	2.77
Fish silage[1]	79.58	59.59	7.05	23.21	2.98	7.17
Snail meal[1]	8.20	54.29	4.18	1.05	18.67	30.45
Shrimp meal[1]	17.28	53.74	8.95	4.49	24.96	10.79
Nereis meal[2]	79.08	60.06	13.96	3.58	-	-
Cow liver meal[2]	14.41	53.51	9.54	3.71	-	-
Carapax crab meal[2]	8.92	21.13	0.65	39.16	-	-
Golden snail[3]	-	54.00	-	-	-	-
Plant origin						
Soybean meal[4]	11.50	43.36	5.32	7.08	2.80	42.65
Corn meal[4]	12.10	10.81	3.66	2.00	2.00	81.59
Flour meal[4]	13.10	12.27	1.16	0.58	-	79.70
Rice bran[4]	10.10	17.11	8.67	8.00	8.68	47.44
Coconut cake meal[2]	4.28	11.85	3.14	2.37	4.45	73.91
Soybean cake meal[4]	10.52	23.86	5.93	-	26.39	42.97
**Cassava meal (fresh leaf)[4]	66.70	1.00	0.40	0.50	1.40	30.00
Azolla leaf meal[4]	8.50	25.10	3.80	23.90	12.00	35.10
Cassava leaf meal[4]	3.80	28.69	8.00		12.16	47.40
Sorghum[4]	10.64	13.00	2.05	12.60	13.50	47.85
Leucaena leaf meal[4]	9.30	14.10	3.43	1.31	18.14	28.50

*Fresh weight basis; **NFE: Nitrogen free extract.

Source: [1]Suhenda, Azwar and Djajasewaka (2003); [2]Information obtained from PSPG-UGM Yogyakarta and Environment Laboratory-CBAD, Jepara (2003); [3]Utomo, Suryana and Jusadi (2003); [4]Sucipto and Prihartono (2005)

not a major problem since most of the areas are accessed easily. However, the aquafeed industry is mainly located in Java and Sumatera and long distance transportation of commercial feeds is sometimes problematic. Inadequate storage and handling of feed (ingredients) can lead to nutrient losses, rancidity, mould and rodent infestation. Farmers are aware of these potential problems and store their bagged ingredients in well ventilated stores on wooden racks.

2.2.4 On-farm feed processing

Farm-made feeds basically consist of mixed, locally available ingredients and are made by extruding a moist cooked dough through a meat mincer. Sun-dried fish is the main source of protein, which is then normally mixed with rice bran or corn meal, molasses and tapioca meal. Farm-made feeds easily disintegrate in water and fish must be fed in such a manner that the feed is consumed quickly. Some of the larger farmers produce up to 500–600 kg feed/day using 3–5 labourers. The price of farm-made feeds ranges from US$0.15–0.18/kg. The net profit using farm-made feeds for milkfish (US$0.016–0.02/kg feed) is less than half of that for commercial pellet feeds (US$0.34/kg feed). The major constraint in making farm-made feeds is the seasonal availability of protein sources such as trash fish and sun dried fish. Other constraints are that the feeds can only be sun dried during the dry season and that it cannot be stored for long periods due to the non incorporation of antioxidants. The nutrient content of some farm-made feeds for milkfish are shown in Table 13.

TABLE 13
Proximate composition (percent as fed basis) of farm-made feeds for milkfish

Proximate analysis	Farm-A	Farm-B	Farm-C
Moisture	3.64	3.49	17.74
Crude protein	11.58	10.55	9.17
Crude lipid	7.75	12.63	5.00
Ash	13.46	8.64	12.15
Fibre	9.79	2.38	6.84
NFE	53.78	62.31	49.10

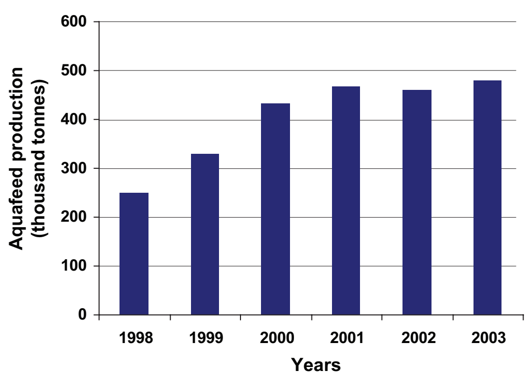
Source: Information obtained from Environment Laboratory-CBAD, Jepara, October, 2005

TABLE 14
Formulation (percent fresh weight basis) and gross nutrient composition (percent dry matter basis) of four farm-made moist feeds for juvenile grouper

Ingredients	**Formulations**			
	1	**2**	**3**	**4**
Trash fish	50	50	60	60
Fishmeal (65% crude protein)	13	12	10	11
Mussel/snail meat	-	7	-	-
Mysid meal	5	-	-	-
Soybean meal (solvent extracted)	-	-	15	-
Groundnut meal	-	-	-	15
Dry blood meal	-	10	-	-
Rice bran	16	15	9	-
Tapioca/cassava starch	-	-	-	9
Wheat gluten (80% crude protein)	10	-	-	-
Fish oil	4	4	4	3
Additives	2	2	2	2
Total	100	100	100	100
Nutrient composition (%)				
Moisture	42	47	50	50
Crude protein	29	26.5	24.5	24
Lipid	7.5	7.5	7.5	7
Ash	7.5	6.5	6.5	5.5

Source: Usman, Laining and Ahmad (2005)

FIGURE 9
Indonesian aquafeed production during 1998–2003



Source: Sukria (2004)

The technology for manufacturing a farm-made moist pellet (Table 14) for juvenile grouper has recently been developed by the Research Institute for Coastal Aquaculture (RICA), South Sulawesi. This offers many advantages for small-scale grouper farmers (Usman, Laining and Ahmad, 2005) such as, being easy to prepare with simple equipment, reducing the dependency on fishmeal, using locally available ingredients, effective vitamin enrichment, reduced feed waste and the feed can also be used to wean the fish onto dry pellets. The disadvantages are that the moist pellets cannot be stored, unless the farmer has a refrigerator, such that the feed has to be made daily and this is time and labour intensive.

3. DEVELOPMENT OF THE AQUAFEED INDUSTRY IN INDONESIA

Indonesia currently has an installed capacity to produce 12 million tonnes of animal feed. 84.5 percent of the capacity is used for the production of poultry feeds and the rest is used for the production of aquafeeds, bird and pet food (Ali Basri, pers. comm., American Soybean Association (ASA)-United States Grain Council (USGC), September 2005). Approximately 7 million tonnes of animal feed were produced in 2005, of which 595 000 tonnes (8.5 percent) comprised aquafeeds. This closely matched the estimated aquafeed requirements for 2005 (Table 15).

Aquafeed production in Indonesia continues to increase (Figure 9) because of increasing fish and shrimp production through expansion and intensification (see future projections in Table 16), the increasing use of formulated, industrially manufactured feeds by farmers and an increase in the number of aquaculture species that require formulated feeds.

To attain the future targets (Table 16) there will be a need for the increased use of locally available feedstuffs supplemented by imports. Some 70 percent and 30 percent of the ingredients for shrimp and fish feeds, respectively are imported (Widyatmoko, pers. comm., PT. Suri Tani Pemuka, 2005). Around 300 000 tonnes of aquafeed ingredients were imported in 2005. Feed ingredient imports are shown in Table 17. There was a downward trend for some ingredients and this is a consequence of the

TABLE 15
Estimation of aquafeed requirements for various cultured species in 2005 in Indonesia

No.	Species	Estimated production (tonnes)	% of production based on feed	Assumed FCR	Estimated use of feed (tonnes)
1	Black tiger shrimp	90 000	20	1.5	27 000
2	Pacific white shrimp	210 000	100	1.5	315 000
3	Milkfish	285 000	10	1.5	42 750
4	Carp	250 000	30	1.5	111 250
5	Tilapia	98 000	30	1.5	44 100
6	Clariid catfish	80 000	50	1.0	40 000
7	Others[a]	50 000	10	2.0	10 000
Total		**1 063 000**			**590 100**

[a] Grouper, seabass, gouramy, etc.

TABLE 16
Projected aquaculture production (tonnes) of various species in Indonesia for the period 2005–2009

Species	2005	2006	2007	2008	2009	% increase per year
Shrimp	300 000	350 000	410 000	470 000	540 000	15.83
Grouper	12 000	15 000	19 000	24 00	30 000	25.75
Seaweed	933 000	1 120 000	1 343 700	1 612 000	1 900 000	19.46
Tilapia	98 000	120 000	140 000	170 000	195 000	18.81
Milkfish	285 000	320 000	360 000	400 000	475 000	13.66
Asian seabass	7 200	8 200	9 500	11 000	12 500	14.79
Clariid catfish	80 000	95 000	115 000	140 000	175 000	21.64
Mud crab	6 600	7 200	7 900	8 800	9 600	9.82
Carp	250 000	270 000	310 000	375 000	446 000	15.68
Gouramy	28 400	31 300	34 400	38 000	45 000	12.25
Mussels	40 000	50 000	62 500	78 000	97 000	24.79
Pearl	12	13	15	16	18	10.72
Pangasius sp	16 500	20 000	25 300	30 300	36 500	21.98
Ornamental fishes	5 000	6 000	7 200	8 640	10 200	19.51
Others	186 288	213 027	244 285	281 744	297 382	12.48
Total	**2 248 000**	**2 625 740**	**3 088 800**	**3 625 900**	**4 269 200**	**17.39**

Source: Ditjenkan Budidaya (2005)

TABLE 17
Feed ingredient imports

Ingredient	2002		2003		Upto June 2004	
	Quantity (tonnes)	%	Quantity (tonnes)	%	Quantity (tonnes)	%
Fishmeal/crustacean meal/ meat & bone meal	294 166	67.53	29 303	39.34	118 916	80.61
Squid meal	5 776	1.32	5 182	6.96	2 631	1.78
Vitamin/mineral mixture	940	0.21	2 911	3.91	1 443	0.98
Wheat gluten/flour	128 665	29.54	24 310	32.64	15 025	10.19
Soybean/lecithin	1 096	0.25	4 523	6.07	3 747	2.54
Shrimp feed	1 283	0.29	3 865	5.19	3 063	2.08
Fish/squid oil	837	0.19	1 137	1.53	604	0.41
Filler	-	-	-	-	712	0.48
Binder	-	-	-	-	397	0.27
Others	2 795	0.64	3 263	4.38	978	0.66
Total	435 558	100	74 494	100	147 516	100

Source: Ditjenkan Budidaya (2004)

government ban (since June 2003) on imports of certain feedstuffs. In particular this relates to meat and bone meal from Canada and poultry by-product meal from the United States of America because of mad-cow disease and avian influenza and soybeans and corn from Brazil because of foot and mouth disease.

To assure that feeds are free of antibiotics such as chloramphenicol samples from feed millers, feed distributors and or farms are routinely tested (Ditjenkan Budidaya, 2005).

4. PROBLEMS AND CONSTRAINTS

Aquaculture production in Indonesia has increased steadily and there is a growing dependence on commercial feeds in semi-intensive and intensive aquaculture. Shrimp, particularly *L.vannamei,* require the most feed (around 50 percent of total estimated aquafeed production). The other 50 percent is required for semi-intensive and intensive culture of common carp, tilapia, catfish and milkfish. Production of farm-made feeds is limited and is decreasing. Tacon (2002) noted that the use of farm-made aquafeed is usually restricted to resource-poor farmers in Asia, and will in all likelihood be gradually replaced by commercial aquafeeds. Another more urgent and recent incentive for the shift to industrial feeds is to avoid the introduction and or spread of diseases from unprocessed marine food organism (including trash fish, crustaceans and molluscs). In general, farmers lack basic knowledge in the selection of ingredients, methods of preparation, dietary nutrient requirements of fish and the use of basic equipment for the production of farm-made feeds. To support the majority of extensive and semi-intensive farmers in Indonesia, there is a need for farmers to be trained in proper farm-made feed preparation methods.

Industrial feeds, especially for grow-out, are available for many farmed species. Currently, there are some 20 registered feed millers in Indonesia and most of them are located in Java and Sumatra. There is a need to increase the number of feed manufacturer in Indonesia to support the increasing aquaculture activities and developments (Poernomo-PT Matahari Sakti; Widyatmoko, PT. Suri Tani Pemuka, pers. comm., 2005). The major problems and constraints facing aquaculture feed and feeding include:

- increasing dependence of the aquafeed industry on imported feed ingredients, especially for marine protein sources and fish oil. The future increase in aquaculture production and the predicted shortage of marine resources in the coming decade will be a problem in aquafeed production (Coutteau *et al*., 2002);
- competing use of ingredients from the poultry sector and for human use;
- escalating cost of ingredients. For example, the price of fishmeal increased from US$675/tonne in January 2005 to US$710/tonne by September 2005 (Ali Basri, ASA-USGC, pers. comm., 2005). As a consequence, shrimp feed prices increased by around US$0.05/kg during the same period;
- production of farm-made feeds with locally available ingredients without considering nutrient availability and the requirements of the cultured species;
- general lack of knowledge with respect to production volumes, seasonal and geographical availability, pre-processing requirements and amino acid composition of several local feed ingredients;
- importance of role played by natural food in freshwater and brackish-water fish culture, particularly in ponds. The combined use of natural food and formulated feeds have to be managed properly so that feeding becomes more effective;
- increasing cost of organic and inorganic fertilizers and feeds as a bottleneck for the expansion of small-scale aquaculture;
- the need to further study the fate of nutrients and nutrient budgets within the captive environment to optimize feeding and minimize waste discharge into the surrounding environment;
- the need to better define the use and benefits of additives (immunostimulants, attractants and probiotics) in feeds;
- the need to train farmers in feed preparation procedures; and
- the need to define the nutritional requirements of all aquaculture species in Indonesia.

5. RESOURCE AVAILABILITY AND THE EXPANSION OF THE AQUAFEED INDUSTRY

Aquaculture production is expected to increase by approximately 17.4 percent per year from 1.47 million tonnes in 2004 (FAO, 2006) to 4.3 million tonnes in 2009. Fish and shrimp will dominate aquaculture production, though it is predicted that seaweed production will also increase significantly during this period.

New areas for aquaculture development are available (Table 18), especially for freshwater aquaculture. Milkfish and shrimp production can be increased through intensification and rehabilitating unused ponds. Mariculture for the next few years is likely to be dominated by seaweed and finfish culture.

The demand for industrially manufactured feeds will therefore also increase. Shrimp, primarily *L.vannamei,* culture is likely to expand rapidly in the country. The high feed demand of *L.vannamei* need to be addressed to produce more cost effective feeds and to minimize the use of protein sources from capture fisheries. The production of other crustacean species, such as *P. merguiensis, P. indicus, Portunus pelagicus* will also increase and this will require speciality feeds. In extensive culture systems, the availability and cost of organic and inorganic fertilizers can constraint future developments in the small-scale farming sector.

The poultry industry will require significantly more feed in future and this will no doubt impact on the availability and cost of ingredients and manufactured feeds.

6. RECOMMENDATIONS AND SUGGESTED POLICY GUIDELINES.

Aquaculture development in Indonesia has three main objectives, viz. to enhance export earnings and domestic fish consumption and aquatic resources conservation. To achieve this there is a need to address the following issues:

- The suitability of farming systems for individual aquaculture species need to be better defined on the basis of location and natural resource availability;
- Fertilizer application rates and the nutrient requirements of aquaculture species must be better defined and more information must be made available to farmers;
- Aquafeed production is too dependent on imported ingredients. There is a need to improve domestic fishmeal processing;
- Alternative protein sources must be found to replace or reduce fishmeal in aquafeeds;
- Natural food availability is important for shrimp and fish growth. Laboratory scale experiments on feed and nutrient formulations need to tested under practical farming conditions to facilitate natural food production;
- The fate of nutrients and nutrient budgets in culture systems needs to be defined to further enhance feed formulations and minimize waste to the environment;
- The use of additives (immunostimulants, attractants and probiotics) in aquaculture needs to be consolidated to improve cost efficiency; and
- Greater consumer awareness of food safety issues requires the feed industry to pay greater attention to traceability of feed materials and feed processing technology.

TABLE 18
Existing use and area available for aquaculture expansion in Indonesia

Aquaculture activity	Existing use (2003)		Area available for potential expansion	
	Area (ha)	% of total	Area (ha)	% of total
Mariculture[1]	**3 780 000**	**84.42**	**8 360 000**	**70.78**
Brackish-water	**450 000**	**10.05**	**1 220 000**	**10.33**
Freshwater	**247 473**	**5.53**	**2 230 000**	**18.89**
Pond	97 000	2.17	526 400	4.46
Paddy field	150 000	3.35	1 545 900	13.09
Common water	473	0.01	158 200	1.34

[1] Mariculture include both marine cage culture and seaweed culture

Source: Ditjenkan Budidaya (2004)

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