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# Demand and supply of feed ingredients for farmed fish and crustaceans

## Trends and prospects

***Cover photograph:***
Drying of farm-made aquafeed for Nile tilapia, Jamalpur, Bangladesh (courtesy of FAO/Mohammad R. Hasan).

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# Abstract

The rise into global prominence and rapid growth of finfish and crustacean aquaculture has been due, in part, to the availability and on-farm provision of feed inputs within the major producing countries. More than 46 percent of the total global aquaculture production in 2008 was dependent upon the supply of external feed inputs. For the aquaculture sector to maintain its current average growth rate of 8 to 10 percent per year to 2025, the supply of nutrient and feed inputs will have to grow at a similar rate. This had been readily attainable when the industry was young. It may not be the case anymore as the sector has grown into a major consumer of and competitor for feed resources. This paper reviews the dietary feeding practices employed for the production of the major cultured fed species, the total global production and market availability of the major feed ingredient sources used and the major constraints to feed ingredient usage, and recommends approaches to feed ingredient selection and usage for the major species of cultivated fish and crustacean. Emphasis is placed on the need for major producing countries to maximize the use of locally available feed-grade ingredient sources, and, in particular, to select and use those nutritionally sound and safe feed ingredient sources whose production and growth can keep pace with the 8 to 10 percent annual average annual growth of the fed finfish and crustacean aquaculture sector.

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# Abbreviations and acronyms

| | |
|---|---|
| ABP | animal by-products |
| BM | blood meal |
| CGM | corn gluten meal |
| CP | crude protein |
| CPC | canola protein concentrate |
| CSM | cottonseed meal |
| DE | digestible energy |
| DHA | docosahexaenoic acid |
| DP | digestible protein |
| EFCR | economic feed conversion ratio |
| EPA | eicosapentaenoic acid |
| EU | European Union |
| FAQ | fair average quality |
| FBM | faba bean meal |
| FM | fishmeal |
| FO | fish oil |
| FOB | free on board |
| FPM | field pea meal |
| G/PM | groundnut/peanut meal |
| HFM | hydrolysed feather meal |
| IFFO | International Fishmeal and Fish Oil Organisation |
| KM | krill meal |
| LKM | lupin kernel meal |
| MA | maize/corn |
| MBM | meat and bone meal |
| MC | mustard seed cake |
| MM | meat meal |
| Mtoe | million tonnes of oil equivalent |
| nei | not elsewhere included |
| PBM | poultry by-product meal |
| PO | poultry oil |
| RB | rice bran |
| R/CM | rapeseed/canola meal |
| R/CO | rapeseed/canola oil |
| SBM | soybean meal |
| SCP | single cell protein |
| SL | soy lecithin |
| SM | squid meal |
| SO | soybean oil |
| SSM | sunflower seed meal |
| US$ | US dollar |
| USDA | United States Department of Agriculture |
| WB | wheat bran |
| WF | wheat flour |
| WGM | wheat gluten meal |
| WH | wheat |
| WM | wheat middlings |

# Executive summary

The rapid rise and growth of finfish and crustacean aquaculture has been due, in part, to the availability and on-farm provision of feed inputs within the major producing countries. If the aquaculture sector is to maintain its current average growth rate of 8 to 10 percent per year to 2025, the supply of nutrient and feed inputs will need to grow at a comparable rate. While this may have been readily attainable when the industry was still in its infancy, this may not be the case in the future as the sector matures and grows into a major consumer and competitor for feed resources.

It is estimated that about 31.5 million tonnes of farmed fish and crustaceans (46.1 percent of the total global aquaculture production in 2008) is dependent upon the supply of external nutrient inputs provided in the form of fresh feed items, farm-made feeds or commercially manufactured feeds. Total industrial compound aquafeed production increased more than threefold, from 7.6 million tonnes in 1995 to 29.2 million tonnes in 2008, with production growing at an average rate of 11.0 percent per year. Aquafeed production is expected to continue growing at a similar rate to 71.0 million tonnes by 2020. Although current estimates for industrially produced aquafeed for the period 2007–2010 vary between 24.4 and 28.9 million tonnes, aquafeed volume represents only 4 percent of the total global animal feed production of the over 708 million tonnes in 2009. In contrast to compound aquaculture feeds, there is no comprehensive information on the global production of farm-made aquafeeds (estimated at between 18.7 and 30.7 million tonnes in 2006) and/or on the use of low-value fish/trash fish as feed, with 2008 estimates for China at 6 to 8 million tonnes.

Fed aquaculture production, in particular, of higher trophic level finfish and crustaceans (includes marine shrimps, salmonids, marine finfishes, eels) are largely dependent upon capture fisheries for the supply of their major dietary source of protein and lipids. For example, on a global basis, it is estimated that the aquaculture sector consumed 3.72 million tonnes of fishmeal (60.8 percent of global fishmeal production) and 0.78 million tonnes of fish oil (73.8 percent of global fish oil production) in 2008; it was 3.84 million tonnes of fishmeal (or 68.4 percent of global production) and 0.82 million tonnes of fish oil (or 81.3 percent of global production) in 2007. Despite this continued dependence of aquaculture production on fishmeal and fish oil, there remains a wide variation in fishmeal and fish oil usage between major producing countries for individual farmed species. This variation mainly reflects differences between countries concerning the selection and use of fishmeal and fish oil replacers from plant sources or by the use of land animal proteins and fats in feeds for high trophic-level fish and crustacean species.

The total use of fishmeal by the aquaculture sector is expected to decrease in the long term. It has gone down from 4.23 million tonnes in 2005 to 3.72 million tonnes in 2008 (or 12.8 percent of total aquafeeds by weight), and is expected to decrease to 3.49 million tonnes by 2020 (or 4.9 percent of total aquafeeds). The reasons for this are the diminishing amount of fishmeal and fish oil supplies owing to tighter quota setting and additional controls on unregulated fishing and the increased use of more cost-effective dietary fishmeal replacers. On the contrary, the use of fish oil by the aquaculture sector will probably increase in the long run albeit slowly; total usage will increase by more than 16 percent, from 782 000 tonnes (2.7 percent of total feeds by weight) in 2008 to the estimated 908 000 tonnes (1.3 percent of total aquafeeds for that year) by 2020. Increased usage will shift from salmonids to marine finfishes and crustaceans because of the current absence of cost-effective alternative lipid sources that are rich in long-chain polyunsaturated fatty acids. Increasing volumes of fishmeal and fish oil are likely to come from fisheries by-products, extracted from both wild capture and farmed fish. Estimates have been made that around 25 percent of fishmeal production in 2007 came from by-products. This will grow as it becomes increasingly viable to process this material.

It is estimated that the total usage of terrestrial animal by-product meals and oils within compound aquafeeds ranges between 0.15 and 0.30 million tonnes, or less than 1 percent of total global compound aquafeed production – clearly, there is considerable room for increased usage. In addition to meat meal, or, to a lesser extent meat and bone meal, ingredients such as blood meal, poultry by-product meal and poultry oil have all been very effective in feeds for a number of aquatic species.

Soybean meal is the most common source of plant proteins used in compound aquafeeds, with feeds for herbivorous and omnivorous fish species and crustaceans usually containing from 15 to 30 percent soybean meal, with a mean of 25 percent in 2008. In global usage terms, and based on a total compound aquafeed production of 27.1 million tonnes in 2007, it is estimated that the aquaculture feed sector consumed about 6.8 million tonnes of soybean meal (25.1 percent of total compound aquafeeds by weight). Other plant proteins being increasingly used include corn products, pulses, oilseed meals and protein from other cereals products.

Alternative lipid sources to fish oil are being used in greater amounts. Key alternatives include vegetable oils, preferably those with high omega-3 contents, and poultry oil. The use of oil from farmed fish offal is also a potential omega-3 source for other farmed fish. The production of marine microalgae or bacteria with very high contents of highly unsaturated fatty acids is currently expensive for use in most aquaculture feeds, but more cost efficient production methods will change this.

Prices for food and feed ingredients have been rising and are likely to continue to rise owing to the increasing demands from an increasing population, the diversion of some grains for use in biofuels, the increasing costs of production and transport, and the changes in global trade owing to the demand of food and raw materials from China and other emerging economies. The focus on carbohydrate-rich fractions for production of biofuels may indeed provide an opportunity to use protein fractions for feed ingredients.

Although current discussion on the use of marine products as aquafeed ingredients focuses on fishmeal and fish oil resources, the sustainability of the aquaculture sector is more likely to be linked with the sustained supply of terrestrial animal and plant proteins, oils and carbohydrate sources for aquafeeds. This is because a significant proportion of aquaculture production is of the non-carnivorous species. Therefore, aquaculture producing countries should place more emphasis to maximize the use of locally available feed-grade ingredient sources and use nutritionally sound and safe feed ingredients that can be sustainably produced and grow with the sector.

*Cage culture of Atlantic salmon* (Salmo salar) *in a fjord, Norway.*

*Courtesy of FAO Fisheries and Aquaculture Department photo library*

# 1. Introduction

The dramatic rise and emergence of acquaculture onto the global marketplace as a major provider of much-needed farmed aquatic food produce were spurred by a combination of factors. Chief among them include:

- the in-country promotion of aquaculture as a viable economic activity and source of livelihood;
- the in-country provision of an enabling legislative framework for conducting the activity;
- the in-country availability of suitable land and water resources and technical know-how for conducting aquaculture farming operations; and
- the in-country availability and on-farm provision of nutrient inputs in terms of fertilizers and/or feed.

For finfish and crustacean aquaculture to maintain its current average annual growth rate of 8 to 10 percent per year to 2025, the external provision of nutrient and feed inputs will have to grow at a similar rate. This had been easily attainable when the industry was young. It will be more difficult as the sector grows into a major consumer and competitor for feed resources.

The aim of this paper is to:

- review the dietary feeding practices employed for the production of the major cultivated fish and crustacean species, including major feed ingredients used;
- review the total production and market availability of the major feed ingredient sources, including current usage by sector;
- review the major constraints to feed ingredient availability and use by the aquaculture sector on a regional and global basis; and
- recommend approaches to feed ingredient selection and usage within dietary feeding regimes for the major cultivated fish and crustacean species.

For the purposes of this paper, only dietary feeds and feeding regimes based on the external provision of fresh feed (usually fed singly, and including low-value/trash fish and cut green fodder), farm-made feed, and commercial feed composed of mixtures of different feed ingredient sources will be considered.

*Hand feeding (broadcasting) of Indian major carps in a pond, Myanmar. Hand feeding in ponds for carp culture has been adopted recently in Myanmar and is not very common; each pond generally varies from 1 to 4 hectares.*

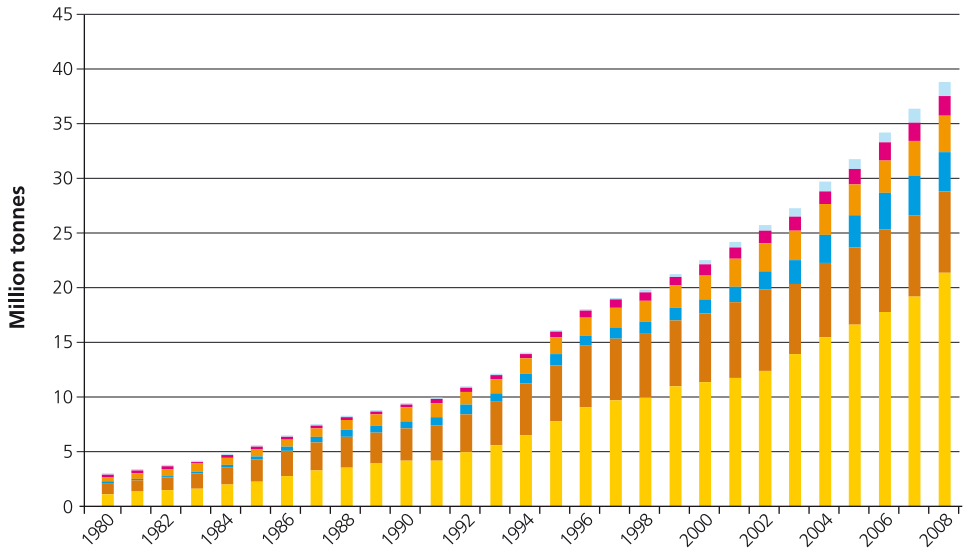
*Courtesy of M.C. Nandeesha*

# 2. Current feeds and feeding practices

## 2.1 MAJOR FED FISH AND CRUSTACEAN SPECIES

In 2008, about 31.5 million tonnes of farmed fish and crustaceans, or the equivalent of 46.1 percent of the total global production of farmed aquatic animals and plants, was dependent upon the supply of nutrient inputs in the form of externally provided fresh feed items, farm-made feeds or commercial pelleted feeds. The above estimate excludes filter-feeding fish species (silver carp and bighead carp: total production 6.10 million tonnes in 2008) and freshwater fish production not reported down to the species level (1.2 million tonnes in 2008; FAO, 2010a). Moreover, of the more than 200 species of fish and crustaceans currently believed to be fed on externally supplied feeds (Annex 1), nine species account for 62.2 percent of total global-fed species production, including grass carp (*Ctenopharyngodon idellus*), common carp (*Cyprinus carpio*), Nile tilapia (*Oreochromis niloticus*), catla (*Catla catla*), whiteleg shrimp (*Litopenaeus vannamei*),

FIGURE 1
**Total global production of fed fish and crustacean species by major FAO species grouping, 1980–2008**




| GROWTH | APR (%/year) | | | | | Change (%) | | |
|---|---|---|---|---|---|---|---|---|
| | 80-85 | 85-90 | 90-95 | 95-00 | 00-05 | 05-06 | 06-07 | 07-08 |
| Freshwater fishes: fed species | +14.9 | +12.3 | +13.5 | +8.0 | +7.9 | +6.5 | +8.5 | +11.3 |
| Freshwater fishes: non-fed species | +16.6 | +8.2 | +11.4 | +3.7 | +2.6 | +7.5 | -2.5 | -1.0 |
| Marine crustaceans: fed species | +24.4 | +25.8 | +7.3 | +5.3 | +17.8 | +16.0 | +5.9 | +3.6 |
| Diadromous fishes: fed species | +6.5 | +12.4 | +4.7 | +8.2 | +4.9 | +4.7 | +8.0 | +2.2 |
| Marine fishes: fed species | +4.0 | +6.6 | +11.5 | +12.2 | +8.1 | +13.9 | +5.8 | +4.5 |
| Freshwater crustaceans: fed species | +23.7 | +12.2 | +8.1 | +32.7 | +16.3 | +4.5 | +33.2 | +7.7 |

*Source*: FAO (2010a).

crucian carp (*Carassius carassius*), Atlantic salmon (*Salmo solar*), pangasiid catfishes (striped/tra catfish [*Pangasianodon hypophthalmus*] and basa catfish [*Pangasius bocourti*]), and rohu (*Labeo rohita*; Table 1; FAO, 2010a). In this respect, aquaculture is no different from animal husbandry, in that global livestock production is concentrated in a few species; in agriculture, the top eight livestock species are pig, chicken, cattle, sheep, turkey, goat, duck and buffalo (FAO, 2010b).

Figure 1 shows the total global production of fed fish and crustaceans by major species grouping, together with their respective growth at five yearly intervals, from 1980 to 2008. In marked contrast to capture fisheries, freshwater fish species dominate finfish aquaculture production (Tacon, Metian and Hasan, 2009), with over 80.8 percent of fed finfish production being freshwater species in 2008 (FAO, 2010a; Annex 1).

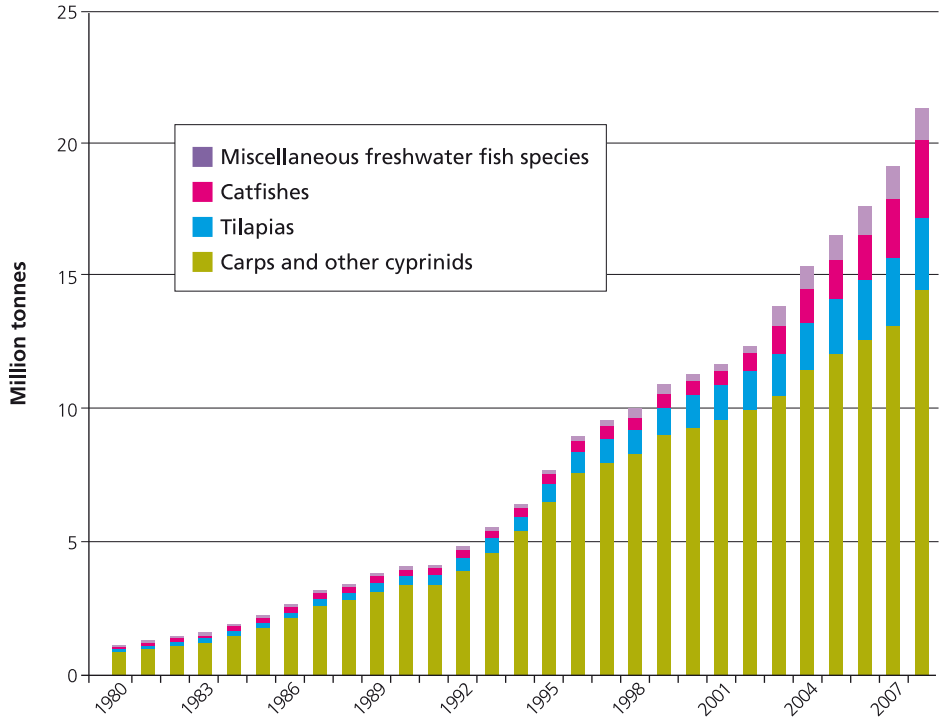
Of particular note is the double-digit growth rates of all major groupings during the 1980s and 1990s, with the overall growth of fed fish and crustacean aquaculture production stabilizing at an average of 10.5 percent per year by 2008. In contrast, livestock meat production and capture fisheries production have grown at an average rate of 2.5 percent and 1.3 percent per year, respectively, since 1980 (FAO, 2010b).

The major fed fish and crustacean species groups can be ranked in order of total global production by weight in 2008, as shown below.

**Fed freshwater fishes:** 21.34 million tonnes, valued at US$27.36 billion (Figure 2; Annex 1):

- carps and other cyprinids – 14.43 million tonnes, nine major species;
- tilapias – 2.80 million tonnes, two major species;
- catfishes – 2.78 million tonnes, six major species; and
- miscellaneous freshwater fishes – 1.33 million tonnes, six major species.

FIGURE 2
**Growth of fed freshwater fish species, 1980–2008**

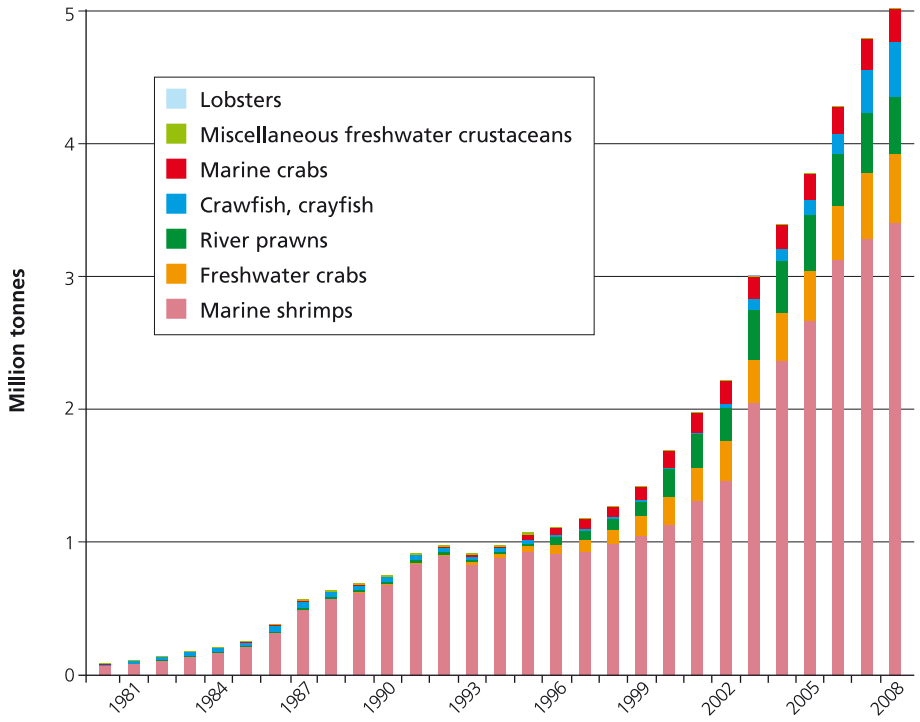



*Source*: FAO (2010a).

**Fed marine crustaceans:** 3.64 million tonnes, valued at US$15.0 billion (Figure 3; Annex 1):

- shrimps – 3.40 million tonnes, six major species; and
- crabs – 241 000 tonnes; one major species.

FIGURE 3
**Growth of fed crustacean species, 1980–2008**




*Source*: FAO (2010a).

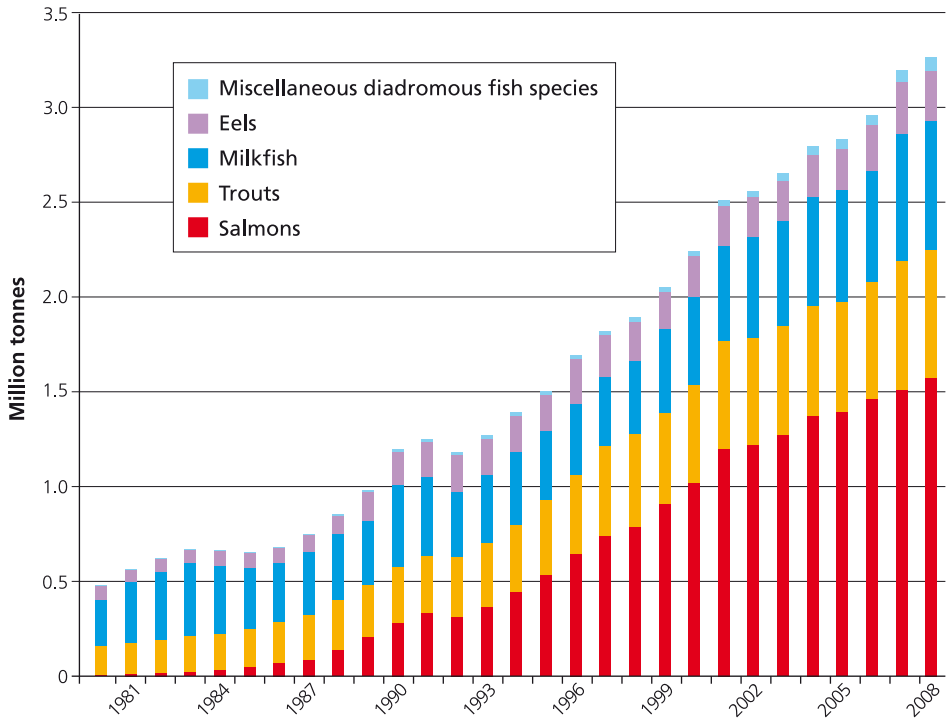
**Fed diadromous fishes:** 3.26 million tonnes, valued at US$12.95 billion (Figure 4; Annex 1):

- salmons – 1.57 million tonnes, two major species;
- trouts – 677 000 tonnes, one major species;
- milkfish – 676 000 tonnes, one major species;
- eels – 265 000 tonnes, one major species; and
- miscellaneous diadromous fish species – 71 000 tonnes; one major species.

**Fed marine fishes:** 1.77 million tonnes, valued at US$6.6 billion (Figure 5; Annex 1):

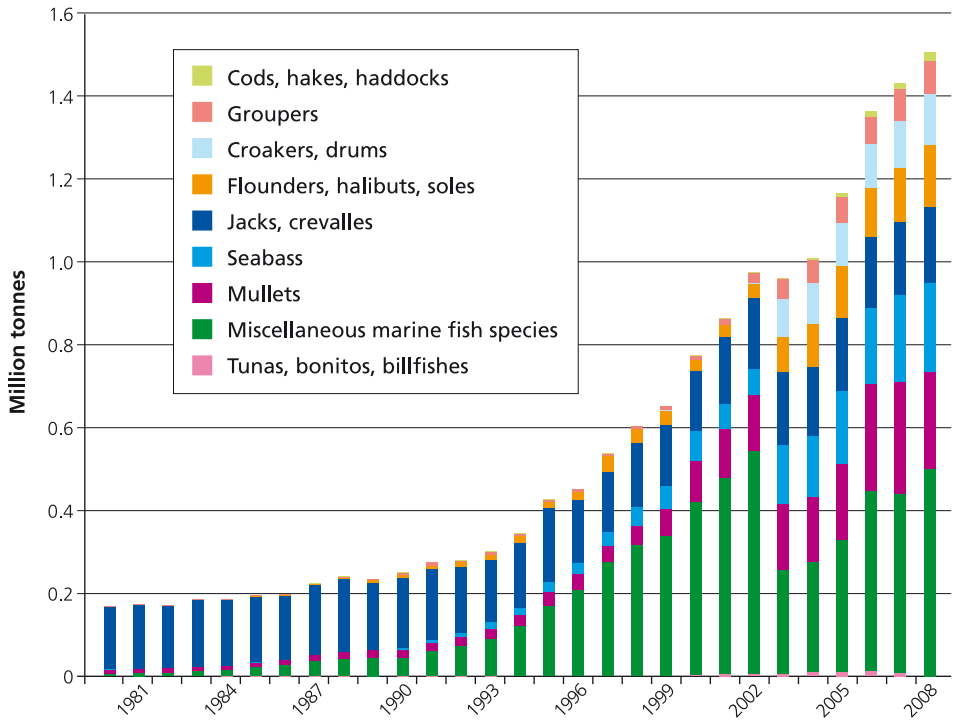
- seabass – 214 000 tonnes, two major species;
- mullets – 235 000 tonnes, one major species;
- porgies, seabreams – 253 000 tonnes, two major species;
- jacks, crevalles – 184 000 tonnes, one major species;
- flounders, halibuts, soles – 149 000 tonnes, two major species;
- croakers, drums – 123 000 tonnes, two major species;
- groupers – 78 000 tonnes;
- cods, hakes, haddocks – 21 387 tonnes, one major species;
- tunas, bonitos, billfishes – 8 926 tonnes, one major species; and
- miscellaneous marine fish species – 499 000 tonnes, three major species.

FIGURE 4
**Growth of fed diadromous fish species, 1980–2008**




*Source*: FAO (2010a).

FIGURE 5
**Growth of fed marine fish species, 1980–2008**




*Source*: FAO (2010a).

**Fed freshwater crustaceans:** 1.37 million tonnes, valued at US$7.7 billion (Figure 3; Annex 1):

- crabs – 518 000 tonnes, one major species;
- crawfishes, crayfishes – 418 000 tonnes, one major species; and
- river prawns – 426 000 tonnes, two major species.

Over the period 2000–2008, the fastest-growing major fed species group was catfishes (23.0 percent annual percentage rate [APR], Figure 2); followed by miscellaneous freshwater fishes (21.7 percent APR, Figure 4); freshwater crustaceans (15.9 percent APR, Figure 3); marine shrimps (14.7 percent APR, Figure 3); tilapias (11.3 percent APR, Figure 2); and marine fishes (8.1 percent APR, Figure 5; FAO, 2010a). This contrasts with the reduced growth of carps (5.6 percent APR, Figure 2); salmons (5.5 percent APR, Figure 4); milkfish (4.7 percent APR, miscellaneous diadromous species, Figure 4); trouts (3.5 percent APR, Figure 4); and eels (2.8 percent APR, Figure 4) over the same period.

## 2.2 IN-COUNTRY FED SPECIES PRODUCTION AND FEEDING PRACTICES

On a global basis, more than 85.5 percent of fed fish and crustacean aquaculture production was produced on the Asian continent in 2008 (26.9 million tonnes), followed by the Americas (1.93 million tonnes, or 6.1 percent), Europe (1.64 million tonnes, or 5.2 percent), Africa (0.94 million tonnes, or 3.0 percent), and Oceania (50 317 tonnes, or 0.2 percent; FAO, 2010a).

Twenty countries accounted for 94 percent of total global fed fish and crustacean production in 2008, with China alone accounting for about half of the global total (Table 1).

These top 20 fed species producers were also the largest consumers and producers of feed, either in the form of fresh feeds, farm-made feeds or commercial feeds.

Table 2 lists the top 53 fed cultured fish and crustacean species/species groups by main country producers in 2008, and includes the average in-country unit value of the cultured species (US$/kg), the reported farm production unit, and the reported feeding practices employed for each species.

TABLE 1
**Top 20 country producers of fed fish and crustacean species in 2008**

| Country | Production (million tonnes) | Percent of total production |
|---|---|---|
| China | 15.67 | 49.8 |
| India | 3.08 | 9.8 |
| Viet Nam | 2.12 | 6.7 |
| Indonesia | 1.64 | 5.2 |
| Thailand | 1.03 | 3.3 |
| Norway | 0.84 | 2.7 |
| Philippines | 0.70 | 2.2 |
| Egypt | 0.69 | 2.2 |
| Myanmar | 0.65 | 2.1 |
| Chile | 0.63 | 2.0 |
| Bangladesh | 0.62 | 2.0 |
| United States | 0.34 | 1.1 |
| Japan | 0.30 | 1.0 |
| Brazil | 0.27 | 0.8 |
| Taiwan Province of China | 0.22 | - |
| Ecuador | 0.17 | - |
| Malaysia | 0.17 | - |
| Turkey | 0.15 | - |
| Mexico | 0.14 | - |
| United Kingdom | 0.14 | - |

*Source:* FAO (2010a).

**Fed carps and other cyprinids (Chinese carps, Indian major carps, other cyprinids):** represent the largest and historically oldest fed species group, with an average growth rate of 5.6 percent per year over the last decade (Figure 2; FAO, 2010a). It is estimated that the percentage of total fed carp production (excluding Indian major carps) based on commercial feeds increased from 20 percent in 1995 to 48 percent in 2008, with total global commercial carp feed production increasing from 2.1 million tonnes in 1995 to 9.1 million tonnes in 2008 and estimated to reach 15.8 million tonnes by 2020 (Table 3). By contrast, almost all Indian major carp production is still based on the use of low-cost locally produced farm-made feeds (Ayyappan and Ahamad Ali, 2007), with fresh feed items still only being fed to Chinese carps (primarily grass carp), depending upon the financial resources of the farmer (Barman and Karim, 2007; Weimin and Mengqing, 2007).

Of particular note is the difference in the estimated farmgate unit value of the same species among producing countries, depending upon preferences. For example, grass carp has a minimum reported unit value of US$0.80/kg in China and a maximum reported unit value of US$3.0 in the Islamic Republic of Iran (FAO, 2010a); the latter higher market values would allow the use of more costly farm production methods and feeding methods.

**Tilapias:** represent the second-largest fed species group among freshwater fishes, with an average growth rate of 11.3 percent per year over the last decade (Figure 2; FAO, 2010a). The percentage of total fed tilapia production based on commercial feeds increased from 70 percent in 1995 to 83 percent in 2008, with total global commercial tilapia feed production increasing from 0.99 to 3.95 million tonnes from 1995 to 2008 and estimated to reach 12.0 million tonnes by 2020 (Table 3).

**Catfishes:** represent the third-largest fed species group among freshwater fishes, with the sector growing at a very high rate of 23.0 percent per year over the last decade (Figure 2; FAO, 2010a). About 72 percent of total fed global catfish production was based on commercial feeds in 2008 (Table 2), with commercial catfish feed production increasing from 586 000 tonnes in 1995 to 3.0 million tonnes in 2008 and estimated to reach 12.5 million tonnes by 2020 (Table 3).

**Miscellaneous freshwater fishes:** represent the fourth-largest fed species group among freshwater fishes, registering a high growth rate of 21.7 percent per year over the last decade (Figure 2; FAO, 2010a). It is estimated that about 18 percent of total fed miscellaneous freshwater fish production was based on commercial feeds in 2008 (Table 2), with commercial feed production increasing from 15 000 tonnes in 1995 to 480 000 tonnes in 2008 and estimated to reach 3.0 million tonnes by 2020 (Table 3). With the exception of omnivorous or herbivorous species (such as pirapatinga, cachama), the bulk of this species grouping is mostly piscivorous fish species and, as such, are still usually fed on live/trash fish feed items (Chen *et al.*, 2007; De Silva and Phillips, 2007; Weimin and Mengqing, 2007).

**Salmons:** represent the largest diadromous fish species group, with an average growth rate of 5.5 percent per year over the last decade (Figure 4; FAO, 2010a). All the salmon aquaculture production was based on commercial feeds, with total global commercial salmon feed production increasing from 806 000 tonnes in 1995 to 2.0 million tonnes in 2008. It is projected to reach 3.7 million tonnes by 2020 (Table 3).

**Trouts:** represent the second-largest diadromous fish species group, with an average growth rate of 3.5 percent per year over the last decade (Figure 4; FAO, 2010a). One hundred percent of the trout aquaculture production was based on commercial feeds, with total global commercial trout feed production increasing from 588 000 tonnes

in 1995 to 880 000 tonnes in 2008. It is projected to reach 1.6 million tonnes by 2020 (Table 2).

**Milkfish:** represent the third-largest diadromous aquaculture species after Atlantic salmon, with species production growing at an average rate of 4.7 percent per year over the last decade (Figure 4; FAO, 2010a). The milkfish production based on commercial feeds increased from 30 percent in 1995 to 42 percent in 2008, with total global commercial milkfish feed production increasing from 220 000 tonnes in 1995 to 568 000 tonnes in 2008 and estimated to reach 1.1 million tonnes by 2020 (Table 3).

**Eels:** represent the fourth-largest diadromous aquaculture species group, with species group production growing at an average rate of 2.8 percent per year over the last decade (Figure 4; FAO, 2010a). The eel production based on commercial feeds increased from 90 percent in 1995 to 95 percent in 2008, with total global commercial eel feed production increasing from 338 000 tonnes in 1995 to 403 000 tonnes in 2008 and estimated to reach 504 000 tonnes by 2020 (Table 3).

**Marine fishes:** represent the last major fish species group by production, with species group production growing at an average rate of 8.1 percent per year over the last decade (Figure 5; FAO, 2010a). The marine fish production based on commercial feeds increased from 50 percent in 1995 to 72 percent in 2008, with total global commercial marine fish feed production increasing from 533 000 tonnes in 1995 to 2.4 million tonnes in 2008 and estimated to reach 6.6 million tonnes by 2020 (Table 3).

At present, the bulk of marine finfish cage aquaculture production in China (Table 1) is still based on the use of lower-cost fresh feeds based on small-sized pelagic fish species in the form of fresh/frozen fish (Chen *et al.*, 2007; Weimin and Mengqing, 2007); China alone reportedly consumed between 4 and 5 million tonnes of low-value pelagic fish as aquaculture feed in 2005 (Jin, 2006).

**Marine shrimps:** represent the largest crustacean species group, with species group production growing at an average rate of 14.7 percent per year over the last decade (Figure 3; FAO, 2010a). The shrimp production based on commercial feeds increased from 75 percent in 1995 to 93 percent in 2008, with total global commercial shrimp feed production increasing from 1.4 million tonnes in 1995 to 5.0 million tonnes in 2008 and estimated to reach 11.3 million tonnes by 2020 (Table 3).

**Freshwater crustaceans:** represent the second-largest crustacean species group, with group production growing at an average rate of 15.9 percent per year over the last decade (Figure 3; FAO, 2010a). The total freshwater crustacean production based on commercial feeds increased from 35 percent in 1995 to 48 percent in 2008, with total global commercial freshwater crustacean feed production increasing from 91 000 tonnes in 1995 to 1.3 million tonnes in 2008 and estimated to reach 2.7 million tonnes by 2020 (Table 3).

TABLE 2
**Top 53 major fed cultured fish and crustacean species/species groups by main country producers in 2008, the average value of the cultured species (US$/kg), reported farm production unit and feeding practice**

| Species | Production (tonnes)[a] | Major producers (% total production)[a] | Unit value (US$/kg)[a] | Farming unit[b] | Feeding practice[b] | Reference |
|---|---|---|---|---|---|---|
| **Freshwater fish species** | | | | | | |
| **Carps** | | | | | | |
| Grass carp | 3 775 267 | China 98.2%*; Bangladesh 0.44%; Islamic Republic of Iran 0.35%**; Myanmar 0.33% | 0.80* – 3.0** | Ponds, lakes/reservoirs, paddy fields, cages, pens | Fresh feeds, farm-made feeds, commercial feeds | 1, 2 |
| Common carp | 2 987 433 | China 78.7%; Indonesia 8.1%*; Viet Nam 2.5%; Russian Federation 1.6%** | 0.92* – 2.5** | Ponds, cages, pens, lakes/reservoirs, paddy fields | Commercial feeds, fresh feeds | 1, 3 |
| Catla | 2 281 838 | India 91.4%; Bangladesh 6.6%**; Myanmar 1.6%; Lao People's Democratic Republic 0.22%* | 1.20* – 1.68** | Ponds, lakes/reservoirs, paddy fields | Farm-made feeds | 2, 4 |
| Crucian carp | 1 957 337 | China 99.9%*; Taiwan Province of China 0.044%; Belarus 0.037%**; Armenia 0.006% | 1.09* – 2.7** | Ponds, pens, cages | Commercial feeds, fresh feeds | 1, 5 |
| Rohu | 1 159 454 | India 44.1%; Myanmar 37.4%*; Bangladesh 17.5%**; Lao People's Democratic Republic 0.5% | 0.90* – 1.90** | Ponds, lakes/reservoirs, paddy fields | Farm-made feeds | 2, 4 |
| Wuchang bream | 599 623 | China 100%* | 1.65* | Ponds, cages, lakes/reservoirs | Commercial feeds, fresh feeds | 1, 5 |
| Black carp | 360 332 | China 99.85%*; Taiwan Province of China 0.15%** | 1.64* – 2.32** | Ponds, cages, pens | Fresh feeds, commercial feeds | 1, 5 |
| Mrigal | 463 520 | India 66.3%; Bangladesh 26.5%; Myanmar 5.4%**; Lao People's Democratic Republic 1.0%* | 1.00* – 1.90** | Ponds, lakes/reservoirs, paddy fields | Farm-made feeds | 2, 4 |
| Silver barb | 107 457 | Thailand 51.4%; Indonesia 24.2%; Myanmar 11.5%*; Cambodia 6.5%** | 0.60* – 1.50** | Ponds, paddy fields, ditch, cages | Farm-made feeds | 6, 7 |
| **Tilapias** | | | | | | |
| Nile tilapia | 2 334 432 | China 47.6%**; Egypt 16.5%; Indonesia 12.5%*; Thailand 9.0% | 0.74* – 1.49** | Ponds, cages, paddy fields | Commercial feeds | 1, 3, 8 |
| **Catfishes** | | | | | | |
| Pangasiid catfishes | 1 380 702 | Viet Nam 90.0%**; Indonesia 7.3%*; Cambodia 1.0%**; Myanmar 1.0% | 0.84* – 1.5** | Ponds, cages | Commercial feeds, farm-made feeds | 10, 11, 31 |
| Channel catfish | 462 416 | United States 50.5%; China 48.5%; Cuba 0.5%*; Brazil 0.4%** | 1.00* – 2.1** | Ponds, cages | Commercial feeds | 1, 12 |
| Amur catfish | 321 071 | China 98.3%; Republic of Korea 1.4%*; Taiwan Province of China 0.5%** | 0.89* – 2.99** | Ponds, cages | Fresh feeds, commercial feeds | 1, 13 |
| Torpedo shaped catfishes | 237 634 | Indonesia 48.1%*; Malaysia 17.5%; Uganda 14.7%**; Egypt 5.9% | 0.77* – 2.10** | Ponds, tanks | Commercial feeds, farm-made feeds | 3, 14 |

TABLE 2, continued

**Top 53 major fed cultured fish and crustacean species/species groups by main country producers in 2008, the average value of the cultured species (US$/kg), reported farm production unit and feeding practice**

| Species | Production (tonnes)[a] | Major producers (% total production)[a] | Unit value (US$/kg)[a] | Farming unit[b] | Feeding practice[b] | Reference |
|---|---|---|---|---|---|---|
| **Catfishes, continued** | | | | | | |
| Catfish, hybrid | 135 507 | Thailand 100% | 0.99 | Ponds, cage, ditch, paddy fields | Commercial feeds, farm-made feeds, fresh feeds | 6 |
| Yellow catfish | 134 448 | China 100% | 1.30 | Ponds, cages, paddy fields | Commercial feeds, fresh feeds | 1, 5 |
| North African catfish | 47 428 | Nigeria 79.3%; Netherlands 9.5%*; Hungary 4.0%**; Syrian Arab Republic 3.2% | 1.4* – 3.4** | Ponds, tanks | Commercial feeds, farm-made feeds | 14, 15 |
| **Others** | | | | | | |
| Snakeheads | 324 318 | China 99.9%*; Republic of Korea 0.1%** | 1.22* – 6.12** | Ponds, paddy fields, cages | Farm-made feeds, fresh feeds | 1, 16 |
| Mandarin fish | 229 269 | China 100% | 9.3 | Ponds, cages | Fresh feeds | 1, 5 |
| Asian swamp eel | 212 209 | China 99.96%**; Thailand 0.02%; Cambodia 0.02%* | 1.50* – 2.61** | Paddy fields, cages | Fresh feeds | 1, 5 |
| Largemouth black bass | 166 672 | China 99.957%*; Italy 0.021%**; Morroco 0.021%; Mexico 0.001% | 1.56* – 8.09** | | | |
| Pirapatinga | 91 951 | China 84.2%; Myanmar 6.7%*; Viet Nam 6.5%; Colombia 2.4%** | 0.6* – 2.6** | Ponds, cages | Commercial feeds, farm-made feeds | 5, 17 |
| Cachama | 44 219 | Brazil 69.2%; Colombia 23.5%; Venezuela 5.3%*; Peru 1.22%** | 1.5* – 3.05** | Ponds, cages | Commercial feeds, fresh feeds | 17, 18 |
| **Diadromous fish species** | | | | | | |
| **Salmons** | | | | | | |
| Atlantic salmon | 1 456 721 | Norway 51.0%*; Chile 26.7%**; United Kingdom 8.8%; Canada 7.1% | 3.6 * – 6.4** | Cages | Commercial feeds | 17, 19, 20 |
| Coho salmon | 105 117 | Chile 87.8%*; Japan 12.2%** | 4.1* – 4.5** | Cages | Commercial feeds | 17, 19 |
| **Trouts** | | | | | | |
| Rainbow trout | 576 289 | Chile 25.9%*; Norway 13.1%; Islamic Republic of Iran 10.9%*; Italy 6.6% | 3.00* – 5.84** | Cages, raceways, ponds | Commercial feeds | 17, 19, 20 |
| **Eels** | | | | | | |
| Japanese eel | 253 795 | China 80.9%*; Taiwan Province of China 8.3%; Japan 8.3%; Republic of Korea 2.5%** | 2.74* – 20.3** | Ponds, indoor tanks | Commercial feeds | 1, 21 |
| **Others** | | | | | | |
| Milkfish | 676 228 | Philippines 51.9%; Indonesia 41.0%*; Taiwan Province of China 6.9%**, Singapore 0.1% | 0.90* – 2.01** | Ponds, pens, cages | Commercial feeds, fresh feeds | 3, 22 |

TABLE 2, continued

**Top 53 major fed cultured fish and crustacean species/species groups by main country producers in 2008, the average value of the cultured species (US$/kg), reported farm production unit and feeding practice**

| Species | Production (tonnes)[a] | Major producers (% total production)[a] | Unit value (US$/kg)[a] | Farming unit[b] | Feeding practice[b] | Reference |
|---|---|---|---|---|---|---|
| **Others, continued** | | | | | | |
| Barramundi | 44 959 | Thailand 33.8%, Malaysia 26.0%**, Taiwan Province of China 22.9%, Indonesia 9.7%* | 1.26* – 3.95** | Cages, ponds | Fresh feeds, commercial feeds | 3, 6, 23 |
| **Marine fish species** | | | | | | |
| **Mullets** | | | | | | |
| Flathead grey mullet | 220 932 | Egypt 94.8%*, Republic of Korea 2.8%**, Israel 0.9%, Taiwan Province of China 0.6% | 2.86* – 4.15** | Ponds, lakes | Commercial feeds | 8 |
| **Seabass** | | | | | | |
| Japanese seabass | 97 754 | China 97.95%*, Republic of Korea 2.05%** | 1.20* – 8.53** | Cages | Fresh feeds, commercial feeds | 1, 5 |
| European seabass | 66 738 | Greece 52.5%, Spain 14.6%, Italy 12.7%**, Egypt 6.6%* | 3.39* – 10.7** | Cages | Commercial feeds | 24 |
| **Jacks, crevalles** | | | | | | |
| Japanese amberjack | 158 508 | Japan 99.87%**, Republic of Korea 0.13%* | 5.45* – 8.50** | Cages, pens | Commercial feeds, farm-made feeds, fresh feeds | 23, 25 |
| **Porgies, seabreams** | | | | | | |
| Gilthead seabream | 133 026 | Greece 39.1%, Turkey 23.8%*, Spain 16.7%, Italy 6.3%** | 4.20* – 10.3** | Cages | Commercial feeds | 24 |
| Silver seabream | 78 515 | Japan 90.4%*, Republic of Korea 9.5%, Taiwan Province of China 0.1%** | 6.00* – 15.1** | Cages | Commercial feeds, farm-made feeds, fresh feeds | 16 |
| **Groupers** | | | | | | |
| Groupers | 70 232 | China 64.4%*, Taiwan Province of China 24.3%**, Indonesia 6.6%, Thailand 4.4% | 1.19* – 9.08** | Cages | Fresh feeds, commercial feeds | 1, 3, 5, 6 |
| **Flounders, halibuts** | | | | | | |
| Lefteye flounders | 78 141 | China 100% | 1.19 | Indoor tanks | Fresh feeds, commercial feeds | 1 |
| Bastard halibut | 50 632 | Republic of Korea 91.7%*, Japan 9.3%** | 8.13* – 16.00** | Indoor tanks, cages | Fresh feeds, commercial feeds | 16 |
| **Croakers, drums** | | | | | | |
| Large yellow croaker | 65 977 | China 100% | 1.19 | Cages | Fresh feeds, commercial feeds | 1, 5 |
| Red drum | 53 511 | China 95.2%*, United States 4.2%, Mauritius 0.3%**, Mayotte 0.15%** | 1.19* – 8.45** | Cages | Fresh feeds, commercial feeds | 1, 5 |
| **Others** | | | | | | |
| Korean rockfish | 35 564 | Republic of Korea 100% | 5.98 | Cages | Fresh feeds, commercial feeds | 16 |

TABLE 2, continued

**Top 53 major fed cultured fish and crustacean species/species groups by main country producers in 2008, the average value of the cultured species (US$/kg), reported farm production unit and feeding practice**

| Species | Production (tonnes)[a] | Major producers (% total production)[a] | Unit value (US$/kg)[a] | Farming unit[b] | Feeding practice[b] | Reference |
|---|---|---|---|---|---|---|
| **Others, continued** | | | | | | |
| Cobia | 29 859 | China 86.6%*, Taiwan Province of China 13.4%**, Mayotte 0.02% | 1.18* – 7.37** | Cages | Fresh feeds, commercial feeds | 5, 26 |
| **Marine crustaceans** | | | | | | |
| **Marine shrimps** | | | | | | |
| Whiteleg shrimp | 2 259 183 | China 47.0%, Thailand 22.1%*, Indonesia 9.2%, Ecuador 6.6%** | 2.86* – 4.80** | Ponds | Commercial feeds | 1, 3, 6, 27, 28 |
| Giant tiger prawn | 721 867 | Viet Nam 45.0%*, Indonesia 18.7%, India 10.5%**, China 8.4%* | 4.00* – 5.00** | Ponds | Commercial feeds | 3, 6, 28, 29 |
| Banana prawn | 80 165 | Malaysia 46.8%**, Indonesia 40.1%, Viet Nam 10.1%, Philippines 2.6%* | 3.26* – 4.23** | Ponds | Commercial feeds | 3, 22, 29 |
| Kuruma prawn | 49 512 | China 96.4%*, Japan 3.2%, Taiwan Province of China 0.2%, Spain 0.1%** | 4.00* – 35.1** | Ponds | Commercial feeds | 1 |
| Fleshy prawn | 42 720 | China 98.9%*, Republic of Korea 1.1%** | 3.96 – 11.34** | Ponds | Commercial feeds | 1 |
| **Marine crabs** | | | | | | |
| Indo-Pacific swamp crab | 138 032 | China 82.5%, Philippines 8.4%**, Indonesia 5.5%*, Myanmar 3.3% | 2.08 * – 5.68** | Ponds, pens, coves | Fresh feeds, farm-made feeds | 1, 22 |
| Swimming crabs | 83 803 | China 100% | 3.51 | Ponds, pens, coves | Fresh feeds, farm-made feeds | 1 |
| **Freshwater crustaceans** | | | | | | |
| **Freshwater crabs** | | | | | | |
| Chinese mitten crab | 518 365 | China 99.998%*, Republic of Korea 0.002%** | 6.96* – 45.1** | Pond, pen, paddy fields | Fresh feeds, farm-made feeds | 1 |
| **Crawfish, crayfish** | | | | | | |
| Red swamp crawfish | 417 904 | China 87.25%**, United States 12.75%* | 2.39* – 4.76** | Ponds | Fresh feeds, commercial feeds | 1, 30 |
| **River prawns** | | | | | | |
| Giant river prawn | 207 749 | China 61.5%, Thailand 13.7%*, Bangladesh 11.2%**, India 6.2% | 4.06* – 7.43** | Ponds | Commercial feeds, farm-made feeds | 1, 6, 28 |
| Oriental river prawn | 205 010 | China 100% | 4.76 | Ponds | Commercial feeds, fresh feeds | 1 |

*Lowest unit cost as reported in one of the major producing countries; ** highest unit cost as reported in one of the major producing countries.

1. Weimin and Mengqing (2007); 2. Barman and Karim (2007); 3. Nur (2007); 4. Ayyappan and Ahamad Ali (2007); 5. Chen *et al.* (2007); 6. Thongrod (2007); 7. Gupta and Abdur Rab (1994); 8. El-Sayed (2007); 9. Hempel (2009); 10. Phan *et al.* (2009); 11. Hung, Truc and Huy (2007); 12. Robinson and Li (2007);13. Nam *et al.* (2001); 14. Ayinla (2007); 15. Hecht (2007); 16. De Silva and Phillips (2007); 17. Flores-Nava (2007); 18. Gomes *et al.* (2006); 19. Rojas and Wadsworth (2007); 20. Grottum and Beveridge (2007); 21. Heinsbroek (2008); 22. Sumagaysay-Chavoso (2007); 23. Rimmer and Ponia (2007); 24. Cardia and Lovatelli (2007); 25. Nakada (2008); 26. Liao *et al.* (2004); 27. Hasan *et al.* (2007); 28. Suresh (2007); 29. Hung and Huy (2007); 30. D'Abramo *et al.* (2002); 31.Merican (2009).

*Source*: [a]Data for production, % country contribution and unit value are from FAO (2010a); [b]Information for farming unit and feeding practices are obtained from the source(s) as shown in reference column.

TABLE 3
**Estimated global aquaculture production and use of commercial aquafeeds, 1995–2020 (thousand tonnes)**

| Year | Total aquaculture production[1] | Growth (%/year)[2] | Percent on feeds[3] | Species EFCR[4] | Total feeds used[5] |
|---|---|---|---|---|---|
| **Fed carps (excluding silver carp, bighead carp and Indian major carps)** | | | | | |
| 1995 | 5 154 | - | 20 | 2 | 2 062 |
| 2000 | 7 508 | 3.9 | 37 | 2 | 5 556 |
| 2005 | 9 100 | 5.5 | 45 | 1.8 | 7 371 |
| 2007 | 9 814 | 4.5 | 47 | 1.8 | 8 303 |
| 2008 | 10 585 | 7.9 | 48 | 1.8 | 9 145 |
| 2010 | 11 670 | 5 | 50 | 1.8 | 10 503 |
| 2015 | 14 198 | 4 | 55 | 1.7 | 13 275 |
| 2020 | 16 459 | 3 | 60 | 1.6 | 15 801 |
| **Tilapias** | | | | | |
| 1995 | 704 | - | 70 | 2 | 985 |
| 2000 | 1 190 | 14.7 | 75 | 1.9 | 1 696 |
| 2005 | 1 980 | 11.3 | 80 | 1.8 | 2 852 |
| 2007 | 2 505 | 12.9 | 82 | 1.7 | 3 493 |
| 2008 | 2 798 | 11.7 | 83 | 1.7 | 3 948 |
| 2010 | 3 386 | 10 | 85 | 1.7 | 4 893 |
| 2015 | 5 453 | 10 | 90 | 1.6 | 7 852 |
| 2020 | 8 012 | 8 | 95 | 1.6 | 12 178 |
| **Catfishes** | | | | | |
| 1995 | 345 | - | 85 | 2 | 586 |
| 2000 | 529 | -2.4 | 81 | 1.8 | 772 |
| 2005 | 1 496 | 18.1 | 73 | 1.6 | 1 747 |
| 2007 | 2 267 | 26.7 | 72 | 1.5 | 2 448 |
| 2008 | 2 718 | 19.9 | 72 | 1.5 | 2 935 |
| 2010 | 3 872 | 19.4 | 73 | 1.5 | 4 240 |
| 2015 | 7 456 | 14 | 75 | 1.4 | 7 829 |
| 2020 | 12 008 | 10 | 80 | 1.3 | 12 488 |
| **Miscellaneous freshwater fishes** | | | | | |
| 1995 | 155 | - | 5 | 2 | 15 |
| 2000 | 278 | -14.7 | 10 | 2 | 56 |
| 2005 | 834 | 10.3 | 15 | 2 | 250 |
| 2007 | 1 057 | 14.9 | 17 | 2 | 360 |
| 2008 | 1 334 | 26.2 | 18 | 2 | 480 |
| 2010 | 1 794 | 16 | 20 | 2 | 718 |
| 2015 | 3 161 | 12 | 25 | 2 | 1 581 |
| 2020 | 5 091 | 10 | 30 | 2 | 3 055 |
| **Salmons** | | | | | |
| 1995 | 537 | - | 100 | 1.5 | 806 |
| 2000 | 1 021 | 12.2 | 100 | 1.3 | 1 327 |
| 2005 | 1 382 | 0.6 | 100 | 1.3 | 1 796 |
| 2007 | 1 561 | 6.3 | 100 | 1.3 | 2 029 |
| 2008 | 1 573 | 0.8 | 100 | 1.3 | 2 045 |
| 2010 | 1 734 | 5 | 100 | 1.3 | 2 255 |
| 2015 | 2 213 | 5 | 100 | 1.3 | 2 877 |
| 2020 | 2 825 | 5 | 100 | 1.3 | 3 672 |
| **Trouts** | | | | | |
| 1995 | 392 | - | 100 | 1.5 | 588 |
| 2000 | 512 | 7.8 | 100 | 1.3 | 666 |
| 2005 | 571 | -0.9 | 100 | 1.3 | 743 |
| 2007 | 694 | 11.4 | 100 | 1.3 | 903 |
| 2008 | 677 | -2.4 | 100 | 1.3 | 880 |
| 2010 | 746 | 5 | 100 | 1.3 | 970 |
| 2015 | 953 | 5 | 100 | 1.3 | 1 238 |
| 2020 | 1 216 | 5 | 100 | 1.3 | 1 581 |
| **Milkfish** | | | | | |
| 1995 | 366 | - | 30 | 2 | 220 |
| 2000 | 468 | 5.9 | 34 | 2 | 318 |
| 2005 | 595 | 3.7 | 39 | 2 | 464 |
| 2007 | 667 | 14 | 41 | 2 | 547 |
| 2008 | 676 | 1.3 | 42 | 2 | 568 |
| 2010 | 745 | 5 | 45 | 2 | 671 |
| 2015 | 951 | 5 | 50 | 1.8 | 856 |
| 2020 | 1 214 | 5 | 55 | 1.6 | 1 068 |

TABLE 3, continued

**Estimated global aquaculture production and use of commercial aquafeeds, 1995–2020 (thousand tonnes)**

| Year | Total aquaculture production[1] | Growth (%/year)[2] | Percent on feeds[3] | Species EFCR[4] | Total feeds used[5] |
|---|---|---|---|---|---|
| **Eels** | | | | | |
| 1995 | 188 | - | 90 | 2 | 338 |
| 2000 | 212 | 6.5 | 92 | 1.8 | 351 |
| 2005 | 217 | -3.1 | 94 | 1.6 | 327 |
| 2007 | 274 | 14.6 | 95 | 1.6 | 416 |
| 2008 | 265 | -3.3 | 95 | 1.6 | 403 |
| 2010 | 276 | 2.1 | 96 | 1.5 | 397 |
| 2015 | 304 | 2 | 98 | 1.5 | 447 |
| 2020 | 336 | 2 | 100 | 1.5 | 504 |
| **Marine fishes** | | | | | |
| 1995 | 533 | - | 50 | 2 | 533 |
| 2000 | 949 | 16.9 | 60 | 2 | 1 139 |
| 2005 | 1 402 | 13.5 | 70 | 1.9 | 2 050 |
| 2007 | 1 690 | 5.8 | 72 | 1.9 | 2 533 |
| 2008 | 1 766 | 4.5 | 72 | 1.9 | 2 416 |
| 2010 | 2 137 | 10 | 73 | 1.9 | 2 964 |
| 2015 | 3 140 | 8 | 75 | 1.8 | 4 239 |
| 2020 | 4 613 | 8 | 80 | 1.8 | 6 643 |
| **Marine shrimps** | | | | | |
| 1995 | 925 | - | 75 | 2 | 1 387 |
| 2000 | 1 133 | 8.2 | 82 | 2 | 1 857 |
| 2005 | 2 664 | 13 | 89 | 1.8 | 4 268 |
| 2007 | 3 275 | 5.3 | 92 | 1.6 | 4 821 |
| 2008 | 3 399 | 3.8 | 93 | 1.6 | 5 058 |
| 2010 | 4 113 | 10 | 95 | 1.6 | 6 251 |
| 2015 | 6 043 | 8 | 97 | 1.5 | 8 793 |
| 2020 | 8 087 | 6 | 100 | 1.4 | 11 322 |
| **Freshwater crustaceans** | | | | | |
| 1995 | 104 | - | 35 | 2.5 | 91 |
| 2000 | 429 | 57.1 | 40 | 2.4 | 412 |
| 2005 | 913 | 8 | 45 | 2.2 | 904 |
| 2007 | 1 337 | 40.3 | 47 | 2.1 | 1 320 |
| 2008 | 1 370 | 2.5 | 48 | 2 | 1 315 |
| 2010 | 1 510 | 5 | 50 | 2 | 1 510 |
| 2015 | 1 928 | 5 | 55 | 1.9 | 2 015 |
| 2020 | 2 460 | 5 | 60 | 1.8 | 2 657 |

**Summary totals for fed species and aquafeed production (thousand tonnes)**

| Year | Total fed aquaculture production | Total feeds used |
|---|---|---|
| 1995 | 4 028 | 7 612 |
| 2000 | 7 684 | 14 150 |
| 2005 | 13 048 | 22 585 |
| 2007 | 16 126 | 26 950 |
| 2008 | 17 476 | 29 194 |
| 2010 | 21 201 | 35 371 |
| 2015 | 32 315 | 51 002 |
| 2020 | 46 917 | 70 969 |

[1] Total reported species group production from 1995 to 2008 taken from FAO (2010a), and estimates for 2010, 2015 and 2020 are calculated based on expected growth.

[2] Mean estimated annual percentage growth rate (APR, %) of species group production for 2008–2010, 2010–2015 and 2015–2020 was modified from Tacon and Metian (2008a) based on the recent evolution of total production.

[3] Estimated percent of total species group production fed on commercial aquaculture feeds (modified after Tacon and Metian, 2008a).

[4] Estimated average species group economic feed conversion ratio (EFCR) – total feed fed/total species group biomass increase (modified after Tacon and Metian, 2008a).

[5] Estimated total species group aquaculture feed used (total species group production x EFCR).

## 2.3 GLOBAL AQUACULTURE FEED PRODUCTION BY MAJOR SPECIES GROUP AND COUNTRY

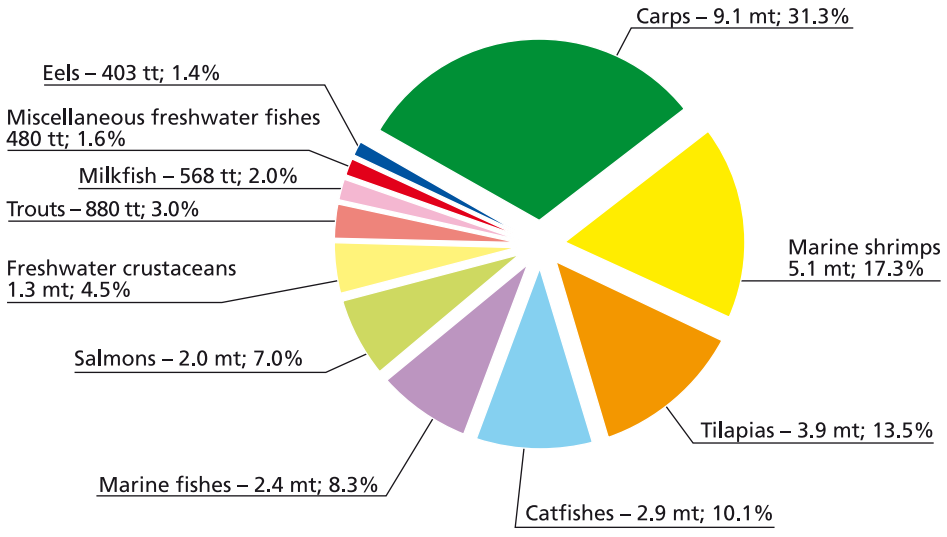
On the basis of the information presented in Table 3, it is estimated that the total global production of commercial aquaculture feeds was 29.2 million tonnes in 2008, including:

- carp feeds (9.1 million tonnes, or 31.3 percent total);
- marine shrimp feeds (5.1 million tonnes, or 17.3 percent);
- tilapia feeds (3.9 million tonnes, or 13.5 percent);
- catfish feeds (2.9 million tonnes, or 10.0 percent);
- marine fish feeds (2.4 million tonnes, or 8.3 percent);
- salmon feeds (2.0 million tonnes, or 7.0 percent);
- freshwater crustacean feeds (1.3 million tonnes, or 4.5 percent);
- trout feeds (880 000 tonnes, or 3.0 percent);
- milkfish feeds (568 000 tonnes, or 2.0 percent);
- eel feeds (403 000 tonnes, or 1.4 percent); and
- miscellaneous freshwater fish feeds (480 000 tonnes, or 1.6 percent).

The above estimate represents a 24.8 percent increase in production from the total estimated commercial aquaculture feed production of 23.4 million tonnes in 2006 (Gill, 2007). The commercial aquaculture feed sector has grown nearly fourfold, from 7.6 million tonnes in 1995 to 29.2 million tonnes in 2008 (average APR of 11.0 percent per year since 1995), and is expected to continue growing at a similar rate over the next decade to 71.0 million tonnes by 2020 (Figure 6; Table 3).

In some countries, however, the increase in the production of commercial acquafeed matched the rapid growth of the aquaculture sector. Thus, in Viet Nam, official figures show that aquafeed production increased from 336 000 tonnes in 1999 to 762 000 tonnes in 2004, with production more than doubling again to 1 863 000 tonnes in 2008 and estimated to be 2.4 million tonnes in 2009; over a 700 percent increase in feed production in a decade (Best, 2010a).

FIGURE 6
**Estimated global production of commercial aquaculture feeds by major species grouping, 2008**
Total global production in 2008 – 29.2 million tonnes




*Note*: tt = thousand tonnes; mt = million tonnes.
*Source*: Based on data from Table 3.

Table 4 shows the major country producers of commercial aquafeeds. The results, based on the responses received to an electronic survey conducted for this paper, show an estimated total production of between 24.4 and 28.9 million tonnes of commercial aquafeeds in 2007–2010. This is in line with the estimates given in Table 3 based on major aquaculture species production.

TABLE 4
**Major country producers of commercial aquaculture feeds, 2007–2010**

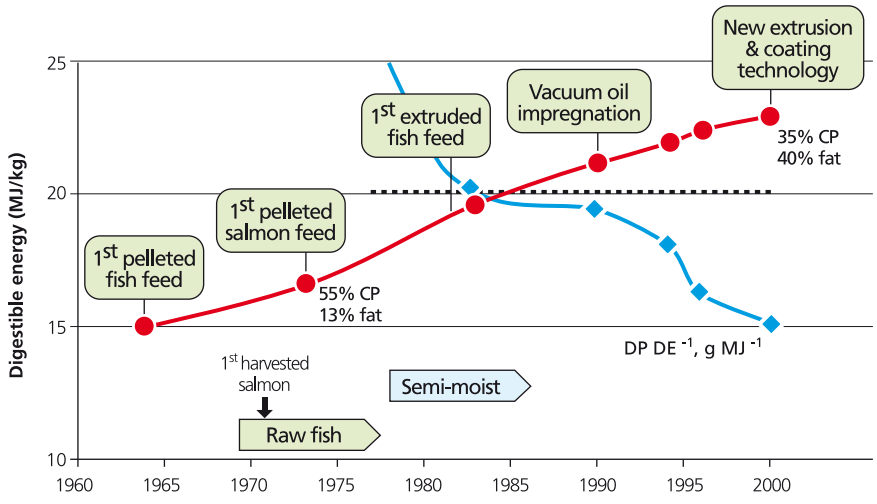
| Country | Commercial aquaculture feed production estimate (tonnes) |
|---|---|
| China (2008) | 13 000 000–15 000 000[1] |
| Viet Nam (2008/09) | 1 625 000–2 800 000[2,3,31] |
| Thailand (2008/09) | 1 210 327–1 445 829[2,4,31] |
| Norway (2008–2010) | 1 136 800–1 382 000[5,6] |
| Indonesia (2008/09) | 1 030 000–1 184 500[2,31] |
| Chile (2008) | 883 305–1 050 000[7,8] |
| United States (2008) | 700 000–750 000[9,10] |
| Japan (2008) | 500–000[11] |
| Philippines (2007) | 400 000–450 000[10] |
| Taiwan Province of China (2007) | 345 054[12] |
| Brazil (2008) | 324 000[13] |
| Egypt (2008) | 310 000[14] |
| Mexico (2008/09) | 222 800–282 500[15] |
| Greece (2009) | 262 000[32] |
| India (2006/07) | 247 283[16] |
| Ecuador (2009) | 235 000[17] |
| Malaysia (2009) | 226 000[31] |
| United Kingdom (2008) | 212 900[8] |
| Turkey (2009) | 170 000[18] |
| Canada (2008) | 161 600[19] |
| Peru (2008) | 145 000[20] |
| Republic of Korea (2008) | 126 898[21] |
| Bangladesh (2007) | 100 000–150 000[10] |
| Myanmar (2007) | 100 000–150 000[10] |
| Russian Federation (2007) | 100 000–150 000[10] |
| Colombia (2009) | 100 000–120 000[10] |
| Honduras (2007) | 75 000–100 000[10] |
| Spain (2007) | 75 000–100 000[10] |
| Italy (2007) | 68 750[22] |
| Australia (2008/09) | 58 125[23] |
| Iran, Islamic Republic of (2007) | 50 000–100 000[10] |
| France (2009) | 44 400[24] |
| Denmark (2008) | 43 500[25] |
| Venezuela, Bolivarian Republic of (2008) | 37 580[26] |
| Germany (2007) | 32 000[27] |
| Nicaragua (2009) | 25 508[28] |
| Costa Rica (2007) | 25 000–35 000[10] |
| Nigeria (2007) | 20 000–30 000[10] |
| Ireland (2009) | 20 000[29] |
| Argentina (2008) | 3 901[30] |
| **Total** | **24.4 to 28.9 million tonnes** |

[1]Wu (2009)/Miao Weimin (personal communication); [2]AAP (2009)/Best (2010a); [3]Dave Robb (personal communication); [4]Supis Thongrod (personal communication); [5]Ian Carr/Sigve Nordum (personal communication); [6]Niels Alsted (personal communication); [7]Aliro Borquez/Ian Carr (2008 data, personal communication); [8]Claudio Larraín estimates total salmonid aquafeed production as 575 000 tonnes in 2009 (personal communication); [9]Menghe Li/Kevin Fitzsimmons/Cheryl Shew (personal communication); [10]Estimate based, in part, on production values reported in Annex 2; [11]Sakashita (2009); [12]Shi-Yen Shiau (personal communication); [13]Rodrigo Carvalho/Silvio Coelho/Daniel Lemos (personal communication); [14]Abdel-Fattah El-Sayed (personal communication; [15]Jessica Montaño/Jesus Zendejas (personal communication); [16]Syed Ahamad Ali (personal communication); [17]Cesar Molina (personal communication); [18]Ozlem Guzel (personal communication); [19]Brad Hicks (personal communication); [20]Christian Berger (personal communication – includes shimp feed exports estimated at about 100 000 tonnes/annum). Peru aquaculture feed production in 2008 estimated at 46 800 tonnes (Carlos Mastrokalo Durand/Patricia Infante, personal communication) and 40 780 tonnes in 2009 (Fabricio Vargas Elias, personal communication); [21]Jeongdae Kim (personal communication); [22]Umberto Luzzana (personal communication); [23]Brett Glencross (personal communication); [24]Michel Autin (personal communication); [25]Hans Erik Bylling (personal communication); [26]José Duarte (personal communication); [27]Christian Lückstädt (personal communication); [28]Francisco Velasquez (personal communication); [29]Dave Jackson (personal communication); [30]Santiago Panné Huidobro (personal communication); [31]AAP (2010); [32]Iannis Zarkadis (personal communication).

At present, no precise statistical information exists on the total global production of farm-made aquafeeds (Tacon and Hasan, 2007), although production in 2006 has been tentatively estimated to be between 18.7 and 30.7 million tonnes (Tacon, 2008). This figure is in general agreement with total farm-made aquafeed production in Asia, which was reported at 19.3 million tonnes in 2004 (De Silva and Hasan, 2007). As expected, the largest farm-made aquafeed producers in 2006 were all countries from the Asian region and included China (10 to 20 million tonnes), India (6.5 to 7.5 million tonnes), Viet Nam (1 to 1.5 million tonnes), Japan (650 000 to 800 000 tonnes), and Thailand (700 000 to 750 000 tonnes; Tacon, 2008). According to Chinese researchers, the volume of farm-made feed production is not known in China (Weimin and Mangqing, 2007), although they estimate that farm-made feeds account for about 40 percent of the country's aquaculture production, natural feeds about 50 percent, and commercial feeds only 10 percent. They also report that 40 to 55 percent of farmed fish production in China are fed industrially compounded aquafeeds. These assumptions are similar to those made by Jin (2006), who estimated that only 20 percent of the aquatic animals that need to be fed on feed in China are fed formulated feeds. Clearly, more detailed studies and information are required concerning the use of forage feed fish in China and the extent and status of the on-farm and commercial aquafeed manufacturing sector.

The current widespread use of forage feed fish-based feeding regimes in the Asian region, particularly for the higher value carnivorous marine fish and crustacean species, is very similar to how the salmon farming industry started in Norway in the early 1970s (Talbot and Rosenlund, 2002): the first farmed Atlantic salmon (*Salmo salar*) were fed raw fish in the 1970s, and the industry then progressed to the development of semi-moist and dry pelleted feeds in the 1980s, to the use of high-energy extruded pelleted feeds in the 1990s and 2000s (Figure 7). Of particular importance is the fact that, as a result of these feed technology advancements (see also Kearns, 2005; Larraín, Leyton and Almendras, 2005), fish growth has increased and feed conversion ratios and fish production costs reduced for the farmer.

FIGURE 7
**Historical development of feeds in the Norwegian salmon industry in relation to prevailing technologies and typical inclusion levels of crude proteins, digestible energy and digestible protein levels, 1960–2000**




*Note*: CP = crude proteins; DE = digestible energy (MJ/kg); DP = digestible protein (g/kg).
*Source*: Talbot & Rosenlund (2002).

Notwithstanding the above discussion, it is important to highlight here the important role played by farm-made aquafeeds, particularly in the production of lower value (in marketing terms) freshwater fish species for home consumption (Tacon and Hasan, 2007); farm-made aquafeeds representing over 97 percent of the total carp feeds used by farmers in India (7.5 million tonnes in 2006/07) (Syed Ahamad Ali, Central Institute of Brackishwater Aquaculture, Chennai, India, personal communication, November 2009), and still providing the mainstay of feed inputs in many southeast Asian (Ng, Soe and Phone, 2007) and sub-Saharan countries (Hecht, 2007).

Moreover, despite the lack of official published information concerning the direct use of "low-value/trash fish" and other small pelagic forage fish species as aquaculture feed, it is estimated that the total use in aquaculture was between 5.6 and 8.8 million tonnes in 2006 (mean 7.2 million tonnes; Tacon and Metian, 2009a); China alone reportedly consumed 4 to 5 million tonnes in 2005 (Jin, 2006). However, estimates for 2008 concerning the direct use of low-value/trash fish as feed in China are currently 6 to 8 million tonnes, 4 to 5 million tonnes of marine trash fish, and 2 to 3 tonnes of freshwater fish, including live food fish (approximately 70 percent of this is used for feeding inland carnivorous aquaculture species and the remainder for marine finfish, Miao Weimin, personal communication).

*Samples of commercially produced pellets for rainbow trout* (Oncorhynchus mykiss) *in a trout farm, Ermstalfischerei, Germany. Rainbow trout are fed with commercially produced pellets throughout their farm production cycles.*

Courtesy of Jayanta Saha

# 3. Feed ingredient production and availability

The global production and market availability of feed ingredient sources commonly used in aquaculture feeds have been reviewed by Hasan *et al.* (2007). The review focuses on developing countries; these countries produced over 91.5 percent of total fed fish and crustacean production in 2007 (FAO, 2009a). In particular, the review includes a global overview (Tacon and Hasan, 2007), regional reviews covering Asia (De Silva and Hasan, 2007), Latin America (Flores-Nava, 2007) and sub-Saharan Africa (Hecht, 2007), and 13 individual country profiles (Bangladesh, Cameroon, China, Egypt, India, Indonesia, Kenya, Malawi, Nigeria, the Philippines, Viet Nam, Thailand and Uganda) concerning aquaculture feed production and ingredient usage (Hasan *et al.*, 2007).

For the purposes of this paper, feed ingredients are categorized into animal nutrient sources, plant nutrient sources and microbial nutrient sources.

## 3.1 ANIMAL NUTRIENT SOURCES

### 3.1.1 Aquatic animal protein meals and lipids

The major aquatic animal protein meals and lipids available in the marketplace can be listed as follows (in order of global production and current market availability):

- *fish/shellfish meals and oils*: produced from wild harvested whole fish and macroinvertebrate animals, including bycatch;
- *fish/shellfish by-product meals and oils*: produced from seafood and/or aquaculture processing wastes;
- *zooplankton meals and oils*: produced from wild harvested marine invertebrates;
- *fish/shellfish hydrolysates, silages and fermentation products*: produced from harvested whole fish, macroinvertebrates, zooplankton and/or seafood processing wastes; and
- *marine polychaete meals*: produced from wild harvested and/or cultured marine annelid worms.

Table 5 summarizes the available published information on the total reported global production of the above listed aquatic animal protein meals and lipids.

***Fish/shellfish meals and oils***

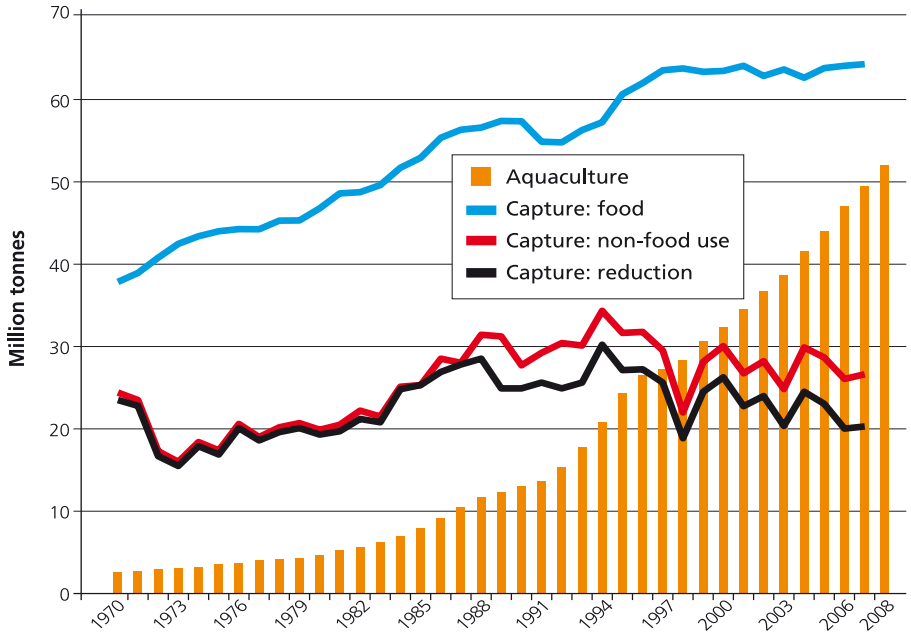
Fishmeals and oils derived from wild harvested whole fish currently constitute the major aquatic protein and lipid sources available within the animal feed marketplace. Despite this, the proportion of the global fisheries catch destined for reduction into fishmeal and fish oil has remained static with respect to the growth of the aquaculture sector (20.4 million tonnes in 2007; Figure 8), with global fishmeal and fish oil production decreasing at an average rate of –1.7 percent per year and –2.6 percent per year since 1995, respectively (Table 5). Moreover, according to FAO (2009a), only 15 percent of total global fishmeal production and 44 percent of total fish oil production was reported down to the species level in 2007. To a large extent this is due to the common practice by the industry (in some countries) of blending different batches and sources of meals and oils so as to attain an overall specific nutrient standard for sale to traders and buyers.

TABLE 5
**Total reported production of aquatic animal protein meals and lipids**

| Ingredient | Global production, growth and market availability |
|---|---|
| **Fish/shellfish meals and oils:** produced from wild harvested whole fish and macroinvertebrate animals, including fishes (anchovy, capelin, crab, grenadier, hake, herring, mackerel, menhaden, pilchard, sandeel, sardine, sardinella, saury, shad, sprat, whiting); crustaceans (marine shrimps, squilla); and molluscs (clams, mussels, squid). | **Fishmeal global production:** 5 621 712 tonnes in 2007 (6 125 420 tonnes in 2008); down from reported lowest production in 1995 (6 851 899 tonnes) and reported highest production in 2000 (6 961 483 tonnes), APR decrease since 1995, -1.7%/year, 85.0% total production in 2007, non-species specific.<br><br>**Fish oil global production:** 1 011 886 tonnes in 2007 (1 060 472 tonnes in 2008); down from lowest production in 1995 (1 378 599 tonnes) and highest production in 1986 (1 667 193 tonnes), APR decrease since 1995, -2.6%/year, 56.3% total production in 2007, non-species specific.<br><br>**Fishmeal country production (2007):** Peru (24.9%); China (18.7%); Chile (12.5%); Thailand (7.6%); United States (4.5%); Japan (3.6%); Denmark (3.1%); Norway (3.0%); Iceland (2.3%); South Africa (1.6%); Ecuador (1.6%); Spain (1.3%); Mexico (1.3%) – total 86.0%.<br><br>**Fish oil country production (2007):** Peru (30.6%); Chile (18.4%); Denmark (11.8%); United States (6.8%); Iceland (6.1%); Japan (5.9%); Norway (4.6%); Morocco (2.5%); Mexico (2.4%); Spain (1.6%); China (1.3%); United Kingdom (1.2%) – total 93.2%.<br><br>**Fishmeal exports:** 3 116 570 tonnes in 2007; down from lowest export in 1995 (4 501 810 tonnes) and highest export in 1994 (4 905 692 tonnes), APR decrease since 1995, -3.1%/year; major exporters in 2007: Peru (41.0%); Chile (15.7%); Germany (5.8%); Denmark (4.6%); Iceland (3.9%); United States (3.4%); Thailand (3.0%); Ecuador (2.8%); Faroe Islands (1.8%); Norway (1.3%); Mexico (1.2%) – total 84.5%.<br><br>**Fish oil exports:** 865 075 tonnes in 2007; down from lowest export in 1995 (941 808 tonnes) and highest export in 1994 (946 763 tonnes), APR decrease since 1995 -0.7%/year; major exporters in 2007: Peru (37.1%); Denmark (14.7%); Chile (8.3%); Iceland (7.1%); Norway (6.6%); United States (6.4%); Morocco (3.0%); France (2.4%); the Netherlands (2.1%) – total 85.6%.<br><br>**Fishmeal imports:** 3 270 499 tonnes in 2007; down from lowest import in 1995 (4 571 860 tonnes) and highest import in 1994 (4 918 553 tonnes), APR decrease since 1995, -2.8%/year; major importers in 2007: China (29.6%); Japan (10.7%); Norway (6.8%); Germany (6.4%); Taiwan Province of China (4.7%); Denmark (5.4%); Viet Nam (3.5%); Greece (2.9%); United Kingdom (2.7%); Spain (2.1%); Russian Federation (1.8%); Italy (1.7%); Turkey (1.7%); Indonesia (1.7%) – total 81.7%.<br><br>**Fish oil imports:** 896 850 tonnes in 2007; down from lowest import in 1995 (1 115 528 tonnes) and highest import in 1995 (1 115 528 tonnes), APR decrease since 1995, -1.8%/year; major importers in 2007: Norway (25.8%); Denmark (17.7%); Chile (10.2%); France (4.3%); Canada (3.9%); the Netherlands (3.6%); Japan (3.4%); China (3.4%); United States (2.8%); Taiwan Province of China (2.8%) – total 77.9%. |
| **Fish/shellfish by-product meals and oils:** produced from seafood and/or aquaculture processing wastes, including catfish, crab, crayfish, hake, pollock, lobster, salmon, shrimp, squid, tilapia, trout and tuna.<br><br>**Zooplankton meals and oils:** produced from wild harvested marine invertebrates, including brine shrimp biomass, calanus and krill.<br><br>**Fish/shellfish hydrolysates, silages and fermentation products:** produced from harvested whole fish, macroinvertebrates, zooplankton and/or seafood processing wastes.<br><br>**Marine polychaete meals:** produced from wild harvested and/or cultured annelid worms. | Total **tuna meal** production reported as 36 054 tonnes in 2007: major reported country producers: Islamic Republic of Iran (38.7%); Seychelles (38.5%); Maldives (5.0%); Fiji Islands (1.1%).<br><br>Total **shrimp meal** production reported as 26 290 tonnes in 2007: major reported country producers: Indonesia (98.6%); Iceland (1.4%).<br><br>Total crustacean meal (no species given) production reported as 20 558 tonnes in 2007: major country producers: Chile (94.8%); El Salvador (5.2%).<br><br>Total **squid oil** production reported as 280 tonnes in 2007: major country producer: Republic of Korea (100%).<br><br>Hardy and Shepherd (2007) reported that 84 579 tonnes of fishmeal and 21 916 tonnes of fish oil was produced in Alaska from Alaskan pollack and cod processing wastes in 2006.<br><br>Total **krill** landings reported as 118 124 tonnes in 2007, with higest production (430 765 tonnes) reported in 1987: major country producers: Norway (33.7%); Republic of Korea (28.0%); Japan 20.6%; India (11.5%); Poland (6.3%).<br><br>Total **fish silage** (no species given) production reported as 1 220 tonnes in 2007: major country producer: Finland (100%). |

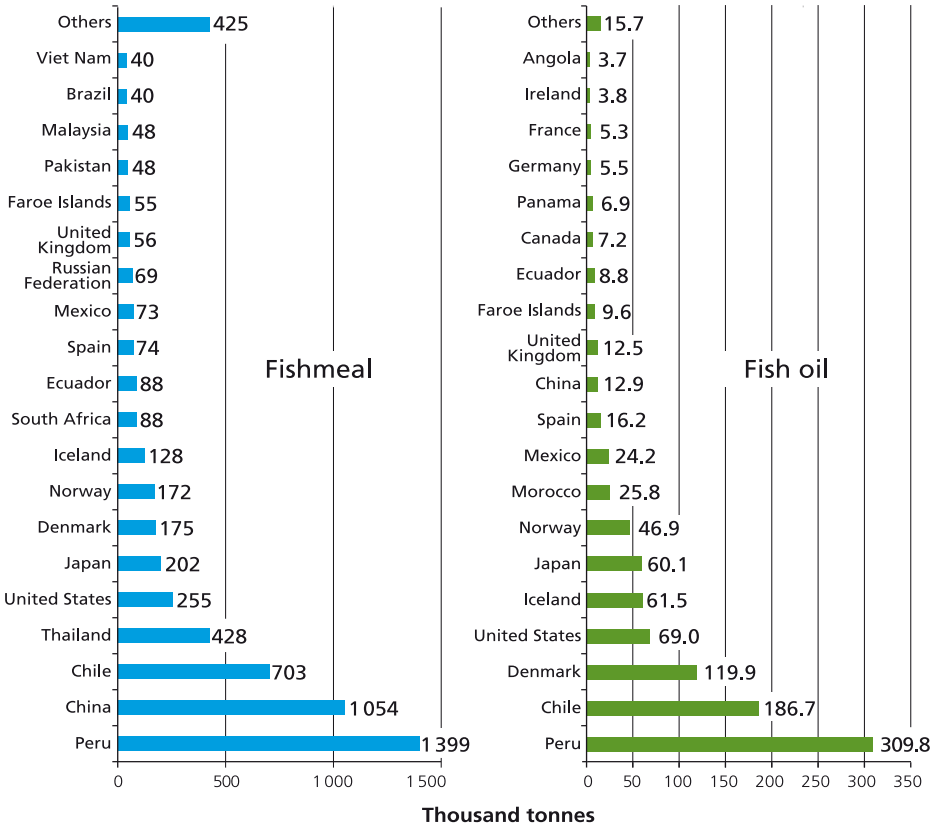
*Source*: FAO (2009a).

FIGURE 8
**Total capture fisheries and aquaculture production and volume of the catch destined for reduction and other non-food uses, 1970–2008**




*Note*: Capture and aquaculture production exclude mammals, reptiles and aquatic plants.
*Source*: FAO (2009a and 2010a).

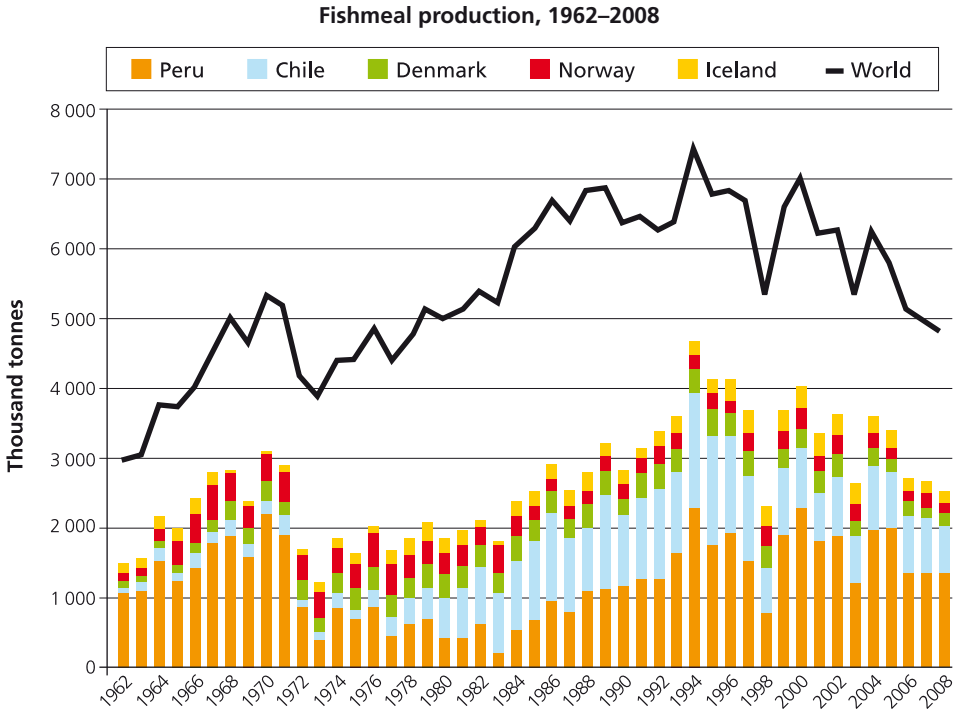
FIGURE 9
**Major country producers of fishmeal and fish oil, 2007**

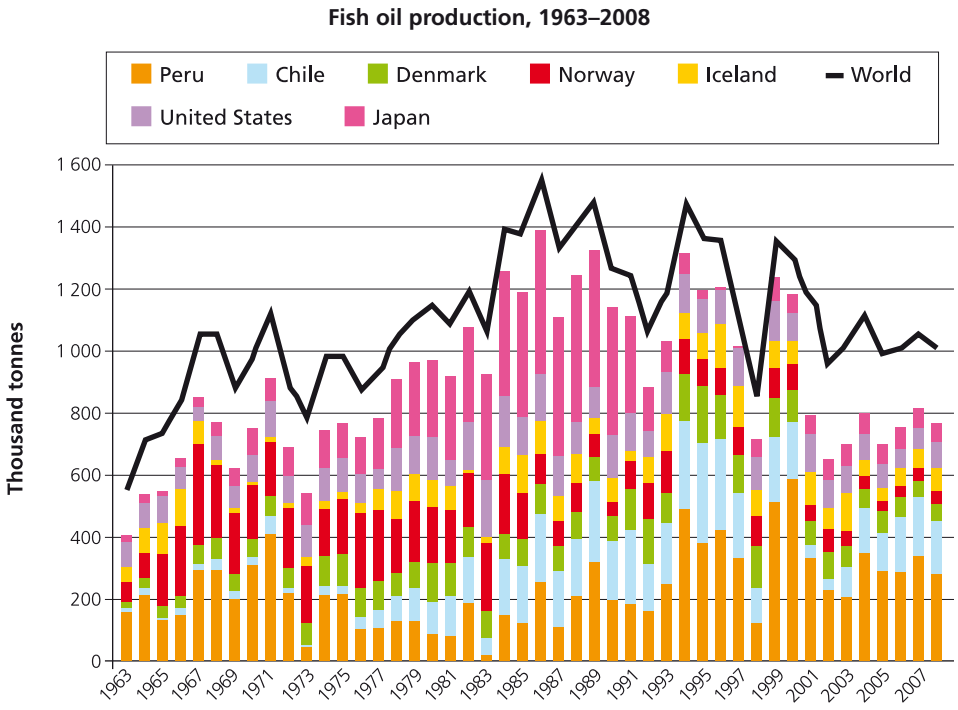



*Source*: FAO (2009a).

Figure 9 shows the major country producers of fishmeal and fish oil, with Peru producing the major share of both commodities. Figure 10 shows total fishmeal and fish oil production by country from 1962 to 2008, according to the latest estimates of the International Fishmeal and Fish Oil Organisation (IFFO) (Shepherd, 2009).

FIGURE 10
**Historical production trend of fishmeal and fish oil, 1962–2008**

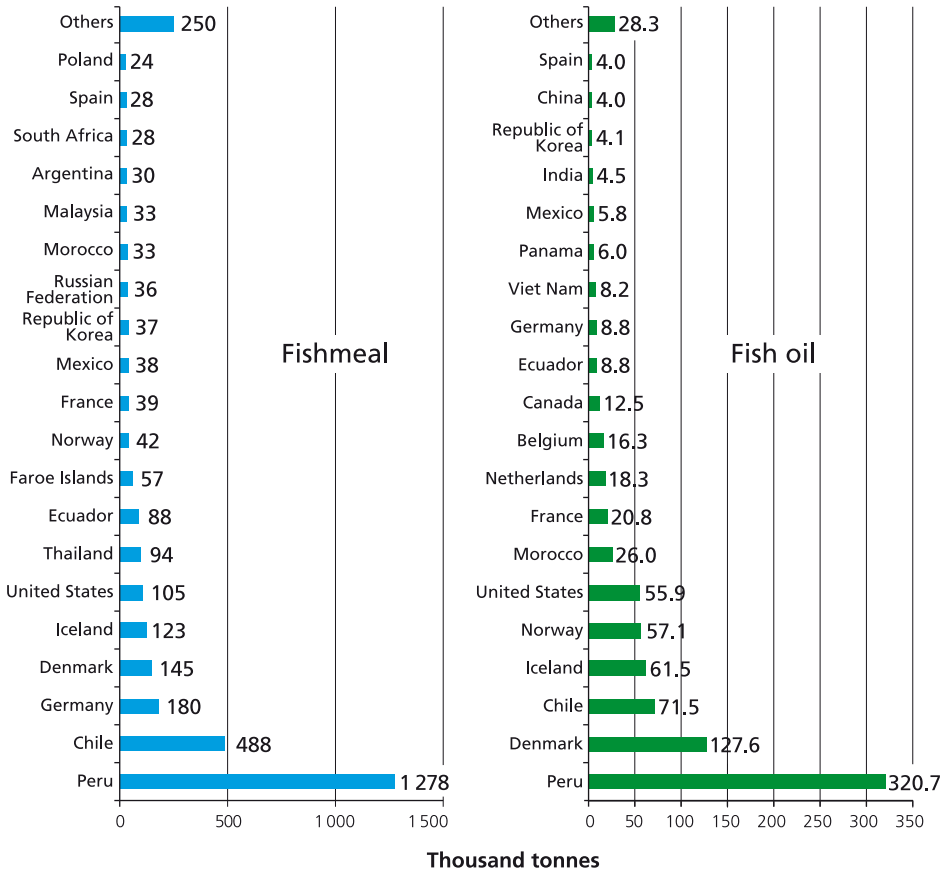



*Source*: Shepard (2009).

As with production, the largest exporter of fishmeal and fish oil in 2007 was Peru, exporting 41 percent and 30.6 percent of total world fishmeal and fish oil exports, respectively (Table 5; Figure 11; FAO, 2009a). As with total global production, fishmeal and fish oil exports decreased at an average annual rate of –3.1 percent and –0.7 percent from 1995, respectively (Table 5; Figure 11). Fishmeal and fish oil imports continue to be dominated by China and Norway, which imported 29.6 percent (969 832 tonnes) and 25.8 percent (231 264 tonnes) of total fishmeal and fish oil imports, respectively, in 2007 (Figure 12). Moreover, in line with global production and exports, the quantity of fishmeal and fish oil available for export decreased at an average annual rate of –2.8 percent and –1.8 percent since 1995 (Table 5; FAO, 2009a). However, recent data suggest that China's consumption continues to increase, with fishmeal imports increasing to 1 348 676 tonnes in 2008 (Peru 65.0 percent, Chile 17.7 percent, the United States of America 5.7 percent) and 1 225 295 tonnes for the first ten months of 2009 (Peru 58.7 percent, Chile 26.0 percent, the United States of America 5.5 percent) (Beckman, Xiping and Han, 2009).

FIGURE 11
**Major exporters of fishmeal and fish oil, 2007**



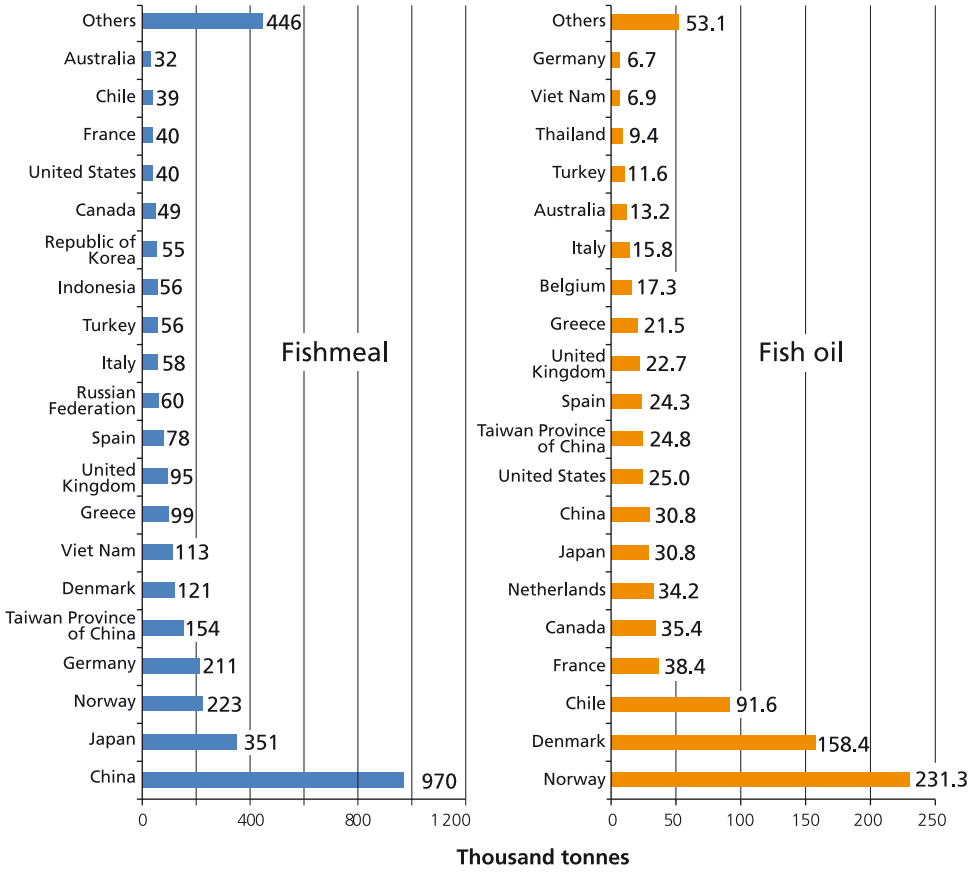

*Source*: FAO (2009a).

### *Fish/shellfish by-product meals and oils*

Statistical information is not available from FAO on the total global production of fishmeal and fish oil from seafood and/or aquaculture processing wastes. However, it has been estimated that about 6 million tonnes of trimmings and rejects from food fish are currently used for fishmeal and fish oil production (SEAFISH, 2009a). For example, according to SEAFISH (2009b), 38 percent of the fishmeal consumed in the United Kingdom of Great Britain and Northern Ireland was produced from trimmings

in 2008 (trade estimates). The same authors quote 2006 trade estimates that 33 percent of the fishmeal produced within the European Union (EU) was manufactured from trimmings/offal from food fish processing plants, and that globally this figure was about 24 percent. Similarly, IFFO estimates that about 25 percent of the total global production of fishmeal is now derived from fisheries by-products (Table 6; Jackson, 2009). No information is available concerning the proportion of by-product fishmeals and oils produced from aquaculture processing waste.

FIGURE 12
**Major importers of fishmeal and fish oil, 2007**




*Source*: FAO (2009a).

Clearly, the data presented in Table 6 are not a true picture of the quantities of by-product meals available in the marketplace. For example, tuna meal production is reported by FAO (2009a) as 36 054 tonnes from only four countries (Fiji, Maldives, the Islamic Republic of Iran and Seychelles), whereas information is not reported on tuna fishmeal and tuna oil from other larger tuna producers, including China, Ecuador, France, Ghana, Indonesia, Japan, Mexico, Panama, Papua New Guinea, Spain, Sri Lanka, Taiwan Province of China, Thailand, the United States of America and Vanuatu. A similar situation exists for shrimp and crustacean meals (including crab meals) and squid meals and oils.

Moreover, at present, no information is available from FAO concerning the total global production of fishmeal and oils produced from aquaculture processing wastes, including those produced from farmed catfish, tilapia, trout, salmon and shrimp. For example, in Chile, it is estimated that the production of 600 000 tonnes of salmon yielded 270 000 tonnes of processing waste and farm mortalities, which in turn

TABLE 6

**IFFO estimate of global fishmeal production derived from fisheries by-products, 2007**

| Country | Fishmeal (thousand tonnes) | By-product coefficient %* | By-product fishmeal production (thousand tonnes) |
|---|---|---|---|
| Angola | 5.3 | 50.0 | 2.7 |
| Argentina | 30.0 | 60.0 | 18.0 |
| Australia | 14.0 | 50.0 | 7.0 |
| Brazil | 40.4 | 20.0 | 8.1 |
| Cambodia | 3.0 | 60.0 | 1.8 |
| Canada | 30.2 | 100.0 | 30.2 |
| Chile | 770.1 | 12.0 | 92.4 |
| China | 204.0 | 5.0 | 10.2 |
| Denmark | 166.0 | 20.0 | 33.2 |
| Ecuador | 40.7 | 14.0 | 5.8 |
| Faroe Islands | 54.6 | 5.0 | 2.7 |
| Finland | 3.6 | 70.0 | 2.5 |
| France | 13.7 | 100.0 | 13.7 |
| Germany | 19.0 | 100.0 | 19.0 |
| Iceland | 152.0 | 35.0 | 52.4 |
| India | 1.0 | 5.0 | 0.1 |
| Indonesia | 15.0 | 30.0 | 4.5 |
| Iran, Islamic Republic of | 25.1 | 30.0 | 7.5 |
| Ireland | 19.3 | 40.0 | 7.7 |
| Italy | 4.3 | 100.0 | 4.3 |
| Côte d'Ivoire | 1.0 | 60.0 | 0.6 |
| Japan | 200.5 | 92.0 | 184.4 |
| Republic of Korea | 50.0 | 20.0 | 10.0 |
| Lithuania | 30.0 | 20.0 | 6.0 |
| Malaysia | 48.2 | 40.0 | 19.3 |
| Maldives | 2.0 | 80.0 | 1.6 |
| Mauritius | 5.0 | 60.0 | 3.0 |
| Mexico | 73.0 | 50.0 | 36.5 |
| Morocco | 60.6 | 15.0 | 9.1 |
| Namibia | 12.5 | 100.0 | 12.5 |
| New Zealand | 30.0 | 10.0 | 3.0 |
| Norway | 172.0 | 22.0 | 37.8 |
| Pakistan | 56.0 | 20.0 | 11.2 |
| Panama | 45.7 | 10.0 | 4.6 |
| Peru | 1 407.0 | 2.0 | 28.1 |
| Poland | 22.1 | 40.0 | 8.8 |
| Russian Federation | 65.8 | 50.0 | 32.9 |
| Senegal | 4.3 | 100.0 | 4.3 |
| Seychelles | 20.0 | 70.0 | 14.0 |
| South Africa | 88.0 | 10.0 | 8.8 |
| Spain | 20.0 | 100.0 | 20.0 |
| Sweden | 23.3 | 50.0 | 11.7 |
| Taiwan Province of China | 18.2 | 70.0 | 12.7 |
| Thailand | 428.0 | 65.0 | 278.2 |
| United Kingdom | 44.2 | 68.0 | 30.1 |
| United States | 251.5 | 26.0 | 65.4 |
| Viet Nam | 52.4 | 50.0 | 26.2 |
| Total 47 countries | 4 842.6 | - | 1 204.7 |
| Others | 127.4 | 20.0 | 25.5 |
| Total world | 4 970.0 | 24.8 | 1 230.2 |

*% contribution of fisheries by-products to total country fishmeal production.

*Source*: Jackson (2009).

resulted in the production of 48 600 tonnes of salmon oil and 43 200 tonnes of salmon meal (Anon, 2006). As mentioned previously, this absence of information on these by-products is partly due to the common practice in some countries of blending different batches and sources of meals and oils so as to attain an overall specific nutrient standard for sale to traders and buyers.

***Zooplankton meals and oils***

Major marine zooplankton species that have potential, and/or have been considered for use as feed ingredients, include the Arctic amphipod *Themisto libellula*, the copepod *Calanus finmarchicus* and the Antarctic krill *Euphausia superba*. Of these, commercial operations only exist for the Antarctic krill, which total landing is reported as 118 124 tonnes in 2007 (Table 5; FAO, 2009a). As with other shrimp and crustacean meals, no information is available concerning the total global production and market availability of krill meal and krill oil. Nonetheless, krill meal and krill oil are available in the marketplace (www.akerbiomarine.com; www.aquaticeco.com/subcategories/1148/Krill-Meal).

***Others***

At present, little or no information is available on the global production and market availability of fish and shellfish hydrolysates, silages and fermentation products, nor of the production of wild harvested and cultured marine polychaete worms. However, as mentioned previously, numerous fish hydrolysates, fermentation products and wild harvested and cultured polychaetes are available in the marketplace (salmon protein hydrolysate [www.rossyew.co.uk/salmon_pro.htm]; farmed polychaetes and polychaete products [www.dragonfeeds.com]).

### 3.1.2 Land animal protein meals and lipids

The major land animal protein meals and lipids available in the marketplace can be listed as follows (in order of global production and current market availability):

- *meat by-product meals and fats:* produced from slaughtered farmed livestock (cattle, pig, sheep, etc.), and includes meat and bone meal, meat meal, meat solubles and lard/tallow;
- *poultry by-product meals and fats:* produced from slaughtered farmed poultry, and includes poultry by-product meal, turkey meal, feather meal, chick hatchery waste and poultry fat;
- *blood by-product meals:* produced from slaughtered farmed livestock (ruminant and monogastric), and includes blood meal, haemoglobin meal and dried plasma products; and
- *miscellaneous invertebrate terrestrial products:* produced from wild harvested and/or cultured annelid worms, insect larvae/pupae, gastropods – golden apple snail, etc.

Table 7 summarizes the available published information on the total reported global production and trade of the above listed terrestrial animal protein meals and fats.

***Global production and major country producers, exporters and importers***

Although no published statistical information exists concerning the individual global production of the above-mentioned animal by-product meals, it has been estimated that the global combined production of rendered animal protein meals and fats in 2008 was about 13.0 and 10.2 million tonnes, respectively (Swisher, 2009a); global production of these animal protein meals being over twice that reported for fishmeal in 2008 (Figure 10). Currently, these terrestrial animal protein meals and fats represent the largest source of animal protein and fats available to the animal feed compounder.

The largest reported producer of rendered animal protein meals and fats in 2008 was the United States of America at 4 094 237 tonnes and 4 576 429 tonnes (total 8 670 666 tonnes), respectively; followed by the EU-18 at 3 870 000 tonnes and 2 687 000 tonnes (total 6 557 000 tonnes); South America at 3 970 578 tonnes and 2 278 379 tonnes (total 6 248 957 tonnes); Australia at 650 000 tonnes and 470 000 tonnes (total 1 120 000 tonnes); New Zealand at 214 300 tonnes and 140 000 tonnes (total 354 300 tonnes); and Turkey at 185 600 tonnes and 84 179 tonnes (total 269 779 tonnes), respectively. However, these global estimates are low as they exclude most Asian countries from the analysis.

Total exports of rendered animal protein meals in 2008 was 1 338 954 tonnes, or 10.3 percent of total global production; the largest reported country exporters being the EU-27 (340 153 tonnes), followed by the United States of America (298 257 tonnes), Australia (259 903 tonnes), New Zealand (149 405 tonnes), Argentina (73 309 tonnes), Brazil (62 903 tonnes), Uruguay (52 081 tonnes), and Canada (25 709 tonnes) (Swisher, 2009a). The largest importers of rendered animal protein meals in 2008 was Indonesia (309 679 tonnes), followed by Thailand (149 490 tonnes), Viet Nam (114 379 tonnes), Mexico (107 187 tonnes), the United States of America (89 675 tonnes), China (62 905 tonnes), Egypt (62 276 tonnes), Chile (53 141 tonnes), Bangladesh (50 315 tonnes), the Philippines (50 054 tonnes), Taiwan Province of China (42 190 tonnes), Russian Federation (38 610 tonnes), and South Africa (35 919 tonnes) (Swisher, 2009a).

TABLE 7
**Total reported production of terrestrial animal protein meals and lipids, 2008**

| Ingredient | Global production, growth and market availability |
|---|---|
| Meat by-product meals and fats: produced from slaughtered farmed livestock (cattle, pig, sheep), and includes meat and bone meal, meat meal, meat soluble, tallows and greases.<br>Poultry by-product meals and fats: produced from slaughtered farmed poultry, and includes poultry by-product meal, turkey meal, feather meal, chick hatchery waste and poultry fat.<br>Blood by-product meals: produced from slaughtered farmed livestock (cattle, poultry, pig), and includes blood meal, haemoglobin meal and dried plasma products. | Total global production of rendered animal protein meals in 2008: 12 984 715 tonnes, major producers including: the United States 31.5%, South America 30.6%, EU-18 29.8%, Australia 5.0%, New Zealand 1.6%, Turkey 1.4%.<br>Total global production of rendered fats and greases in 2008: 10 235 987 tonnes, major producers including: United States 44.7%, EU-18 26.2%, South America 22.2%, Australia 4.6%, New Zealand 1.4%, Turkey 0.8%.<br>Total global exports of rendered animal protein meals: exports increasing by 57.8% from 848 656 tonnes in 2004 to 1 338 954 tonnes in 2008; major exporters in 2008 included: EU-27 25.4%, United States 22.3%, Australia 19.4%, New Zealand 11.1%, Argentina 5.5%, Brazil 4.7%, Uruguay 3.9%, Canada 1.9%, data exclude intra-EU trade.<br>Total global imports of rendered animal protein meals: imports increasing by 57.8% from 848 656 tonnes in 2004 to 1 338 954 tonnes in 2008; major importers in 2008 included: Indonesia 23.1%, Thailand 11.2%, Viet Nam 8.5%, Mexico 8.0%, United States 6.7%, China 4.7%, Egypt 4.6%, Chile 4.0%, Bangladesh 3.7%, Philippines 3.7%, Taiwan Province of China 3.1%, Russian Federation 2.9%, South Africa 2.7%.<br>Total global tallow exports: exports increasing by 1.5% from 1 850 973 tonnes in 2002 to 1 878 661 tonnes in 2008; major exporters in 2008 included: United States 55.4%, Australia 19.8%, Canada 9.8%, New Zealand 7.9%, Uruguay 3.3%, EU-27 1.8%, Brazil 1.3%.<br>Total global tallow imports: imports increasing by 1.5% from 1 850 973 tonnes in 2002 to 1 878 661 tonnes in 2008; major importers in 2008 included: Mexico 27.5%, China 19.4%, Nigeria 6.6%, Turkey 6.4%, CAR* 6.2%, Republic of Korea 5.6%, Pakistan 3.4%, Japan 3.1%. |

*Central Asian Republics include Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

*Source*: Swisher (2009a).

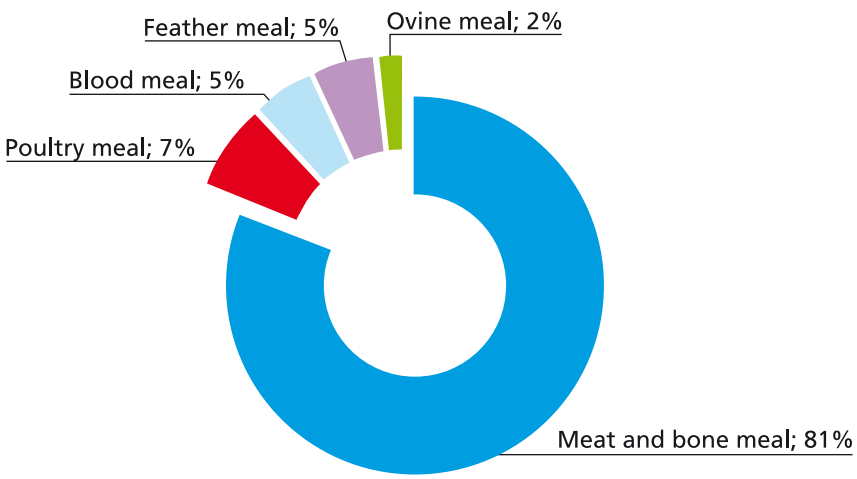
Data for global rendered fats and greases are currently only available for tallows, with total global tallow exports and imports reported at 1 878 661 tonnes in 2008. The major tallow exporters were the United States of America (1 040 926 tonnes), Australia (372 532 tonnes), Canada (183 765 tonnes) and New Zealand (148 405 tonnes); and the major tallow importers in 2008 were Mexico (516 266 tonnes), China (365 351 tonnes) and Nigeria (123 567 tonnes) (Swisher, 2009a).

More detailed production data are available for Australia (Palmer, 2009) and the United States of America (Swisher, 2009b). For example, in the case of Australia, total rendered animal protein meal production in 2008 has been estimated at 650 000 tonnes, with meat and bone meals representing 81 percent of total meal production, followed by poultry meal, feather meal, blood meal and ovine (sheep) meal, respectively (Figure 13).

Similarly, in the case of the United States of America (the largest global producer and exporter of rendered animal protein meals), the bulk of production in 2008 was in the form of meat and bone meals (2 339 500 tonnes, or 56.8 percent total protein meal production), followed by poultry by-product meal (1 176 500 tonnes, or 28.5 percent), and feather meal (603 900 tonnes, or 14.6 percent (Swisher, 2009b). In the case of animal fats and greases, the bulk of production was in the form of inedible tallow (1 604 800 tonnes, or 35.6 percent); greases (1 215 100 tonnes, or 27.0 percent); edible tallow (807 300 tonnes, or 17.9 percent); poultry fat (656 800 tonnes, or 14.6 percent); and lard (220 300 tonnes, or 4.9 percent) (Swisher, 2009b). Moreover, total protein meal and fat/grease production increased by 12 percent and 6 percent, from 3 675 300 tonnes in 2003 to 4 119 900 tonnes (meals) and 4 243 400 tonnes to 4 504 300 tonnes (fats) in 2008, respectively (Swisher, 2009b; Figures 14 and 15).

The United States exports of all rendered products were estimated at 1 895 000 tonnes in 2008, including 1 503 500 tonnes of fats and greases and 371 500 tonnes of animal protein meals; the latter includes 298 300 tonnes of animal protein meals (mammalian meat and bone meal and poultry by-product meal) and 73 300 tonnes of feather meal (Swisher, 2009b). The largest importers of the United States of America animal protein meals and feather meal in 2008 were primarily in Asia. Importing countries included Indonesia (173 822 tonnes, or 46.8 percent total exports), Mexico (107 164 tonnes, or 28.8 percent), Canada (35 234 tonnes, or 9.5 percent), Viet Nam (22 160 tonnes, or 6.0 percent), Ecuador (7 405 tonnes, or 2.0 percent), Thailand (6 825 tonnes, or 1.8 percent), the Philippines (5 736 tonnes), China (5 249 tonnes), Bangladesh (1 546 tonnes), Honduras (1 449 tonnes), Taiwan Province of China (1 154 tonnes), Malaysia (860 tonnes), the Netherlands (787 tonnes), and Switzerland (291 tonnes) (Swisher, 2009b).

FIGURE 13
**Composition of rendered animal protein by meal type in Australia, 2008**

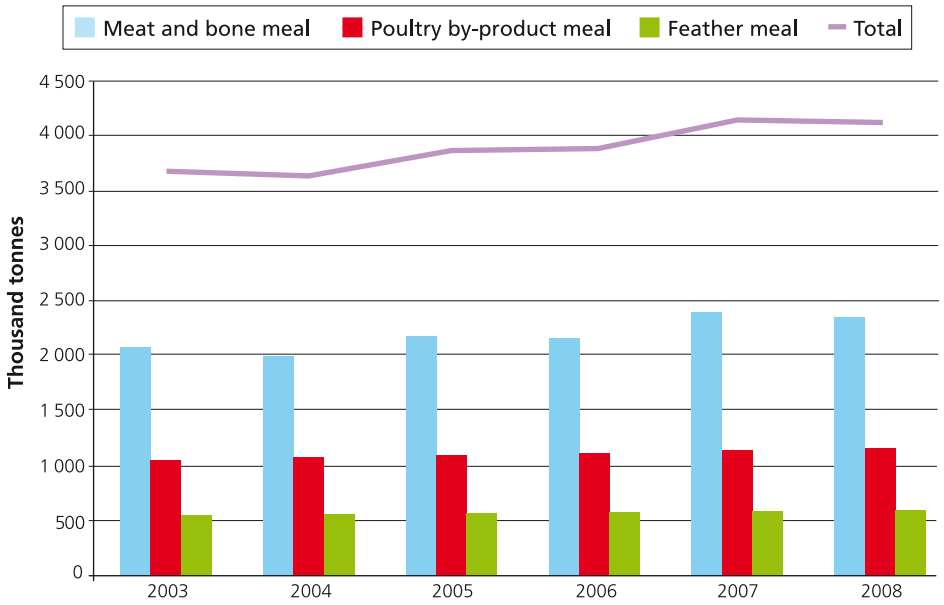



*Source*: Palmer (2009).

### *Miscellaneous invertebrate terrestrial products*

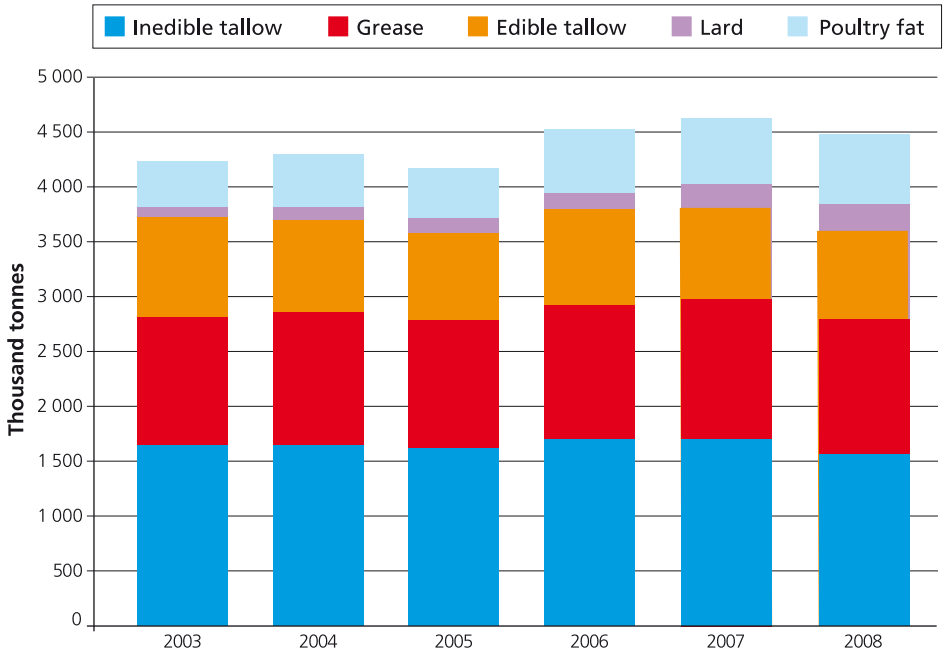
No statistical information is available concerning the total global production of terrestrial invertebrate animal products, the majority being highly localized and serving as supplementary feed items or for use within farm-made aquafeeds (Hasan *et al.*, 2007).

FIGURE 14
**Annual production of animal protein meals in the United States, 2003–2008**




*Source*: Swisher (2009b).

FIGURE 15
**Annual production of animal fats and grease in the United States, 2003–2008**




*Source*: Swisher (2009b).

## 3.2 PLANT NUTRIENT SOURCES

The major plant dietary nutrient sources, including meals and oils, available in the marketplace can be listed as follows (in order of global production and current market availability):

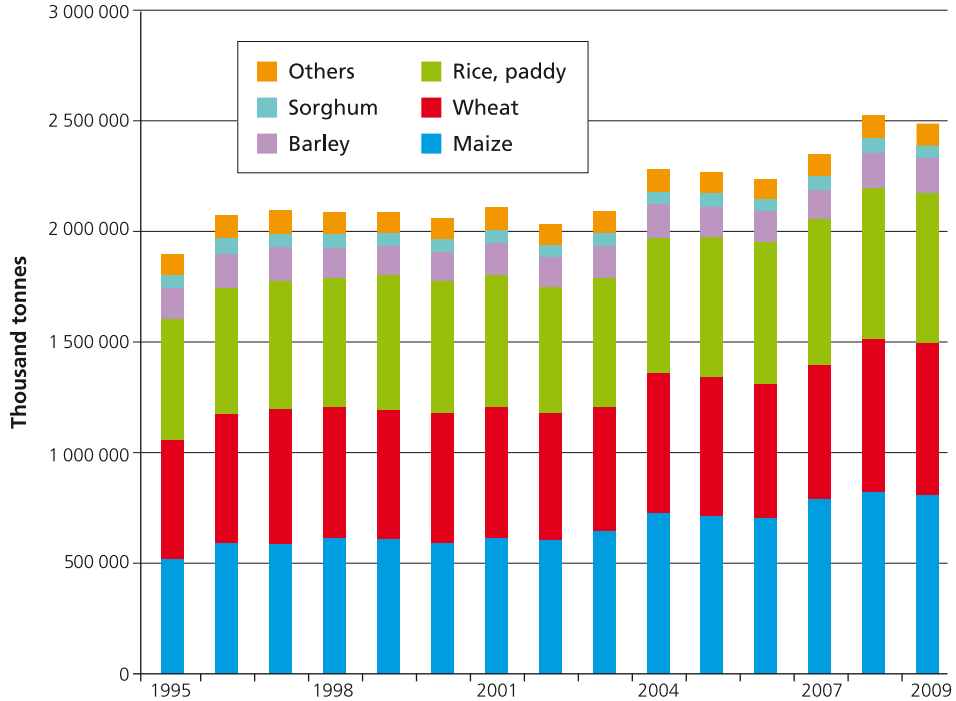
- *cereals, including by-product meals and oils:* includes milled/processed cereals (maize/corn, wheat, rice, barley, sorghum, oats, rye, millet, triticale, etc.); by-product meals (corn/maize gluten, wheat gluten, dried distillers grains with solubles, rice protein concentrate, rice bran, wheat bran); and extracted oils (corn/maize, rice);
- *oilseed meals and oils:* includes full-fat (soybean) and solvent extracted oilseed meals (soybean, rapeseed, cotton, groundnut/peanut, sunflower, palm kernel, copra); by-product meals (soybean protein concentrates, rapeseed/canola protein concentrate); and extracted oils (palm, soybean, rapeseed, sunflower, linseed, cottonseed, olive); and
- *pulses and protein concentrate meals:* includes milled/processed pulses (peas, lupins) and by-product meals (pea protein concentrate, lupin protein concentrate).

Table 8 summarizes the total reported global production and trade of the major traded cereals, oilseeds, pulses and grain legume meals, and by-products and oils available to the animal feed compounder, including for the manufacture of aquaculture feeds.

### *Cereals and by-products*

Total global cereal production was 2 489 million tonnes in 2009, up by 31.2 percent from 1 898 million tonnes in 1995, with production growing at an average annual rate of 2.2 percent per year (Figure 16); maize totalling 817.1 million tonnes, or 32.8 percent of the total cereal crop in 2009, followed by wheat at 681.9 million tonnes (27.4 percent), rice paddy at 678.7 million tonnes (27.3 percent), barley at 150.3 million tonnes (6.0 percent), and sorghum at 62.1 million tonnes (2.5 percent; Figure 17). Maize remains the fastest growing cereal crop, with global production up by 57.9 percent since 1995 and growing at an annual percent rate of 3.3 percent per year (Figure 16; FAO, 2010c).

FIGURE 16
**Total global production of cereals by commodity, 1995–2009**




*Source*: FAO (2010c).

TABLE 8
**Estimated global production and trade of major agricultural food/feed commodities, 2008/09 (values given in million tonnes and presented in order of production by weight)**

| Production | | Exports | | Imports | |
|---|---|---|---|---|---|
| **Cereals** | | | | | |
| **Maize/corn** | **817.1 (2009)[1]** | **Export total** | **84.0 (2008/09)[1]** | **Import total** | **84.1 (2008/09)[1]** |
| United States | 333.0 | United States | 46.1 | Japan | 16.4 |
| China | 163.1 | Argentina | 12.1 | Mexico | 7.9 |
| European Union | 57.8 | Brazil | 6.9 | Republic of Korea | 7.5 |
| Brazil | 51.2 | Ukraine | 5.5 | Egypt | 5.2 |
| Mexico | 20.2 | South Africa | 2.3 | China | 4.2 |
| Indonesia | 17.6 | European Union | 1.7 | Taiwan Province of China | 4.1 |
| India | 17.3 | India | 1.5 | European Union | 3.0 |
| Argentina | 13.1 | Russian Federation | 1.3 | Islamic Republic of Iran | 3.0 |
| South Africa | 12.1 | Serbia | 1.2 | Colombia | 2.8 |
| Ukraine | 10.5 | Thailand | 0.7 | Malaysia | 2.6 |
| **Wheat** | **681.9 (2009)[1]** | **Export total** | **139.1(2008/09)[1]** | **Import total** | **136.1 (2008/09)[1]** |
| European Union | 138.7 | United States | 26.9 | Egypt | 9.9 |
| China | 115.0 | European Union | 24.7 | Islamic Republic of Iran | 8.5 |
| India | 80.7 | Russian Federation | 18.7 | European Union | 7.9 |
| Russian Federation | 61.7 | Canada | 17.8 | Brazil | 6.7 |
| United States | 60.3 | Australia | 13.5 | Algeria | 6.4 |
| Canada | 26.5 | Ukraine | 12.6 | Indonesia | 5.3 |
| Pakistan | 24.0 | Argentina | 8.1 | Japan | 5.4 |
| Australia | 21.7 | Kazakhstan | 5.8 | Morocco | 3.7 |
| Ukraine | 20.9 | Turkey | 2.3 | Nigeria | 3.6 |
| Turkey | 20.6 | Pakistan | 2.0 | Iraq | 3.6 |
| **Rice (milled equivalent)** | **678.7 (2009)[1]** | **Export total** | **30.4 (2009)[1]** | **Import total** | **30.4 (2009)[1]** |
| China | 197.3 | Thailand | 8.6 | Nigeria | 1.8 |
| India | 131.3 | Viet Nam | 6.3 | Philippines | 1.8 |
| Indonesia | 64.4 | United States | 3.1 | Islamic Republic of Iran | 1.3 |
| Bangladesh | 45.1 | Pakistan | 2.8 | European Union | 1.2 |
| Viet Nam | 38.9 | India | 2.5 | Iraq | 1.1 |
| Thailand | 31.5 | China | 0.9 | Saudi Arabia | 1.0 |
| Philippines | 16.3 | Myanmar | 0.8 | Malaysia | 0.9 |
| Brazil | 12.6 | Uruguay | 0.8 | Côte d'Ivoire | 0.9 |
| Japan | 10.6 | Brazil | 0.7 | Senegal | 0.9 |
| Pakistan | 10.3 | Egypt/Argentina | 0.5 | South Africa | 0.9 |

TABLE 8, continued

**Estimated global production and trade of major agricultural food/feed commodities, 2008/09 (values given in million tonnes and presented in order of production by weight)**

| | Production | | Exports | | Imports | |
|---|---|---|---|---|---|---|
| **Barley** | **150.3 (2009)[1]** | **Export total** | **19.7 (2008/09)[1]** | **Import total** | **20.1 (2008/09)[1]** |
| European Union | 62.4 | Ukraine | 6.3 | Saudi Arabia | 7.3 |
| Russian Federation | 17.9 | European Union | 3.5 | Islamic Republic of Iran | 2.0 |
| Ukraine | 11.8 | Russian Federation | 3.5 | Syrian Arab Republic | 1.7 |
| Canada | 9.5 | Australia | 3.3 | China | 1.4 |
| Australia | 8.1 | Canada | 1.4 | Japan | 1.4 |
| Turkey | 7.3 | Argentina | 0.9 | Tunisia | 0.6 |
| United States | 4.9 | Kazakhstan | 0.3 | United States | 0.6 |
| Poland | 4.0 | United States | 0.3 | Algeria | 0.4 |
| Islamic Republic of Iran | 3.4 | | | Morocco | 0.4 |
| China | 3.4 | | | Libya | 0.4 |
| **Sorghum** | **62.1 (2009)[1]** | **Export total** | **6.9 (2008/09)[1]** | **Import total** | **6.0 (2008/09)[1]** |
| United States | 9.7 | United States | 3.8 | Mexico | 2.3 |
| India | 7.2 | Australia | 1.4 | Japan | 1.3 |
| Mexico | 6.2 | Argentina | 0.9 | European Union | 0.4 |
| Sudan | 4.2 | Sudan | 0.3 | Sudan | 0.3 |
| Ethiopia | 2.8 | Burkina Faso | 0.1 | China | 0.1 |
| Australia | 2.7 | Nigeria | 0.1 | Ethiopia | 0.1 |
| China | 2.3 | | | | |
| Brazil | 1.8 | | | | |
| Argentina | 1.8 | | | | |
| Mali | 1.5 | | | | |
| **Oilseed crops, by-products and olis** | | | | | |
| **Soybeans** | **210.9 (08/09)[3]** | **Export total** | **76.7 (2008/09)[3]** | **Import total** | **76.5 (2008/09)[3]** |
| United States | 80.7 | United States | 34.9 | China | 41.1 |
| Brazil | 57.0 | Brazil | 30.0 | European Union-27 | 13.3 |
| Argentina | 32.0 | Argentina | 5.6 | Japan | 3.4 |
| China | 15.5 | Paraguay | 2.4 | Mexico | 3.3 |
| India | 9.1 | Canada | 2.0 | Taiwan Province of China | 2.1 |
| Paraguay | 3.9 | Others | 1.8 | Thailand | 1.5 |
| Canada | 3.3 | | | Indonesia | 1.2 |
| Others | 9.3 | | | Egypt | 1.2 |
| | | | | Republic of Korea | 1.2 |
| | | | | Turkey | 1.0 |
| | | | | Others | 7.1 |

TABLE 8, continued

**Estimated global production and trade of major agricultural food/feed commodities, 2008/09 (values given in million tonnes and presented in order of production by weight)**

| | Production | | Exports | | Imports | |
|---|---|---|---|---|---|---|
| **Soybean meal** | **151.6 (08/09)[3]** | **Export total** | **52.10 (08/09)[3]** | **Import total** | **51.39 (08/09)[3]** |
| United States | 35.47 | Argentina | 23.99 | European Union-27 | 21.50 |
| China | 32.47 | Brazil | 13.00 | Indonesia | 2.45 |
| Argentina | 24.95 | United States | 7.72 | Viet Nam | 2.30 |
| Brazil | 24.33 | India | 3.16 | Thailand | 2.16 |
| European Union-27 | 10.11 | Plurinational State of Bolivia | 1.04 | Republic of Korea | 1.81 |
| India | 5.98 | Others | 3.19 | Japan | 1.81 |
| Mexico | 2.73 | | | Mexico | 1.50 |
| Others | 15.50 | | | Philippines | 1.31 |
| | | | | Canada | 1.27 |
| | | | | Bolivarian Republic of Venezuela | 1.05 |
| | | | | Others | 14.21 |
| **Rapeseed** | **58.24 (08/09)[3]** | **Export total** | **12.40 (08/09)[3]** | **Import total** | **12.26 (08/09)[3]** |
| European Union-27 | 19.04 | Canada | 7.90 | European Union-27 | 3.34 |
| Canada | 12.64 | Others | 4.50 | China | 3.03 |
| China | 12.10 | | | Japan | 2.12 |
| India | 7.00 | | | Others | 3.76 |
| Ukraine | 2.87[2] | | | | |
| Australia | 1.61[2] | | | | |
| Russian Federation | 0.75[2] | | | | |
| United States | 0.66[2] | | | | |
| Others | 1.56 | | | | |
| **Palm oil** | **42.40 (08/09)[3]** | **Export total** | **34.23 (08/09)[3]** | **Import total** | **34.07 (08/09)[3]** |
| Indonesia | 19.50 | Malaysia | 16.0 | India | 6.87 |
| Malaysia | 17.26 | Indonesia | 14.65 | China | 6.12 |
| Thailand | 1.20 | Benin | 0.47 | European Union-27 | 4.90 |
| Nigeria | 0.82 | Papua New Guinea | 0.40 | Pakistan | 2.20 |
| Colombia | 0.75 | United Arab Emirates | 0.35 | United States | 1.04 |
| Others | 2.87 | Others | 2.36 | Egypt | 0.85 |
| | | | | Bangladesh | 0.75 |
| | | | | Malaysia | 0.70 |
| | | | | Islamic Republic of Iran | 0.57 |
| | | | | Japan | 0.53 |
| | | | | Others | 9.54 |

TABLE 8, continued

**Estimated global production and trade of major agricultural food/feed commodities, 2008/09 (values given in million tonnes and presented in order of production by weight)**

| | Production | | Exports | | Imports | |
|---|---|---|---|---|---|---|
| **Soybean oil** | **35.76 (08/09)[3]** | **Export total** | **9.05 (08/09)[3]** | **Import total** | **8.86 (08/09)[3]** |
| United States | 8.50 | Argentina | 4.71 | China | 2.49 |
| China | 7.31 | Brazil | 1.91 | India | 1.06 |
| Argentina | 6.12 | United States | 0.99 | European Union-27 | 0.82 |
| Brazil | 6.02 | European Union-27 | 0.40 | Algeria | 0.32 |
| European Union-27 | 2.31 | Paraguay | 0.24 | Bolivarian Republic of Venezuela | 0.32 |
| India | 1.34 | Bolivia | 0.18 | Egypt | 0.31 |
| Mexico | 0.61 | Russian Federation | 0.13 | Morocco | 0.28 |
| Others | 3.54 | Others | 0.48 | Islamic Republic of Iran | 0.27 |
| | | | | Republic of Korea | 0.27 |
| | | | | Bangladesh | 0.25 |
| | | | | Others | 2.46 |
| **Sunflower** | **33.05 (08/09)[3]** | **Export total** | **2.08 (08/09)[3]** | **Import total** | **1.86 (08/09)[3]** |
| Russian Federation | 7.35 | Ukraine | 0.77 | European Union-27 | 0.59 |
| Ukraine | 7.00 | European Union-27 | 0.30 | Turkey | 0.44 |
| European Union-27 | 6.96 | Russian Federation | 0.16 | Argentina | 0.11 |
| Argentina | 2.90 | Argentina | 0.06 | Others | 0.71 |
| China | 1.85[2] | Others | 0.78 | | |
| United States | 1.55[2] | | | | |
| India | 1.11[2] | | | | |
| South Africa | 0.88[2] | | | | |
| Turkey | 0.83 | | | | |
| Others | 2.62 | | | | |
| **Rapeseed meal** | **30.76 (08/09)[3]** | **Export total** | **3.45 (08/09)[3]** | **Import total** | **3.54 (08/09)[3]** |
| European Union-27 | 11.69 | Canada | 1.89 | China | 0.26 |
| China | 8.32 | India | 0.70 | European Union-27 | 0.16 |
| India | 3.26 | China | 0.27 | Japan | 0.11 |
| Canada | 2.49 | European Union-27 | 0.16 | Others | 3.00 |
| Japan | 1.25 | Others | 0.45 | | |
| Others | 3.75 | | | | |
| **Rapeseed oil** | **20.39 (08/09)[3]** | **Export total** | **2.37 (08/09)[3]** | **Import total** | **2.44 (08/09)[3]** |
| European Union-27 | 8.43 | Canada | 1.53 | European Union-27 | 0.45 |
| China | 4.70 | European Union-27 | 0.14 | China | 0.45 |
| India | 2.06 | Others | 0.70 | Canada | 0.11 |
| Canada | 1.78 | | | Others | 1.41 |
| Japan | 0.88 | | | | |
| Others | 2.53 | | | | |

TABLE 8, continued

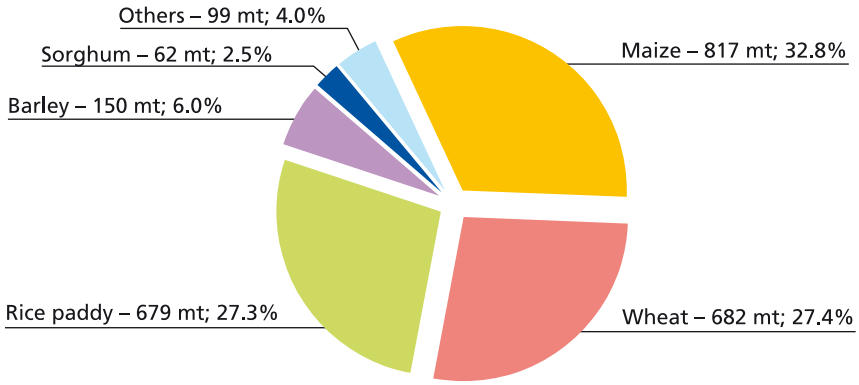
**Estimated global production and trade of major agricultural food/feed commodities, 2008/09 (values given in million tonnes and presented in order of production by weight)**

| | Production | Exports | | Imports | |
|---|---|---|---|---|---|
| **Sunflower meal** | **12.59 (08/09)[3]** | **Export total** | **4.21 (08/09)[3]** | **Import total** | **4.11 (08/09)[3]** |
| European Union-27 | 3.21 | Ukraine | 2.21 | European Union-27 | 2.35 |
| Ukraine | 2.59 | Russian Federation | 0.96 | Turkey | 0.31 |
| Russian Federation | 2.31 | Argentina | 0.80 | Others | 1.45 |
| Argentina | 1.47 | European Union-27 | 0.08 | | |
| Turkey | 0.45 | Others | 0.16 | | |
| Others | 2.56 | | | | |
| **Sunflower oil** | **11.74 (08/09)[3]** | **Export total** | **4.49 (08/09)[3]** | **Import total** | **4.04 (08/09)[3]** |
| Ukraine | 2.63 | Ukraine | 2.10 | European Union-27 | 1.05 |
| Russian Federation | 2.56 | Argentina | 1.00 | Turkey | 0.43 |
| European Union-27 | 2.33 | Russian Federation | 0.80 | Others | 2.55 |
| Argentina | 1.44 | Turkey | 0.13 | | |
| Turkey | 0.51 | European Union-27 | 0.13 | | |
| Others | 2.26 | Others | 0.33 | | |
| **Peanut oil** | **4.97 (08/09)[3]** | **Export total** | **0.19 (08/09)[3]** | **Import total** | **0.16 (08/09)[3]** |
| China | 2.17 | India | 30 000 tonnes | India | 96 000 tonnes |
| India | 1.54 | China | 10 000 tonnes | United States | 24 000 tonnes |
| United States | 0.06 | United States | 4 000 tonnes | China | 20 000 tonnes |
| Others | 1.19 | European Union-27 | 2 000 tonnes | Others | 21 000 tonnes |
| | | Others | 148 000 tonnes | | |
| **Cottonseed oil** | **4.84(08/09)[3]** | **Export total** | **0.19 (08/09)[3]** | **Import total** | **0.19 (08/09)[3]** |
| China | 1.60 | United States | 87 000 tonnes | India | 5 000 tonnes |
| India | 1.03 | China | 5 000 tonnes | United States | 5 000 tonnes |
| United States | 0.30 | Others | 98 000 tonnes | Turkey | 4 000 tonnes |
| Turkey | 0.12 | | | Others | 61 000 tonnes |
| European Union-27 | 47 000 tonnes | | | | |
| Others | 1.74 | | | | |
| **Olive oil** | **2.97 (08/09)[3]** | **Export total** | **0.68 (08/09)[3]** | **Import total** | **0.59 (08/09)[3]** |
| European Union-27 | 2.25 | European Union-27 | 0.41 | United States | 0.28 |
| Turkey | 0.17 | Turkey | 42 000 tonnes | European Union-27 | 0.15 |
| Others | 0.54 | Others | 0.22 | Others | 0.17 |

[1]FAO (2010b); [2]FAO (2010c); [3]USDA (2010a).

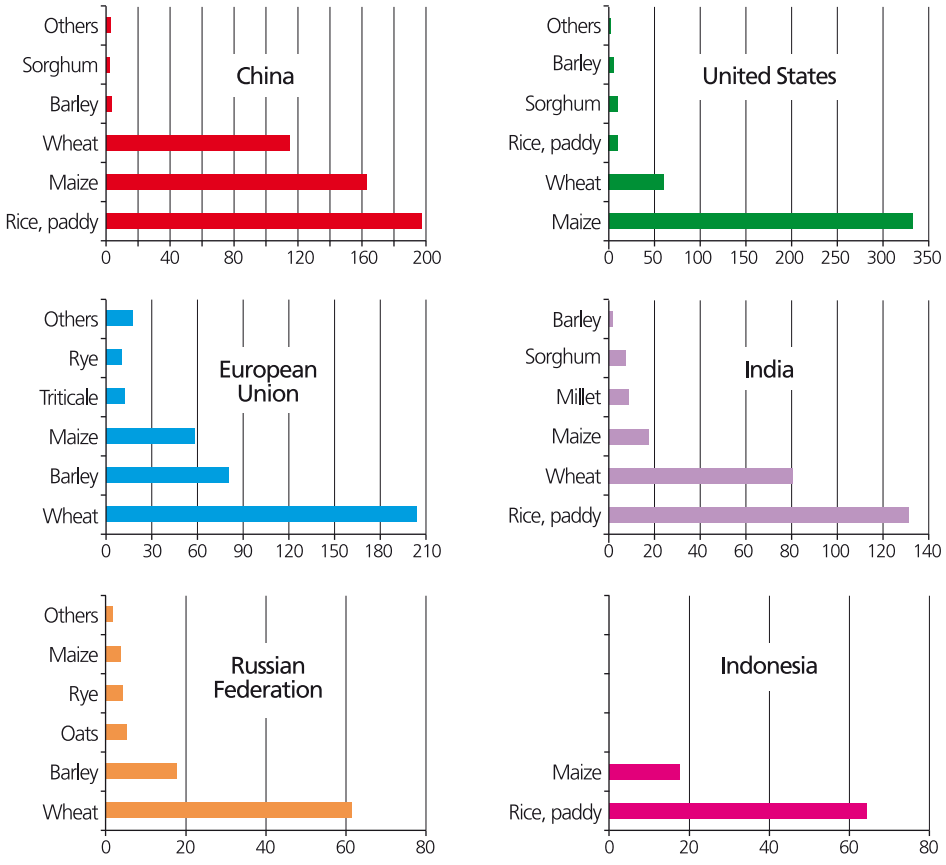
The largest producer of maize in 2009 was the United States of America at 333 million tonnes, or 40.8 percent of global production, followed by China (163.1 million tonnes, or 20.0 percent), and the EU (57.8 million tonnes, or 7.1 percent; Figure 18).

FIGURE 17
**Composition of commodities in global production of cereals, 2009**
Total global production of cereals in 2009 – 2 489 million tonnes




*Note*: mt = million tonnes.
*Source*: FAO (2010c).

FIGURE 18
**Top cereal producer countries by commodity, 2009**



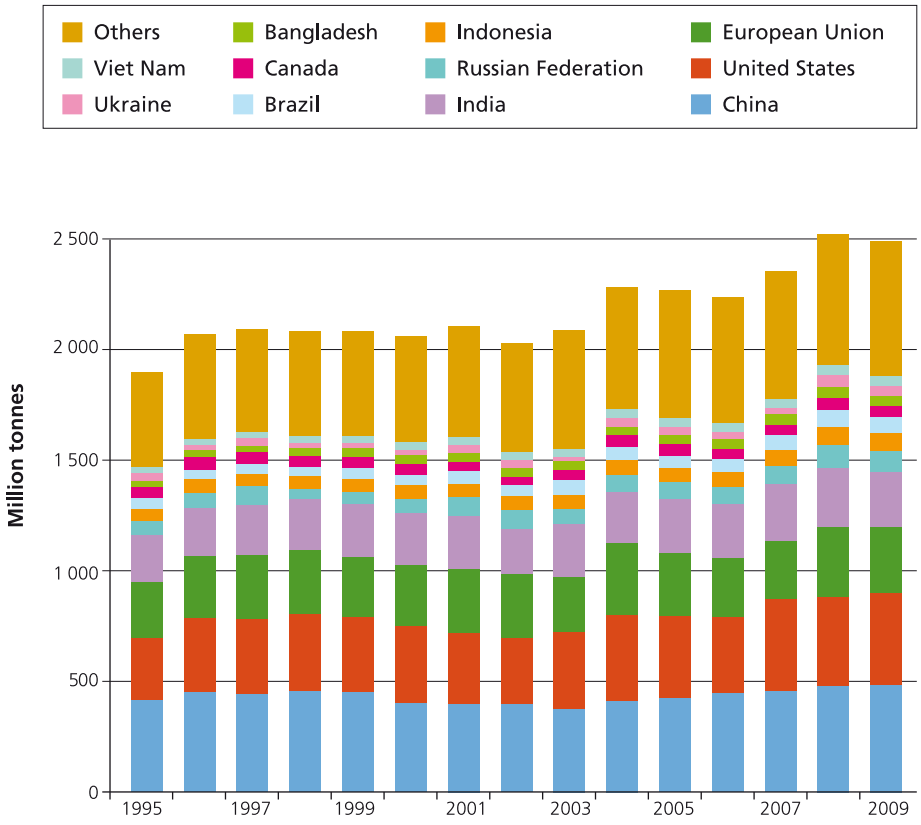

*Source*: FAO (2010c).

Asia remains the largest global producer of cereals at 1 193 million tonnes, or 47.9 percent of global production, in 2009 (with rice paddy being the main cereal crop at 51.3 percent); followed by the Americas at 633.9 million tonnes, or 25.5 percent (with maize being the main cereal crop at 67.8 percent); Europe at 504.4 million tonnes, or 20.0 percent (with wheat being the main cereal crop at 49.2 percent); Africa at 160.8 million tonnes, or 6.5 percent (with maize being the main cereal crop at 35.2 percent); and Oceania at 36.1 million tonnes, or 1.4 percent (with wheat being the main cereal crop at 61.1 percent; FAO, 2010c).

By country, China maintains its position as the world's top cereal producer at 484 million tonnes (19.4 percent of global production in 2009), followed by the United States of America (419.8 million tonnes, or 16.9 percent), the EU (298 million tonnes, or 12.0 percent), India (246.8 million tonnes, or 9.9 percent), the Russian Federation (95.1 million tonnes), and Indonesia (82.0 million tonnes); these countries account for over 65.3 percent of total global cereal production in 2009 (Figure 19) (FAO, 2010c).

In marked contrast to cereal production, non-Asian countries dominate the cereal export market. For example, the top cereal exporters in 2008/09 included the United States of America at 80.3 million tonnes (only includes the major traded cereal exports listed in Table 8), followed by the EU (30.2 million tonnes), Ukraine (24.5 million tonnes), the Russian Federation (23.6 million tonnes), Argentina (22.5 million tonnes), Canada (21.5 million tonnes) and Australia (18.5 million tonnes); the largest cereal exporters, mostly rice, in Asia are Thailand (9.4 million tonnes) and Viet Nam (6.3 million tonnes; Figure 20).

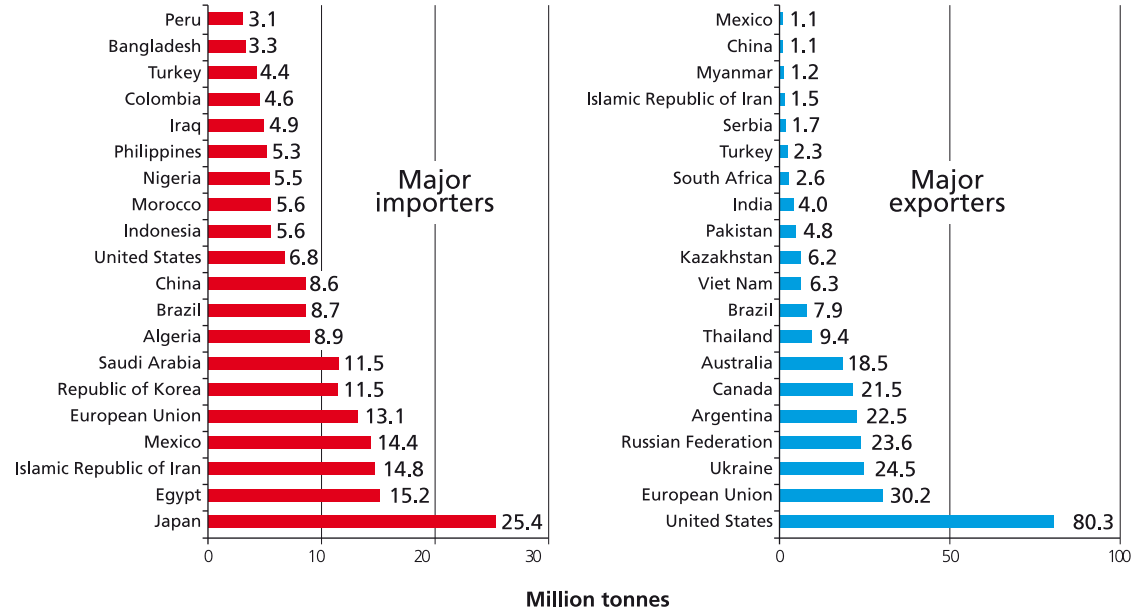
FIGURE 19
**Total global production of cereals by country, 1995–2009**




*Source*: FAO (2010c).

Japan continues to be the world's largest cereal importer at over 25.4 million tonnes in 2008/09, followed by Egypt (15.2 million tonnes), the Islamic Republic of Iran (14.8 million tonnes), Mexico (14.4 million tonnes), EU (13.1 million tonnes), Republic of Korea (11.5 million tonnes), Saudi Arabia (11.5 million tonnes), Algeria (8.9 million tonnes), Brazil (8.7 million tonnes), China (8.6 million tonnes), the United States of America (6.8 million tonnes), Indonesia (5.6 million tonnes), Morocco (5.6 million tonnes) and Nigeria (5.5 million tonnes) (Figure 20).

FIGURE 20
**Top cereal importers and exporters, 2008/09**




*Source*: FAO (2009b).

In addition to the above global market overview, the FAO FAOSTAT Agriculture database on trade also reports the country imports and exports of specifically traded cereal by-product meals and oils, including:

- brans of cereals (buckwheat, barley, fonio, maize, millet, oats, rice, rye, sorghum, wheat);
- cakes of cereals (maize, rice bran);
- flours of cereals (buckwheat, maize, millet, rye, sorghum, wheat);
- germ of cereals (maize, wheat);
- gluten feed and meal (no cereal specified); and
- oils of cereals (maize, rice bran).

Apart from the absence of statistical information on the total global production of cereal by-product meals and oils, the list currently excludes major wheat by-products (wheat middlings/wheat pollard) and by-products from corn ethanol production.

According to the Renewable Fuels Association, ethanol biorefineries within the United States of America reportedly produced nearly 27 million tonnes of corn cereal by-products for use as animal feed in 2008, including 23 million tonnes of distillers grains (production up tenfold from 2.3 million tonnes in 1999), 3 million tonnes of corn gluten feed, and 600 000 tonnes of corn gluten meal (Figure 21). The association also reported that the estimated market value of feed co-products from ethanol production in 2007/08 was US$3 billion, with an estimated additional US$1.7 billion from the sales of corn oil produced from wet-mill ethanol refineries (Renewable Fuels Association: www.ethanolrfa.org/pages/industry-resources-coproducts; Renewable Fuels Association, 2008; Deutscher, 2009).

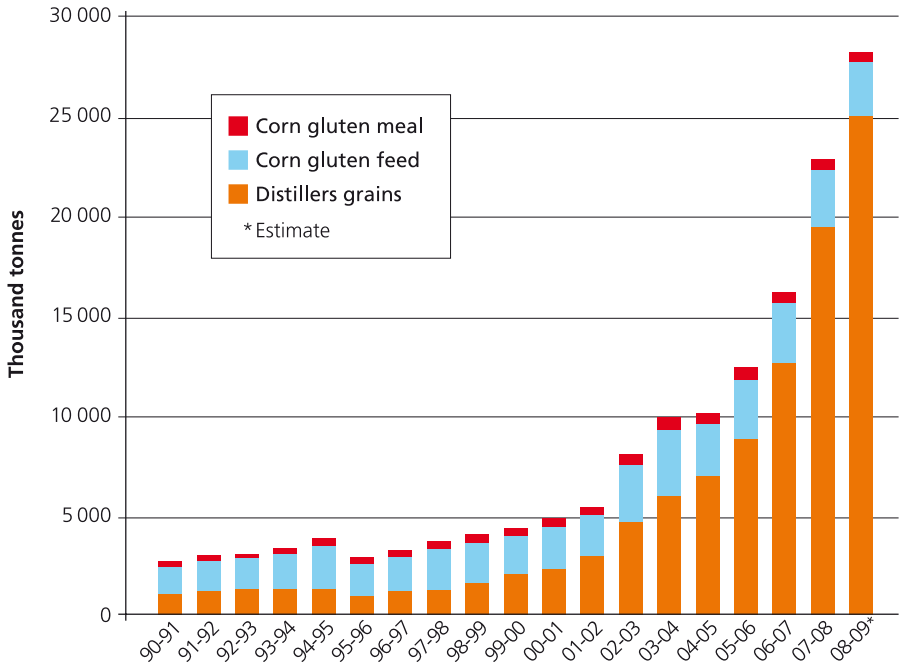
In 2009, distillers grains production was expected to reach 31.5 million tonnes, with exports expected to reach 6.6 million tonnes over the next ten years (Deutscher, 2009). According to the United States Grains Council, the United States of America exported over 4.5 million tonnes of dried distillers grains with solubles in 2008; the largest export markets in 2008 were Mexico (1.2 million tonnes, or 26.3 percent total exports), followed by Canada (772 000 tonnes, or 17.1 percent), Japan (198 000 tonnes, or 4.4 percent), Taiwan Province of China (189 000 tonnes, or 4.2 percent), and Republic of Korea (185 000 tonnes, or 4.1 percent) (Chen, 2009).

### *Oilseed crops, by-product meals and oils*

According to FAO (2010c), the total global production of oilseeds in 2009 was 415 million tonnes, with production up by 56.4 percent since 1995 and growing at an average annual rate of 3.24 percent per year (Table 9; Figure 22); soybean represented 53.6 percent of the total oilseed crop in 2009, followed by rapeseed (14.9 percent), cottonseed (9.9 percent), groundnut (8.6 percent), sunflower seed (7.7 percent), and palm kernel (2.9 percent) (Figure 23).

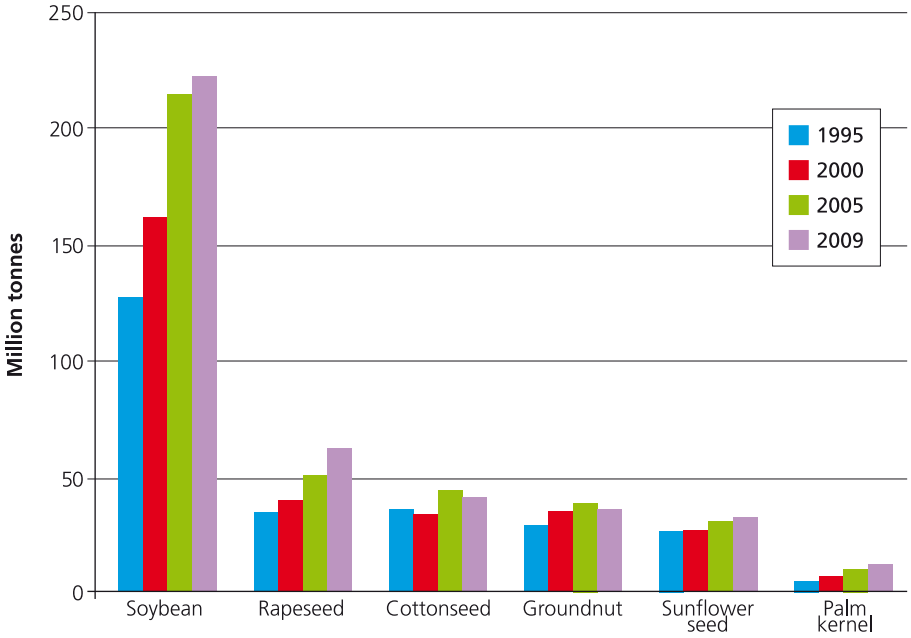
Soybean production continues to be the largest and one of the fastest growing oilseed crops, with global production up by 75.1 percent to 222.3 million tonnes since 1995 and growing at an annual percent rate of 4.1 percent per year (Figure 24, Table 9). The largest producer of soybean in 2009 was the United States of America at 91.4 million tonnes (41.1 percent total oilseed production), followed by Brazil (57.0 million tonnes, or 25.6 percent), Argentina (31.0 million tonnes, or 13.9 percent), China (14.5 million tonnes, or 6.5 percent) and India (10.2 million tonnes, or 4.6 percent) (Figure 25; FAO, 2010c). Other major oilseeds produced in 2009 are listed in Table 9 and include rapeseed (61.6 million tonnes), cottonseed (40.9 million tonnes), groundnut (35.5 million tonnes), sunflower seed (32.0 million tonnes) and palm kernel (11.9 million tonnes).

FIGURE 21
**Production of corn feed by-products from alcohol biorefineries in the United States, 1990/91 to 2008/09**



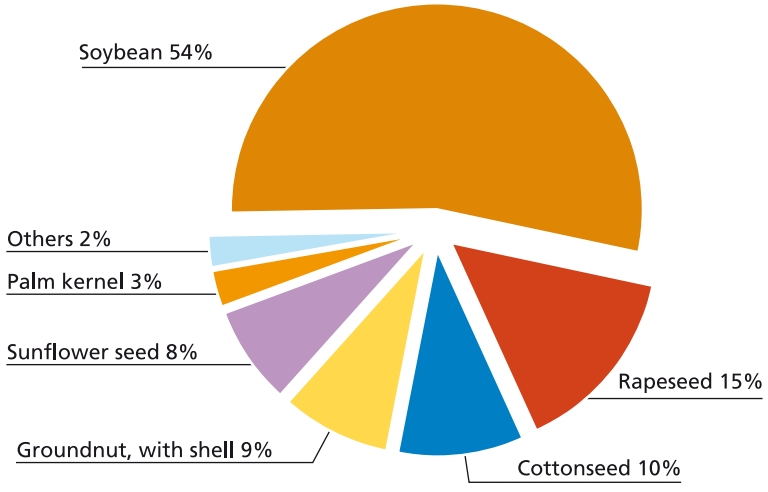

*Source*: Renewable Fuels Association: www.ethanolrfa.org/pages/industry–resources–coproducts.

FIGURE 22
**Global production of major plant oilseed crops, 1995–2009**




*Source*: FAO (2010c).

FIGURE 23
**Composition of commodities in global production of oilseed crops, 2009**
Total global oilseed crop production in 2009 – 415 million tonnes




*Source*: FAO (2010c).

The total global production and trade of oilseeds and extracted oilseed meals and oils is shown in Table 9. The data are based on the recent oilseed review of the United States Department of Agriculture (USDA) (2010a) and covers the period of 2008/09 and 2009/10; current FAO estimates for oilseed trade within FAOSTAT are only available up to 2007 (FAO, 2009c), at the time of writing this report. In terms of the total global supply of oilseed protein meals, these follow global oil crop production, with the largest supply by far being for soybean meal at 151.55 million tonnes in 2008/09 (Figures 26 and 27); the largest country producers of soybean meal in 2008/09 were the United States of America (35.47 million tonnes, or 23.4 percent), China (32.47 million tonnes,

TABLE 9
**Global production (tonnes) and growth of major oilseed crops, 1995–2009**

| Oilseed | 1995 | 2000 | 2005 | 2009 | % increase (1995–2009) | APR % (1995–2009) |
|---|---|---|---|---|---|---|
| Soybean | 126 950 271 | 161 290 903 | 214 462 151 | 222 268 904 | 75.1 | 4.1 |
| Rapeseed | 34 185 574 | 39 517 577 | 50 014 339 | 61 630 798 | 80.3 | 4.3 |
| Cottonseed | 35 562 917 | 33 251 468 | 43 517 078 | 40 869 553 | 14.9 | 1.0 |
| Groundnuts, with shell | 28 599 004 | 34 721 018 | 38 325 794 | 35 520 257 | 24.2 | 1.6 |
| Sunflower seed | 26 297 585 | 26 454 517 | 30 549 976 | 32 002 190 | 21.7 | 1.4 |
| Palm kernel | 4 759 764 | 6 478 254 | 9 889 639 | 11 932 886 | 150.7 | 6.8 |
| Sesame seed | 2 530 393 | 2 786 267 | 3 373 202 | 3 511 042 | 38.8 | 2.4 |
| Oilseeds, nes | 1 719 041 | 1 918 741 | 2 271 990 | 2 373 606 | 38.1 | 2.3 |
| Linseed | 2 525 094 | 2 060 823 | 2 781 281 | 2 206 288 | (–12.6) | –1.0 |
| Melonseed | 552,100 | 595 128 | 705 405 | 757 803 | 37.3 | 2.3 |
| Mustard seed | 487 449 | 487 048 | 562 611 | 661 326 | 35.7 | 2.2 |
| Safflower seed | 844 467 | 624 610 | 582 043 | 653 791 | (–22.6) | –1.8 |
| Poppy seed | 70 237 | 42 175 | 75 671 | 96 333 | 37.2 | 2.3 |
| Hempseed | 30 306 | 34 591 | 49 541 | 56 523 | 86.5 | 4.6 |
| Total | 265 114 202 | 310 263 120 | 397 160 721 | 414 541 300 | 56.4 | 3.2 |

*Note*: nes = not elsewhere specified.
*Source*: FAO (2010c).

or 21.4 percent), Argentina (24.95 tonnes, or 16.5 percent), Brazil (24.33 million tonnes, or 16.0 percent), EU-27 (10.11 million tonnes, or 6.7 percent), India (5.98 million tonnes, or 3.9 percent), and Mexico (2.73 million tonnes, or 1.8 percent (Table 8).

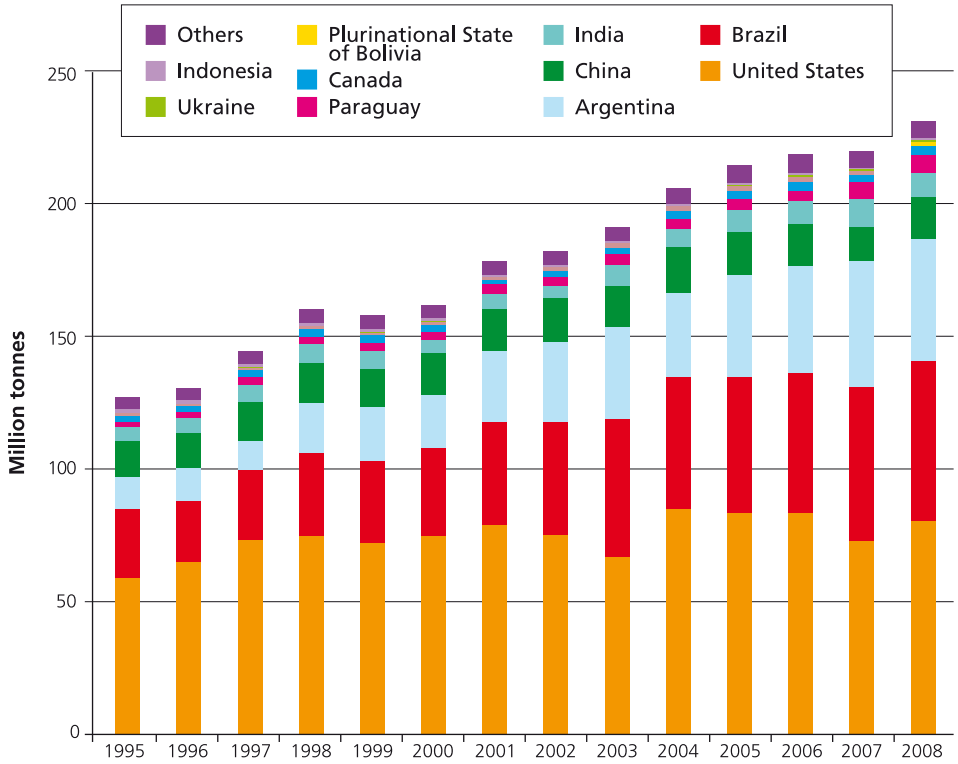
Other major oilseed protein meals produced in 2008/09, ranked in order of production volume, included: rapeseed meal (30.76 million tonnes), cottonseed meal (14.44 million tonnes), sunflower seed meal (12.59 million tonnes), palm kernel meal (6.2 million tonnes), groundnut/peanut meal (6.02 million tonnes), and copra/coconut meal (1.90 million tonnes) (Figures 26 and 27). However, no published information is currently available concerning the global production of oilseed protein concentrate meals, including soybean protein concentrate, rapeseed/canola protein concentrate, cottonseed protein concentrate or sunflower seed protein concentrate meals.

In terms of oil supply, palm oil was the top extracted oil produced in 2008/09 at 42.40 million tonnes (Figure 28), the largest country producers being Indonesia (19.5 million tonnes, or 46.0 percent) and Malaysia (17.26 million tonnes, or 40.7 percent; Figure 29). The second-largest volume of extracted oil was soybean oil at 35.76 million tonnes, with the major producers being the United States of America 8.50 million tonnes; China 7.31 million tonnes; Argentina 6.12 million tonnes; Brazil 6.02 million tonnes; EU-27 2.31 million tonnes; India 1.34 million tonnes; and Mexico 0.61 million tonnes (Figure 30). Other major oilseed oils produced in 2008/09, ranked in order of production volume, included rapeseed oil (20.39 million tonnes); sunflower seed oil (11.74 million tonnes); palm kernel oil (5.13 million tonnes); peanut/groundnut oil (4.97 million tonnes); cottonseed oil (4.84 million tonnes); copra oil (3.63 million tonnes); and olive oil (2.97 million tonnes; Figure 28).

As with the cereals, corn/maize and wheat, more than 85 percent of global oilcrop exports originate from within the Americas (FAO, 2009b), including the United States of America (45.5 percent and 14.8 percent global soybean and soybean meal exports, respectively); Brazil (39.1 percent, 25.0 percent and 21.0 percent of global soybean, soybean meal and soybean oil exports, respectively); Canada (63.7 percent, 54.8 percent and 64.5 percent of global rapeseed, rapeseed meal and rapeseed oil

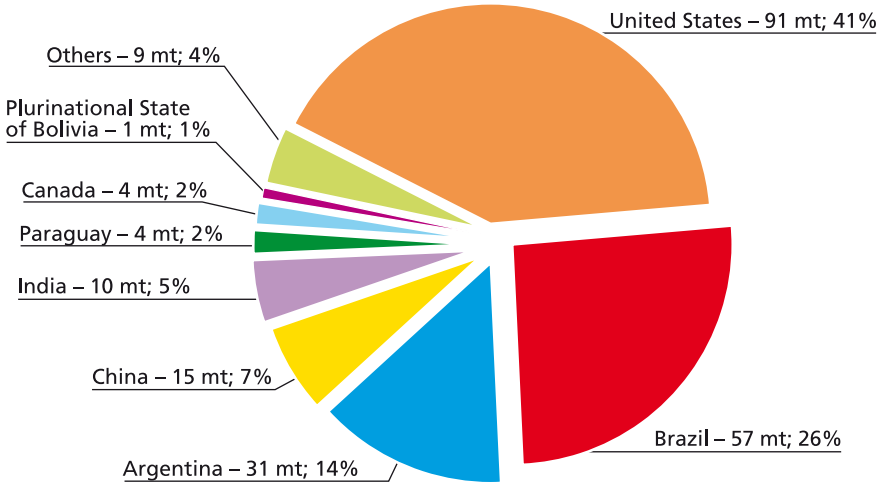
exports, respectively); and Argentina (7.3 percent, 46.0 percent and 52.0 percent total soybean, soybean meal and soybean oil exports (Table 8). The major role played by the United States of America in the global supply and exports of agricultural products, including cereals and oilseeds, is shown in Figure 31.

FIGURE 24
**Global production of soybean oilseed crop by country, 1995–2009**




*Source*: FAO (2010c).

FIGURE 25
**Global production of soybean oilseed crop by country, 2009**

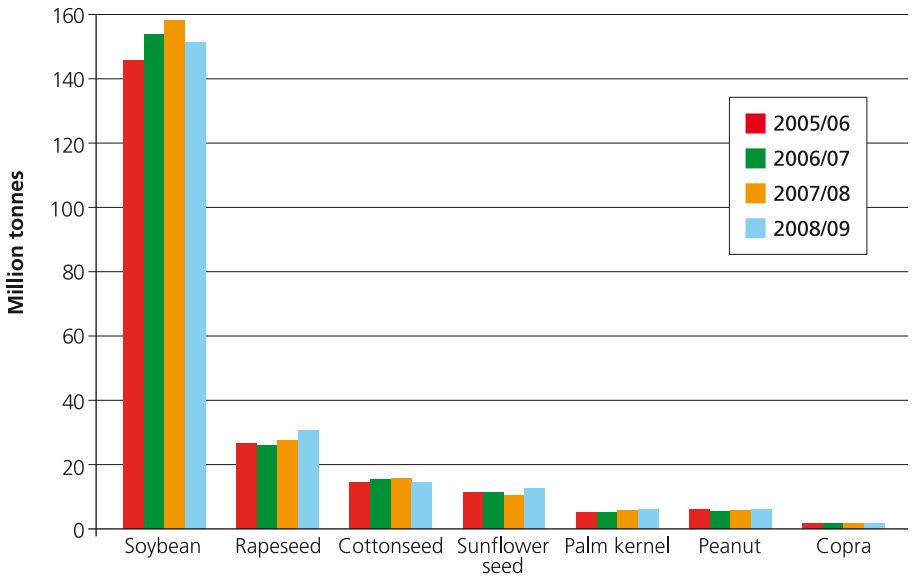



*Note*: mt = million tonnes.
*Source*: FAO (2010c).

In marked contrast, China continues to be the world's largest importer of oilseeds (46.6 million tonnes, or 48.0 percent of global oilseed imports in 2008/09 (FAO, 2009b), including 53.7 percent of global soybean imports, 28.1 percent soybean oil imports, 24.7 percent global rapeseed imports, 18.4 percent global rapeseed oil imports, and 18.0 percent global palm oil imports (Table 8; Figure 32).

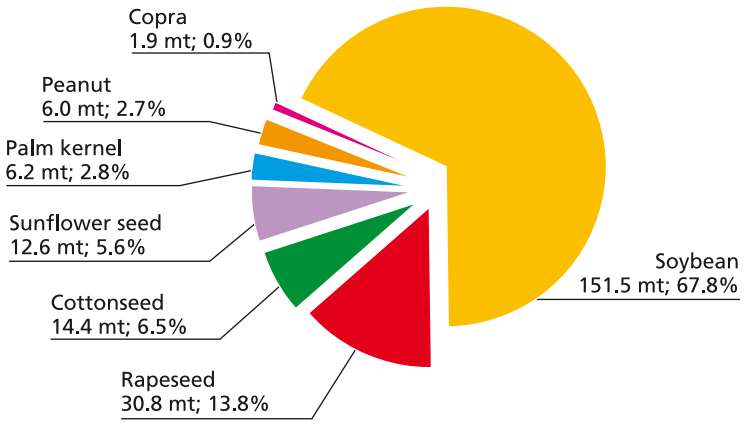
The second largest importer of oilseeds was the EU (18.6 million tonnes, or 19.1 percent global oilcrop imports in 2008/09 (FAO, 2009b), including 57.2 percent global sunflower seed meal imports, 41.9 percent global soybean meal imports, 31.7 percent sunflower seed imports, 27.2 percent global rapeseed imports, 26.0 percent global sunflower seed oil imports, 18.4 percent rapeseed oil imports (Figure 33).

FIGURE 26
**Global production of major oilseed meals, 2005/06 to 2008/09**




*Source*: USDA (2010a).

FIGURE 27
**Global production of major oilseed meals by commodity, 2008/09**
Total global production of major oilseed meals in 2008/09 – 223.5 million tonnes



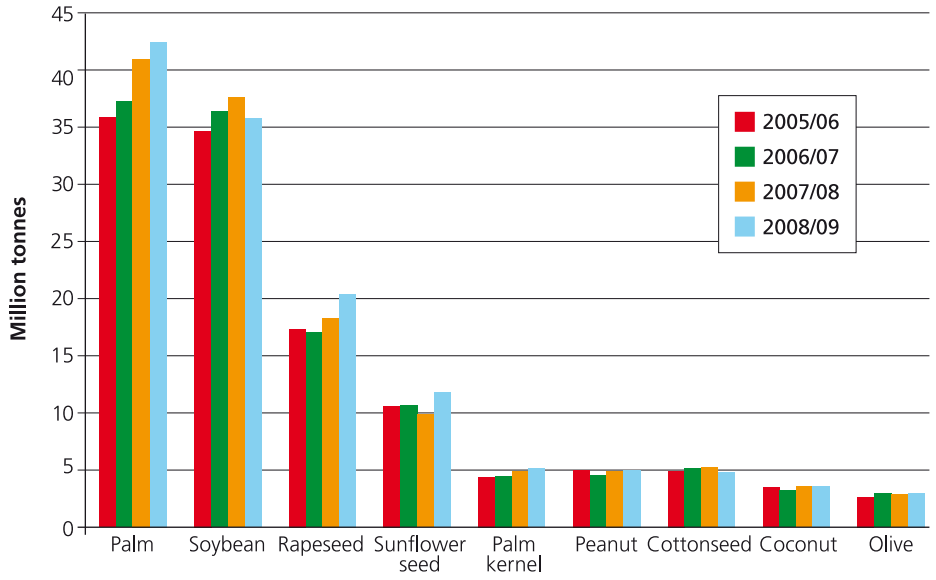

*Note*: mt = million tonnes.
*Source*: USDA (2010a).

### *Pulses and protein concentrate meals*

For the purposes of this paper only peas and lupins will be considered, as their protein concentrate meals are commercially available for use within compounded animal feeds, including aquaculture feeds.

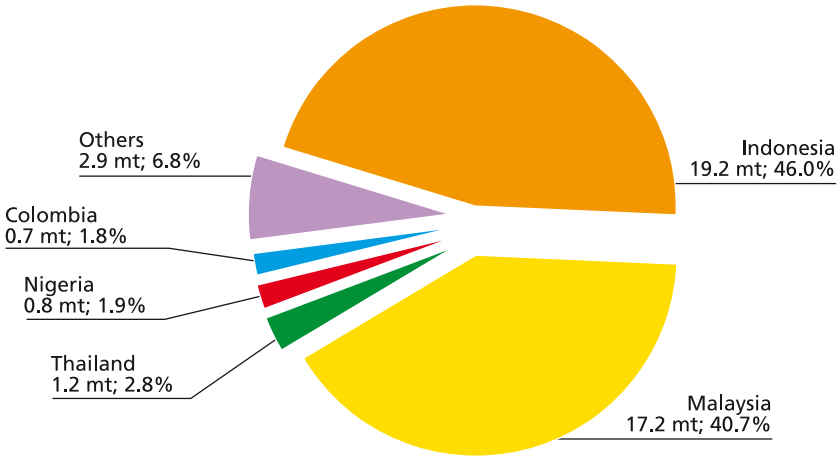
The total global production of dry peas was 10.5 million tonnes in 2009, with production down by 8.7 percent from 1995; the major country producers in 2009 include Canada (3.38 million tonnes or 32.2 percent of global production), followed by the Russian Federation (1.35 million tonnes or 12.9 percent of global production),

FIGURE 28
**Global production of major oilseed oils, 2005/06 to 2008/09**



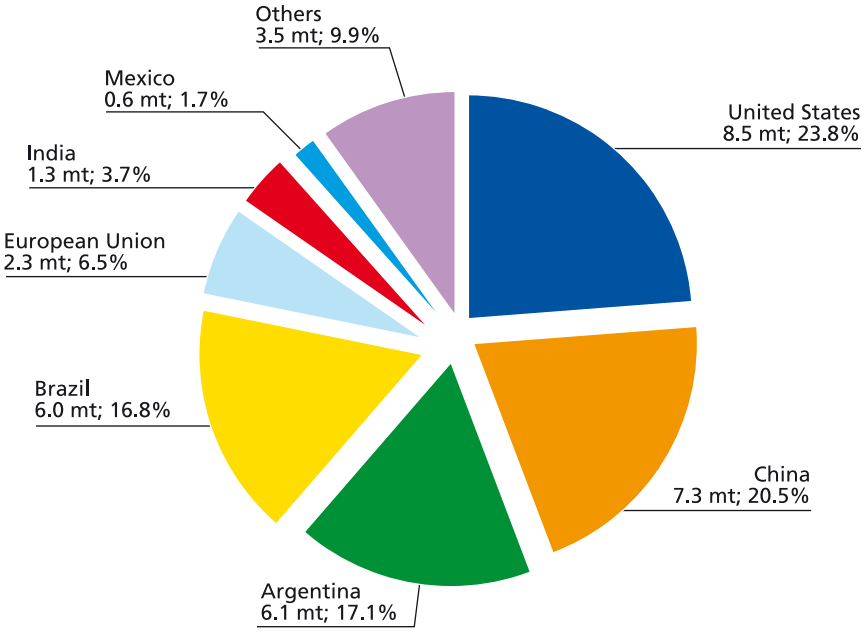

*Source*: USDA (2010a).

FIGURE 29
**Global production of palm oil by country, 2008/09**



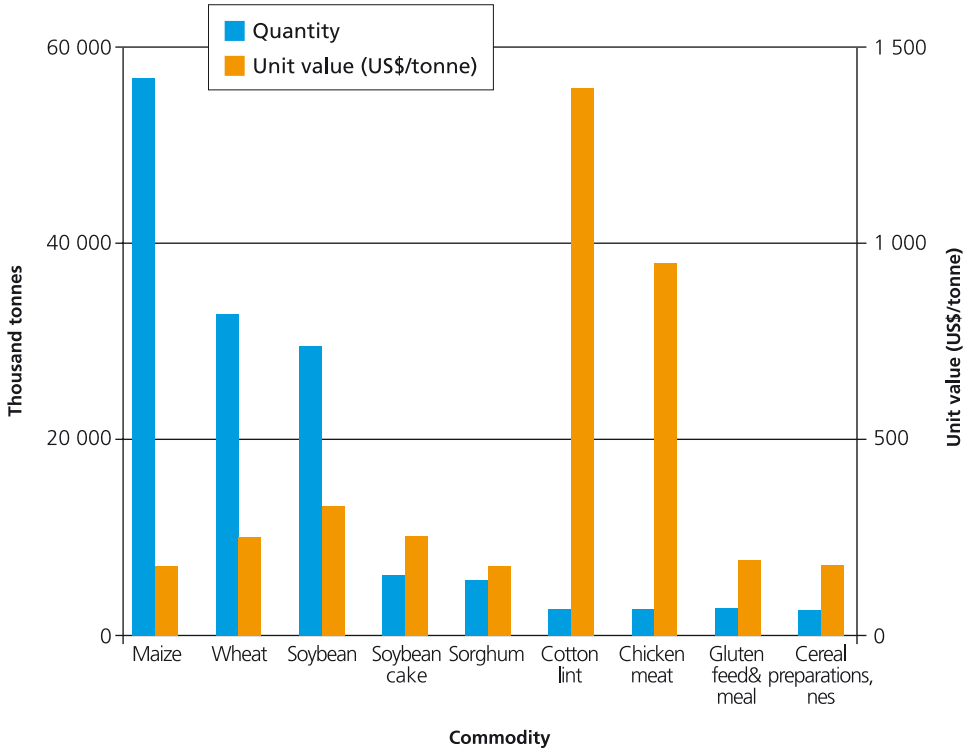

*Note*: mt = million tonnes.
*Source*: USDA (2010a).

FIGURE 30
**Global production of soybean oil by country, 2008/09**




*Note*: mt = million tonnes.
*Source*: USDA (2010a).

FIGURE 31
**Top agricultural exports by quantity from the United States, 2007**



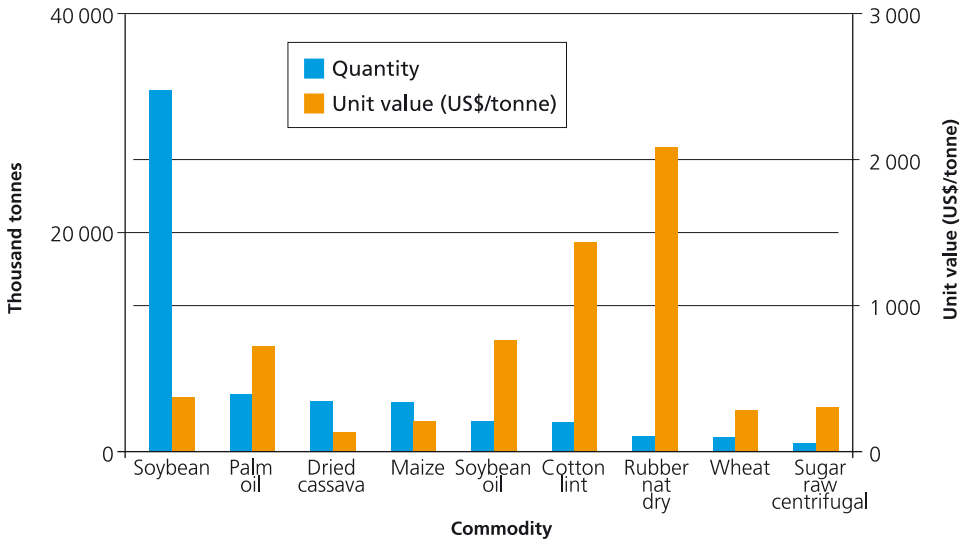

*Note*: nes = not elsewhere specified.
*Source*: FAO (2009b).

China (960 000 tonnes), the United States of America (777 320 tonnes), India (754 459 tonnes), France (546 846 tonnes), Ukraine (493 600 tonnes), Australia (356 000 tonnes), Ethiopia (235 872 tonnes) and Germany (165 907 tonnes) (Figure 34).

The total global production of lupins was 925 412 tonnes in 2009, with production down by 46.0 percent from 1995; the major country producers in 2009 include Australia (614 000 tonnes or 66.3 percent global production), followed by Belarus (73 708 tonnes), Germany (59 627 tonnes), Poland (57 000 tonnes), Ukraine (26 800 tonnes), South Africa (20 654 tonnes), Chile (12 311 tonnes), Lithuania (10 600 tonnes), Peru (9 907 tonnes), and the Russian Federation (9 290 tonnes) (Figure 35).

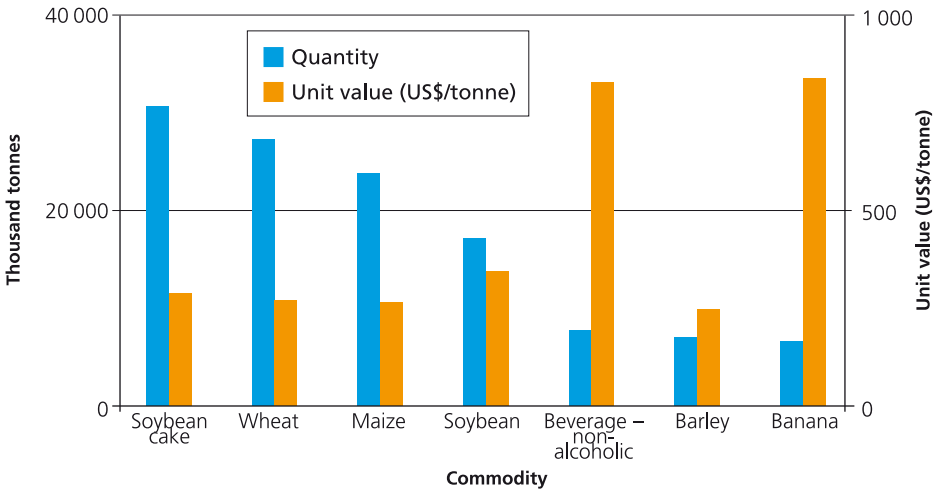
At present, no information is available concerning the global production of pea and/or lupin protein concentrates.

FIGURE 32
**Top agricultural imports by quantity in China, 2007**



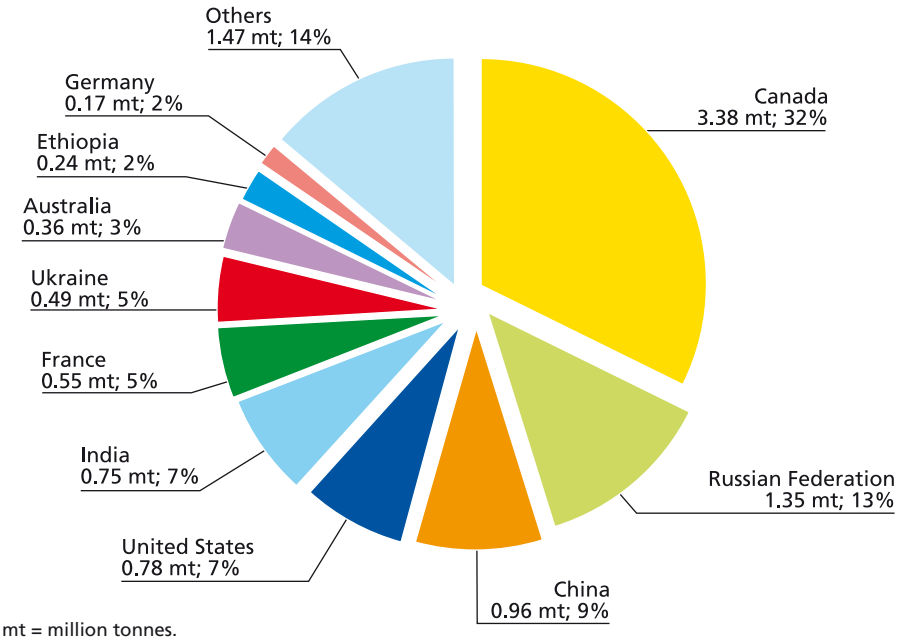

*Source*: FAO (2009b).

FIGURE 33
**Top agricultural imports by quantity in the European Union, 2007**



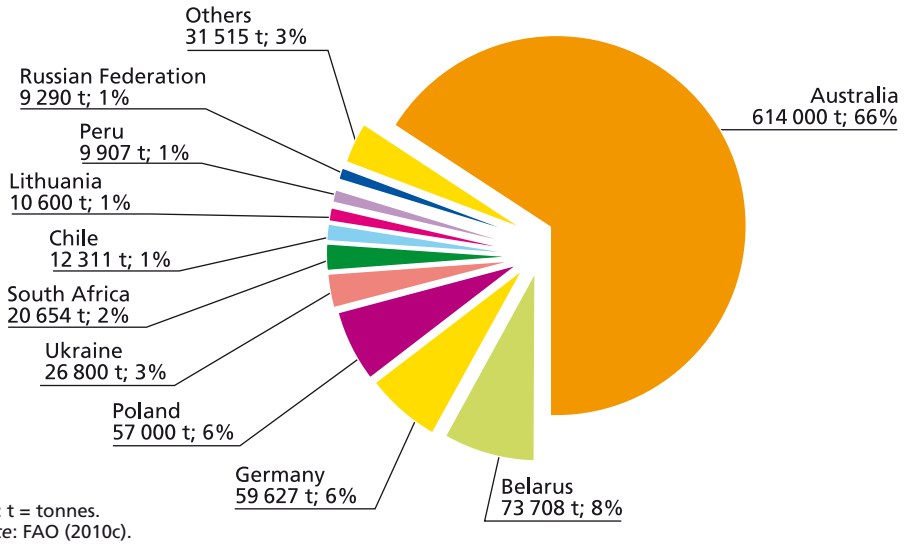

*Source*: FAO (2009b).

FIGURE 34
**Global production of dry peas by country, 2009**




*Note*: mt = million tonnes.
*Source*: FAO (2010c).

FIGURE 35
**Global production of lupins by country, 2009**




*Note*: t = tonnes.
*Source*: FAO (2010c).

## 3.3 MICROBIAL INGREDIENT SOURCES

Microbial derived feed ingredient sources include the use of mass-produced harvested/extracted algae, thraustochytrids, yeasts, fungi, bacteria and/or mixed bacterial/microbial single cell protein (SCP) sources. Apart from the limited market availability of algal and thraustochytrid products, the only microbial ingredient sources currently available in commercial quantities globally are yeast-derived products, including brewer's yeast and extracted fermented yeast products (Tacon, Metian and Hasan, 2009). No information, however, is available concerning the total global production and market availability of these products.

*Harvest of Indian major carps in Andhra Pradesh, India. Major carps are fed with feeds ranging from supplementary feed, farm-made aquafeed and commercially produced industrial aquafeed in India.*

Courtesy of FAO/R. Ramakrishna

# 4. Current levels of feed ingredient usage and constraints

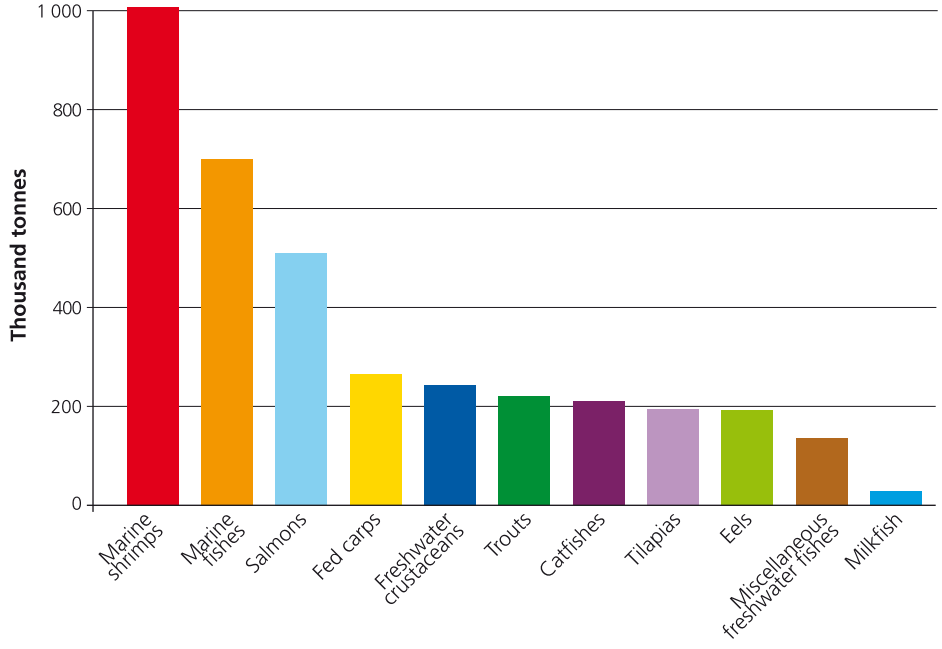
Table 10 shows the feed ingredients currently used in compound aquafeeds for the major cultivated finfish and crustacean species. The results are based on the responses received from commercial feed manufacturers and/or nutritionists to an electronic survey conducted for this study. Although by no means complete, the results show some significant findings, as detailed below.

## 4.1 CONTINUED USE OF FISHMEAL AND FISH OIL AS MAJOR DIETARY ANIMAL PROTEIN AND LIPID SOURCES

Fishmeal (FM) and fish oil (FO) are continued to be used as the major sources of dietary protein and lipid within compound aquafeeds for the higher trophic level fish and crustacean species, e.g. eels (FM 55–65 percent, FO 3–18 percent, total of FM and FO 58–83 percent); marine finfishes (FM 20–65 percent, FO 5–20 percent, total 25–85 percent); salmons (FM 25–40 percent, FO 10–25 percent, total 35–65 percent); trouts (FM 18–40, FO 5–25 percent, total 23–65 percent); marine shrimps (FM 5–40 percent, 1-9 percent, total 6–49 percent); and freshwater prawns (FM 20–65 percent, FO 0–7 percent, total 20–72 percent) (Table 10).

However, in total usage terms, the largest consumers of fishmeal in 2008 (average species levels based partly on the results of the current survey and shown in Table 11) were shrimps (27.2 percent of total fishmeal used in compound aquafeeds), followed by marine fishes (18.8 percent), salmons (13.7 percent), carps (7.4 percent), freshwater crustaceans (6.4 percent), trouts (5.9 percent), catfishes (5.5 percent), tilapias (5.3 percent),

FIGURE 36
**Estimated global consumption of fishmeal by major aquaculture species group, 2008**

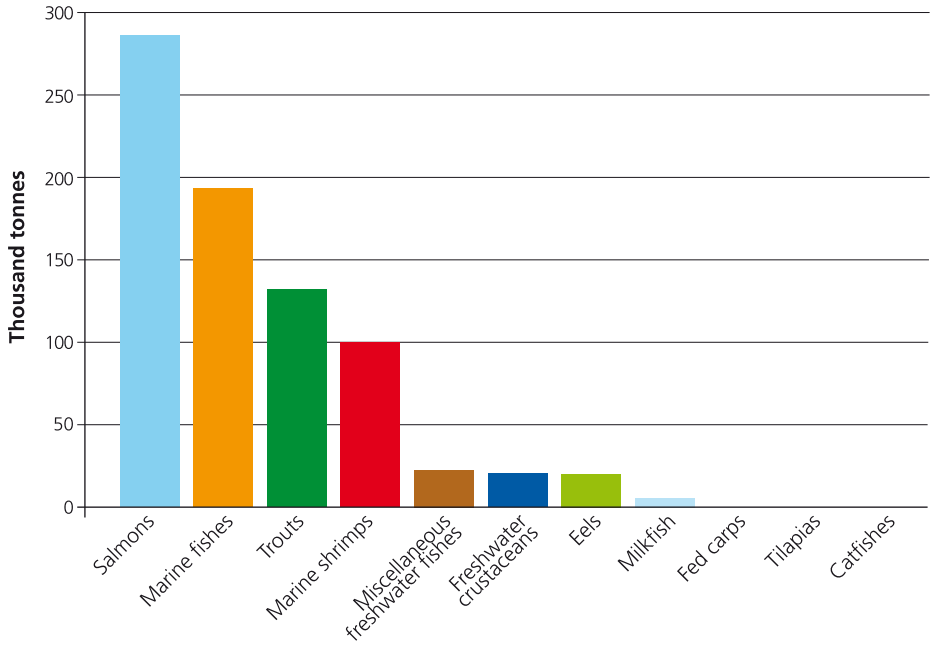



*Source*: Based on data from Table 11.

eels (5.2 percent), miscellaneous freshwater fishes (3.9 percent) and milkfish (0.8 percent) (Figure 36). On a global basis, it is estimated that the aquaculture sector consumed 3 723 000 tonnes of fishmeal (60.8 percent of global fishmeal production; FAO, 2011b) in 2008 (Table 11). In 2007, the aquaculture sector consumed 3 844 000 tonnes of fishmeal, or about 68.4 percent, of total reported global fishmeal production for that year.

Similarly, in total usage terms the largest consumers of fish oil in 2008 were salmons (36.6 percent total fish oil used in compound aquafeeds), followed by marine fishes (24.7 percent), trouts (16.9 percent), marine shrimps (12.9 percent), miscellaneous freshwater fishes (3.1 percent), freshwater crustaceans (2.6 percent), eels (2.6 percent), and milkfish (0.7 percent; Table 11) (Figure 37). On a global basis, it is estimated that the aquaculture sector consumed 782 000 tonnes of fish oil (73.8 percent of global fish oil production; FAO, 2011b) in 2008 (Table 11). In 2007, the aquaculture sector consumed 823 000 tonnes of fish oil or about 81.3 percent of total reported global fish oil production for that year.

FIGURE 37
**Estimated global consumption of fish oil by major aquaculture species group, 2008**



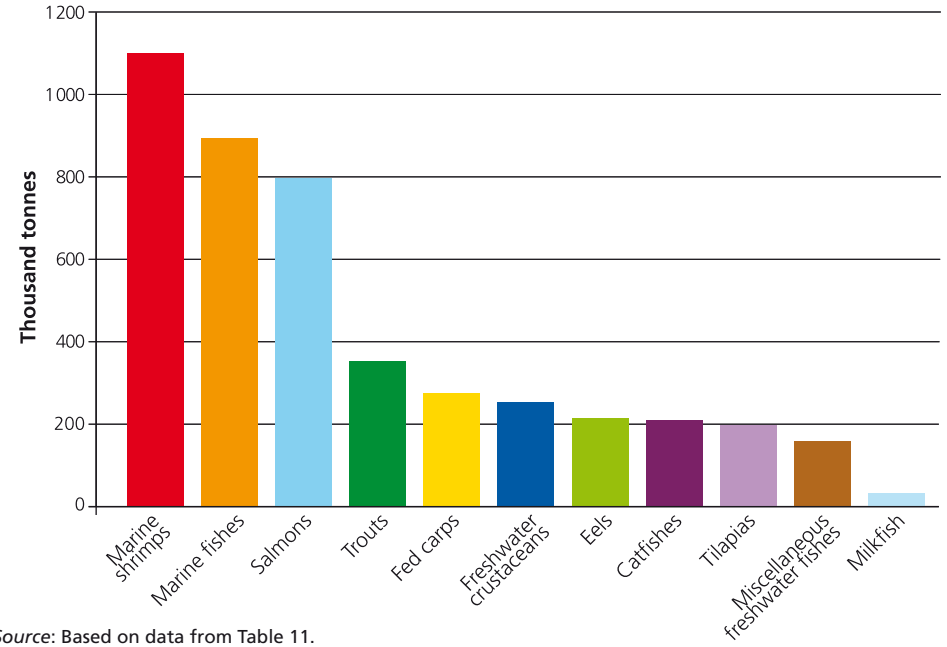

*Source*: Based on data from Table 11.

Although there has been a gradual reduction of combined fishmeal and fish oil use in aquaculture since 2006, the aquaculture sector has continued to remain the largest user of fishmeal and fish oil. The sector consumed over 4 667 000 tonnes of fishmeal and fish oil, or about 70.3 percent, of the total global production of these two ingredients in 2007. In 2008, the sector consumed about 4 506 000 tonnes of fishmeal and fish oil, or about 62.7 percent, of the global production of these two ingredients for that year. However, there is a wide variation in fishmeal and fish oil usage between major producing countries for species/species groups with shrimp, marine fish and salmon being the largest users of fishmeal and fish oil (Figure 38).

Overall, this variation reflects the differences in the selection and use by countries of fishmeal and fish oil replacers and the differences between countries in cost and availability of ingredients. One other factor is the increased use of land animal proteins and fats within feeds for high trophic level fish species and crustaceans within the Americas and Australia.

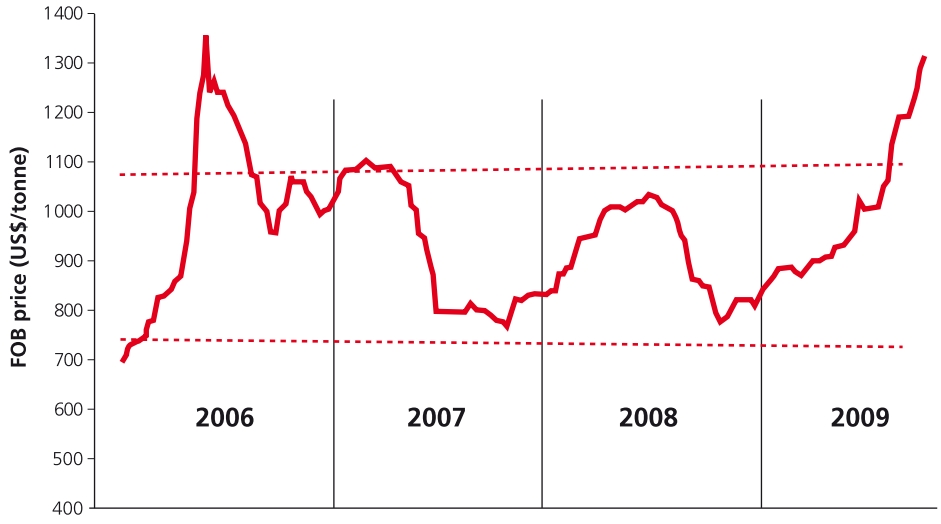
In total usage terms, it is expected that the total use of fishmeal by the aquaculture sector will decrease in the long term, decreasing from 4.23 million tonnes in 2005 to 3.72 million tonnes in 2008 (or 12.8 percent of total aquafeeds by weight), and expected to decrease further to 3.49 million tonnes by 2020 (or 4.9 percent of total aquafeeds for that year) (Table 11). The reasons for this decrease are the increasing market demand and prices (Figure 39), decreased supplies from tighter quota setting and more controls on unregulated fishing, and increased use of more cost-effective dietary fishmeal replacers (Davis and Sookying, 2009; Hardy, 2009; Manomaitis, 2009; Nates *et al.*, 2009; Quintero *et al.*, 2010; Wang, 2009).

FIGURE 38
**Estimated total global consumption of fishmeal and fish oil by major aquaculture species group, 2008**




*Source*: Based on data from Table 11.

FIGURE 39
**Variation in price of fair average quality (FAQ) Peru fishmeal, January 2006 to October 2009**




*Note*: FOB = free on board.
*Source*: Mittaine (2009).

On the contrary, it is expected that the use of fish oil by the aquaculture sector will continue to increase in the long run albeit slowly; total usage will increase by over 16 percent by volume, from 782 000 tonnes (2.7 percent of total feeds by weight) in 2008 to the estimated 908 000 tonnes (1.3 percent of total aquafeeds for that year) by 2020 (Table 11). The reasons for the increased use in global terms are believed to be the rising demand for these resources by the rapidly growing marine finfish and crustacean aquaculture sector and the absence of cost-effective alternative sources of dietary lipids that are rich in long-chain, highly unsaturated fatty acids, including eicosapentaenoic acid (EPA; 20:5n-3) and docosahexaenoic acid (DHA; 22:6n-3) (Hole, 2009; Turchini, Torstensen and Ng, 2009; Wang, 2009).

## 4.2 INCREASED USE OF TERRESTRIAL ANIMAL PROTEIN MEALS AND OILS AS DIETARY NUTRIENT SOURCES

The use (within non-European countries) of terrestrial animal protein meals and lipids is increasing within compound aquafeeds, for both high and low trophic level species, and concern specifically the following species groups (Table 10):

- *salmons* – poultry by-product meal (10–30 percent); hydrolysed feather meal (5–12 percent); blood meal (1–8 percent); meat meal (10–30 percent); poultry oil (1–15 percent);
- *trouts* – poultry by-product meal (5–30 percent); hydrolysed feather meal (5–20 percent); blood meal (1–8 percent); meat meal (10–30 percent); poultry oil (1–15 percent);
- *marine finfishes* – poultry by-product meal (10–30 percent); blood meal (1–10 percent); meat meal (10–30 percent) (1–10 percent);
- *marine shrimps* – poultry by-product meal (2–30 percent); hydrolysed feather meal (5–10 percent); meat meal (2–30 percent);
- *catfishes* – poultry by-product meal (2–4 percent);
- *tilapia* – meat and bone meal (5–10 percent); poultry oil (2–4 percent);
- *freshwater crayfishes* – meat meal (10–30 percent); meat and bone meal (10–30 percent);
- *carps* – meat and bone meal (5–10 percent); and
- *grey mullets* – meat and bone meal (5–10 percent).

The fact that non-European feed manufacturers are able to utilize this largely untapped dietary nutrient source allows them to be less reliant on the use of fishmeal and fish oil as dietary nutrient sources and, by virtue of their greater availability and lower cost, makes them more economically competitive than their European counterparts. For example, salmon feeds in Chile currently contain about 10–20 percent terrestrial animal by-products and only 20–25 percent fishmeal and 12–15 percent fish oil, whereas in the United Kingdom of Great Britain and Northern Ireland, salmon feeds contain 35 percent fishmeal, 25 percent fish oil and 0 percent terrestrial animal by-products (Table 10). Despite this, it is estimated that the total direct usage of terrestrial animal by-product meals and oils within compound aquafeeds is, at present, only between 150 000 tonnes and 300 000 tonnes (Table 10), or less than 1 percent of total global compound aquafeed feed production. Clearly, there is considerable room for further growth and expansion (Nates *et al.*, 2009).

According to the European Commission, the only animal by-products (ABP) that can be used within aquafeeds are Category 3 ABP (for review, see Woodgate, 2010; European Commission Regulation No. 1774/2002 and No. 999/2001). These are animal by-products or parts of slaughtered animals that are fit for human consumption in accordance with Community legislation but are not intended for human consumption for commercial reasons. These include:

TABLE 10
**Country responses regarding feed ingredient usage for major cultivated species groups (percentage values represent country ranges and/or means)**

| Country | Year | FM | FO | R/CO | SBM | WH | WGM | SSM | CGM | R/CM | LKM | FPM | FBM | KM | PO | PBM | HFM | BM | MM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Salmons – Atlantic salmon, coho salmon, chinook salmon** | | | | | | | | | | | | | | | | | | | |
| Australia | 2008/09 | 25–40 | 10–25 | - | - | 10–20 | 2–10 | - | - | - | 5–15 | - | - | 5–10 | 0–10 | 10–30 | - | 1–5 | 10–30 |
| Canada | 2008 | 25–35 | 15–25 | - | 3–10 | 12–18 | - | - | 10–40 | 3–10 | - | - | - | - | 10-15 | 15-25 | 5-12 | 6-8 | - |
| Chile | 2008 | 25 | 12 | 12 (20:80 rape:soya oil); 20 (plant: SBM <12, RSM <6, LKM <6, CGM <10, SPC <8, CSM <12); 17 (poultry by-products: HFM <12, PBM <8, BM <7) | | | | | | | | | | | | | | | |
| Chile | 2010 | 20–25 | 15 | 15 | Plant protein sources: 25 | | | | | | | | | - | - | Animal by-products: 10-20 | | | |
| Norway | 2008 | 26–30 | 17–19 | 11–13 | 8–12 | 10–14 | 3–4 | 7–9 | - | - | - | - | - | +[1] | - | - | - | - | - |
| Norway | 2010 | 25 | 15 | 15 | 12 | 12 | Other plant protein sources: 20 | | | | | | | | | - | - | - | - |
| United Kingdom | 2008 | 35 | 25 | 5 | 10 | 10 | - | 5 | - | 5 | - | 3 | 5 | - | - | - | - | - | - |
| United Kingdom | 2010 | 35 | 25 | + | + | 12 | No other information given | | | | | | | | | | | | |
| **Trouts – rainbow trout, sea trout** | | | | | | | | | | | | | | | | | | | |
| Argentina | 2009 | 18–40 | 5–20 | - | 10–35 | 15 | - | - | 3–8 | - | - | - | - | - | - | - | 10–20 | - | - |
| Australia | 2008/09 | 20–40 | 10–20 | - | - | 10–20 | 2–10 | - | - | - | 5–15 | 5–10 | - | - | 0–10 | 10–30 | - | 1–5 | 10–30 |
| Canada | 2008 | 25–35 | 15–25 | - | 3–10 | 12–18 | - | - | 10–40 | 3–10 | - | - | - | - | 10–15 | 15–25 | 5–12 | 6–8 | - |
| Chile | 2008 | 25 | 12 | 12 (20:80 rape: soya oil); 20 (plant: SBM <12, RSM <6, LKM <6, CGM <10, SPC <8, CSM <12); 17 (poultry by-products: FM <12, PBM <8, BM <7). | | | | | | | | | | | | | | | |
| Chile | 2010 | 20–25 | 15 | 15 | Plant protein sources: 25 | | | | | | | | | | | Animal by-products: 10–20 | | | |
| Denmark | 2008 | 32 | 20 | - | 12 | 12 | - | - | - | - | - | - | No other details given | | | | | | |
| Ecuador | 2009 | >30 | 10–15 | - | <15 | Corn <15; No other details given | | | | | | | | | | | | | |
| France | 2009 | 20–30 | 10–15 | 5–8 | 10–15 | 5–10 | 3–5 | 5–8 | 5–8 | - | - | 5–10 | Pea protein meal 5–10; soybean protein concentrate 5–10% | | | | | | |
| Greece | 2009 | 20–40 | 7–15 | - | 10–35 | 5–15 | 5–12 | 5–10 | 5–12 | 5–10 | - | 5–10 | | | | | | | |
| Mexico | 2009 | 15–25 | 10–15 | - | 20–35 | Corn <10; Soy lecithin 2-3 | | | 4–5 | 2–5 | - | - | - | - | - | 5-10 | Hog and blood meal <10 | | |
| Norway | 2008 | 28–32 | 16–19 | 10–12 | 8–12 | 10–14 | 3–4 | 7–9 | - | - | - | - | - | - | - | - | - | - | - |
| Norway | 2010 | 25 | 15 | 15 | 12 | 12 | Other vegetable proteins: 20 | | | | | | | | | | | | |
| United Kingdom | 2008 | 30 | 20 | - | 15 | 10 | - | 8 | - | 5 | - | 3 | 8 | - | - | - | - | - | - |

TABLE 10, continued

**Country responses regarding feed ingredient usage for major cultivated species groups (percentage values represent country ranges and/or means)**

| Country | Year | FM | FO | R/CO | SBM | WH | WGM | SSM | CGM | R/CM | LKM | FPM | FBM | KM | PO | PBM | HFM | BM | MM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Marine shrimps – whiteleg shrimp, giant tiger prawn** | | | | | | | | | | | | | | | | | | | |
| Australia | 2008/09 | 20–40 | 2–5 | - | - | 10–30 | - | 2–10 | - | - | 5–15 | - | - | 5–15 | - | 10–30 | - | - | 10–30 |
| China | 2008 | 20–30 | - | - | 10–25 | Wheat and wheat by-products 15–25 | | | | 0–20 | - | - | - | - | - | - | - | - | - |
| China | 2008 | 30 | 1–2 | Other ingredients listed include soybean meal, peanut cake/meal, rapeseed cake/meal, corn, wheat flour – no levels given | | | | | | | | | | | | | | | |
| Ecuador | 2009 | 5–20 | - | <5 | >30 | <15 | Other ingredients listed: corn <20; cassava <20; polished rice 15; broken rice 15%; | | | | | | | | | | | | |
| India | 2006/07 | 20–30 | 2–3 | 3 | 20–25 | Wheat and other cereals 20–25; groundnut meal 15–20; | | | | | | | 1–2 | Squid meal and acetes shrimp 3–10 | | | | | |
| Mexico | 2009 | 12–20 | 3–6 | 1–2 | 15–40 | 12–22 | 3–6 | Corn by-products 2–4 | | 3–8 | - | - | 1–4 | - | - | 2–4 | - | - | 2–4 |
| Nicaragua | 2009 | 12.5 | 3 | - | 15 | 20 | Rice bran 19; sorghum 15; peanut/groundnut meal 4; | | | | | | | | | 3 | | | |
| Venezuela (Bolivarian Republic of) | 2008 | 22 | 4 | - | 25 | 10 | 25 | Broken rice 5; rice meal 5; | | | | | 1 | - | - | - | - | - | - |
| United States | 2009 | 30–40 | 5–9 | 5–10 | 5–15 | Wheat, wheat flour, wheat middlings 10–25; squid oil 1–5; imported special fishmeals 10-15 | | | | | | | | | | | 5–10 | | |
| **Marine fishes – barramundi, cobia, cods, groupers, halibuts, seabass, seabreams, tunas, yellowtail** | | | | | | | | | | | | | | | | | | | |
| Australia | 2008/09 | 20–40 | 5–20 | - | - | 10–20 | 2–10 | Other ingredients: lupin kernel meal 5–15, field pea 25 | | | | | | - | 0-10 | 10-30 | - | 1-5 | 10-30 |
| China | 2008 | 20–50 | 5 | - | 10–25 | Wheat and wheat by-products 15–25 | | | | 0–20 | Others listed: soybean meal, peanut meal/cake, rapeseed cake/meal, corn, wheat | | | | | | | | |
| France | 2009 | 20–30 | 5–10 | - | 15–25 | 5–10 | 3–5 | 5–8 | 10–18 | Others listed: rapeseed oil 3–5, peas 5–10, pea protein 5–10, soy protein concentrate 5–10 | | | | | | | | | |
| Greece | 2009 | 20-40 | 7–15 | - | 10–35 | 5–15 | 5–12 | 5–10 | 5–12 | 5–10 | Pea meal 5–10 | | | | | | | | |
| Norway | 2010 | 50 | 12 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Spain | 2009 | 45–64 | 7–12 | 6 | | 1–5 | 9–13 | - | 4 | 7 | 10 | Other ingredients: soybean concentrate 5–19, pea meal 5–10 | | | | | | | |
| Taiwan Province of China | 2007 | 50–65 | 6-8 | 3–5 | 15–25 | 10–15 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| United Kingdom | 2008 | 60 | 15 | - | 15 | 10 | Other ingredients listed: beans 5, others 5 | | | | | | | | | | | | |
| United States | 2009 | 20–40 | 5–20 | - | 10–15 | 5–15 | - | - | 5–10 | - | 5–10 | 2–4 | 10–15 | - | - | - | - | 5–10 | - |

TABLE 10, continued

**Country responses regarding feed ingredient usage for major cultivated species groups (percentage values represent country ranges and/or means)**

| Country | Year | FM | FO | SO | SBM | WH | WB | MA | CGM | R/CM | CSM | FPM | SL | KM | PO | PBM | HFM | BM | RB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Carps – grass carp, common carp, crucian carp, catla, rohu** | | | | | | | | | | | | | | | | | | | |
| China | 2008 | 0–3 | - | - | 0–25 | 0–25 | | 0–25 | - | 20–40 | Spirit-based distillers grains 0–8% | | | | | | | | |
| Egypt | 2008 | 4–12 | - | - | 20–25 | - | 10–25 | 10–25 | - | - | Other ingredients listed: yellow corn 30–40, local meat and bone meal 5–10 | | | | | | | | |
| India | 2006/07 | - | - | - | 5 | - | 50 | 50 | - | - | Other ingredients listed: groundnut/peanut cake 30, mustard cake 10 | | | | | | | | |
| **Catfishes – channel catfish, pangasiid catfishes** | | | | | | | | | | | | | | | | | | | |
| India | 2006/07 | 5–10 | - | - | 10 | 15–20 | | | | | Other ingredients listed: groundnut/peanut cake 30, mustard cake 10 | | | | | | | | |
| Mexico | 2009 | 10–15 | 3–6 | 1–4 | 30 | 15–20 | | 15-20 | - | 5–10 | - | - | 1–4 | - | - | 2–4 | - | - | - |
| United States | 2008 | - | - | - | 20–50 | 10–20 | | 30–45 | | - | 10–20 | - | - | - | - | - | - | - | - |
| Viet Nam | 2008 | 0–10 | | | 30–60 | - | - | - | - | Other ingredients listed: cassava 20–35 | | | | | 20–30 | - | - | - | - |
| **Tilapias** | | | | | | | | | | | | | | | | | | | |
| China | 2008 | 0–3 | - | - | 0–25 | 0–25 | | 0–15 | | 20–40 | 0–25 | Spirit based distillers grains 0–8 | | | | | | | |
| Ecuador | 2009 | <10 | - | - | >40 | - | - | 20–30 | Other ingredients listed: sorghum <25, rice polishing 15, broken rice 15 | | | | | | | | | | |
| Egypt | 2008 | 4–12 | - | - | 20–25 | - | 10–25 | 30–40 | - | - | - | | - | - | - | - | 5–10 | - | 10–25 |
| Mexico | 2009 | 10–15 | 3–6 | 1–4 | 30 | 15–20 | 15–20 | - | 5–10 | - | - | 1–4 | - | - | 2–4 | - | - | - | - |
| Peru | 2008 | 20 | - | - | 40 | - | - | 30 | - | - | - | - | - | - | - | - | - | - | - |
| Taiwan Province of China | 2007 | 20–25 | 3–5 | 5–8 | 30–35 | 15–20 | | - | - | - | - | - | - | - | - | - | - | - | 10–25 |
| United States | 2008 | 2–5 | 1 | - | 30–35 | Other ingredients reported: corn, sorghum and wheat products | | | | | | | | | | | | | |
| Venezuela (Bolivarian Republic of) | 2008 | 16 | - | 2 | 23 | 34 | 22 | - | 6 | - | - | Broken/milled rice 7, sorghum grain meal 20 | | | | | | | |
| Viet Nam | 2008 | 5 | - | - | 30–60 | - | - | - | Other ingredients listed: cassava 20–35 | | | | | | | | | | 20–30 |
| **Eels** | | | | | | | | | | | | | | | | | | | |
| Denmark | 2008 | 55 | 18 | - | 10 | 15 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Taiwan Province of China | 2007 | 60–65 | 3–5 | 6–8 | 8–10 | Starch 15–20 | | | | | | | | | | | | | |

TABLE 10, continued

**Country responses regarding feed ingredient usage for major cultivated species groups (percentage values represent country ranges and/or means)**

| Country | Year | FM | FO | SO | SBM | WH | WB | MA | CGM | R/CM | CSM | FPM | SL | KM | PO | PBM | HFM | BM | RB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Freshwater prawns** | | | | | | | | | | | | | | | | | | | |
| China | 2008 | 20–30 | 0–1 | - | - | - | 5–10 | Other ingredients listed: soybean meal, peanut meal/cake, rapeseed cake/meal, corn, and wheat flour | | | | | | | | | | | 5–10 |
| India | 2006/07 | 20–30 | 2–3 | - | 20–25 | 20–25 | | Other marine prote ins: squid, acetes | | | | 3–10 | 1–2 | Other: groundnut cake 15–20, mustard cake 15–20 | | | | | |
| Taiwan Province of China | 2007 | 20–65 | 5–7 | 4–5 | 15–20 | 10–15 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Milkfish** | | | | | | | | | | | | | | | | | | | |
| Taiwan Province of China | 2007 | 5–10 | 3–5 | 5–8 | 35–40 | 15–20 | | - | - | - | - | - | - | - | - | - | - | - | 15–20 |
| **Cachama** | | | | | | | | | | | | | | | | | | | |
| Venezuela (Bolivarian Republic of) | 2008 | 7–18 | - | 2 | 13 | 46 | 25 | - | 6 | Other ingredients listed: sorghum gain meal 20, broken rice/meal 7 | | | | | | | | | |
| **Freshwater crayfishes** | | | | | | | | | | | | | | | | | | | |
| Australia | 2008/09 | 5–10 | 0–5 | - | - | 20–40 | 2–10 | Other ingredients: lupin kerneal meal 5–30 | | | | | | - | - | - | - | 1–5 | 10–30 |
| Grey mullets | | | | | | | | | | | | | | | | | | | |
| Egypt | 2008 | 4–12 | - | - | 20–25 | - | 10–25 | 10–25 | Other ingredients: yellow corn 30–40 | | | | | | | | | | 5–10 |

*Note*: BM = blood meal; CGM = corn gluten meal; CPC = canola protein concentrate; CSM = cottonseed meal; FPM = field pea meal; FBM = faba bean meal; FM = fishmeal; FO = fish oil; G/PM = groundnut/peanut meal; HFM = hydrolysed feather meal; KM = krill meal; LKM = lupin kernel meal; MA = maize/corn; MBM = meat and bone meal; MC = mustard seed cake; MM = meat meal (hog/ovine); PBM = poultry by-product meal; PO = poultry oil; R/CM = rapeseed/canola meal; RB = rice bran; R/CO = rapeseed/canola oil; SL = soy lecithin; SO = soybean oil; SBM = soybean meal; SSM =sunflower seed meal; WH = wheat; WGM = wheat gluten meal; SM = squid meal; WF = wheat flour; WB = wheat bran; WM = wheat middlings.

[1]5–10 percent krill meal used in specialty diets, including starter feeds and broodstock feeds.

TABLE 11
**Estimated global use and demand for fishmeal and fish oil (thousand tonnes), 1995-2020**

| Year | Total feeds use[1] | Mean % FM[2] | Mean % FO[2] | Total FM use | Total FO use |
|---|---|---|---|---|---|
| **Fed carps** | | | | | |
| 1995 | 2 062 | 10 | 0 | 206 | 0 |
| 2000 | 5 556 | 9 | 0 | 500 | 0 |
| 2005 | 7 371 | 8 | 0 | 590 | 0 |
| 2007 | 8 303 | 3 | 0 | 249 | 0 |
| 2008 | 9 145 | 3 | 0 | 274 | 0 |
| 2010 | 10 503 | 2 | 0 | 210 | 0 |
| 2015 | 13 275 | 1 | 0 | 133 | 0 |
| 2020 | 15 801 | 1 | 0 | 158 | 0 |
| **Tilapias** | | | | | |
| 1995 | 985 | 10 | 0 | 99 | 0 |
| 2000 | 1 696 | 9 | 0 | 153 | 0 |
| 2005 | 2 852 | 8 | 0 | 228 | 0 |
| 2007 | 3 493 | 5 | 0 | 175 | 0 |
| 2008 | 3 948 | 5 | 0 | 197 | 0 |
| 2010 | 4 893 | 3 | 0 | 147 | 0 |
| 2015 | 7 852 | 2 | 0 | 157 | 0 |
| 2020 | 12 178 | 1 | 0 | 122 | 0 |
| **Catfishes** | | | | | |
| 1995 | 586 | 5 | 0 | 29 | 0 |
| 2000 | 772 | 8 | 0 | 62 | 0 |
| 2005 | 1 747 | 12 | 0 | 210 | 0 |
| 2007 | 2 448 | 8 | 0 | 196 | 0 |
| 2008 | 2 935 | 7 | 0 | 205 | 0 |
| 2010 | 4 240 | 5 | 0 | 212 | 0 |
| 2015 | 7 829 | 3 | 0 | 235 | 0 |
| 2020 | 12 488 | 2 | 0 | 250 | 0 |
| **Miscellaneous freshwater fishes** | | | | | |
| 1995 | 15 | 55 | 8 | 8 | 1 |
| 2000 | 56 | 50 | 6 | 28 | 3 |
| 2005 | 250 | 45 | 5 | 113 | 13 |
| 2007 | 360 | 36 | 5 | 130 | 18 |
| 2008 | 480 | 30 | 5 | 144 | 24 |
| 2010 | 718 | 24 | 4 | 172 | 29 |
| 2015 | 1 581 | 12 | 3 | 190 | 47 |
| 2020 | 3 055 | 8 | 2 | 244 | 61 |
| **Salmons** | | | | | |
| 1995 | 806 | 45 | 25 | 363 | 202 |
| 2000 | 1 327 | 40 | 23 | 531 | 305 |
| 2005 | 1 796 | 35 | 21 | 629 | 377 |
| 2007 | 2 029 | 28 | 16 | 568 | 325 |
| 2008 | 2 045 | 25 | 14 | 511 | 286 |
| 2010 | 2 255 | 22 | 12 | 496 | 271 |
| 2015 | 2 877 | 16 | 10 | 460 | 288 |
| 2020 | 3 672 | 12 | 8 | 441 | 294 |
| **Trouts** | | | | | |
| 1995 | 588 | 40 | 20 | 235 | 118 |
| 2000 | 666 | 36 | 17 | 240 | 113 |
| 2005 | 743 | 34 | 16 | 253 | 119 |
| 2007 | 903 | 28 | 15 | 253 | 135 |
| 2008 | 880 | 25 | 15 | 220 | 132 |

TABLE 11, continued
**Estimated global use and demand for fishmeal and fish oil (thousand tonnes), 1995-2020**

| Year | Total feeds use[1] | Mean % FM[2] | Mean % FO[2] | Total FM use | Total FO use |
|---|---|---|---|---|---|
| **Trouts, continued** | | | | | |
| 2010 | 970 | 22 | 12 | 213 | 116 |
| 2015 | 1 238 | 16 | 10 | 198 | 124 |
| 2020 | 1 581 | 12 | 8 | 190 | 126 |
| **Milkfish** | | | | | |
| 1995 | 220 | 15 | 3 | 33 | 7 |
| 2000 | 318 | 10 | 2 | 32 | 6 |
| 2005 | 464 | 5 | 1 | 23 | 5 |
| 2007 | 547 | 5 | 1 | 27 | 5 |
| 2008 | 568 | 5 | 1 | 28 | 6 |
| 2010 | 671 | 4 | 1 | 27 | 7 |
| 2015 | 856 | 3 | 1 | 26 | 9 |
| 2020 | 1 068 | 2 | 1 | 21 | 11 |
| **Eels** | | | | | |
| 1995 | 338 | 65 | 8 | 220 | 27 |
| 2000 | 351 | 62 | 6 | 218 | 21 |
| 2005 | 327 | 60 | 5 | 196 | 16 |
| 2007 | 416 | 50 | 5 | 208 | 21 |
| 2008 | 403 | 48 | 5 | 193 | 20 |
| 2010 | 397 | 46 | 4 | 183 | 16 |
| 2015 | 447 | 38 | 3 | 170 | 13 |
| 2020 | 504 | 30 | 2 | 151 | 10 |
| **Marine fishes** | | | | | |
| 1995 | 533 | 50 | 15 | 267 | 80 |
| 2000 | 1 139 | 44 | 10 | 501 | 114 |
| 2005 | 2 050 | 38 | 8 | 779 | 164 |
| 2007 | 2 533 | 32 | 8 | 811 | 203 |
| 2008 | 2 416 | 29 | 8 | 701 | 193 |
| 2010 | 2 964 | 26 | 6 | 771 | 178 |
| 2015 | 4 239 | 18 | 5 | 763 | 212 |
| 2020 | 6 643 | 12 | 4 | 797 | 266 |
| **Marine shrimps** | | | | | |
| 1995 | 1 387 | 28 | 2 | 388 | 28 |
| 2000 | 1 857 | 25 | 2 | 464 | 37 |
| 2005 | 4 268 | 24 | 2 | 1024 | 85 |
| 2007 | 4 821 | 20 | 2 | 964 | 96 |
| 2008 | 5 058 | 20 | 2 | 1012 | 101 |
| 2010 | 6 251 | 16 | 2 | 1000 | 125 |
| **Marine shrimps** | | | | | |
| 2015 | 8 793 | 12 | 1.5 | 1055 | 132 |
| 2020 | 11 322 | 8 | 1 | 906 | 113 |
| **Freshwater crustaceans** | | | | | |
| 1995 | 91 | 25 | 2 | 23 | 2 |
| 2000 | 412 | 23 | 2 | 95 | 8 |
| 2005 | 904 | 20 | 1.5 | 181 | 14 |
| 2007 | 1 320 | 20 | 1.5 | 264 | 20 |
| 2008 | 1 315 | 18 | 1.5 | 237 | 20 |
| 2010 | 1 510 | 16 | 1.5 | 242 | 23 |
| 2015 | 2 015 | 12 | 1 | 242 | 20 |
| 2020 | 2 657 | 8 | 1 | 213 | 27 |

TABLE 11, continued
**Estimated global use and demand for fishmeal and fish oil (thousand tonnes), 1995-2020**

| Year | Total fed production | Total feeds used | Total fishmeal used | Total fish oil used |
|---|---|---|---|---|
| **Summary totals for fed species and aquafeed production and fishmeal and fish oil use** | | | | |
| 1995 | 4 028 | 7 612 | 1 870 | 463 |
| 2000 | 7 684 | 14 150 | 2 823 | 608 |
| 2005 | 13 048 | 22 585 | 4 225 | 792 |
| 2007 | 16 126 | 26 950 | 3 844 | 823 |
| 2008 | 17 476 | 29 194 | 3 728 | 782 |
| 2010 | 21 201 | 35 371 | 3 670 | 764 |
| 2015 | 32 315 | 51 002 | 3 626 | 845 |
| 2020 | 46 917 | 70 969 | 3 490 | 908 |

[1, 2] Data taken from Table 3; mean % fishmeal and fish oil use for species/species groups has been adapted from Tacon and Metian (2008a).

- fishmeal (with restrictions – intraspecies recycling is prohibited, see Regulation (EC 999/2001);
- dicalcium phosphate and tricalcium phosphate of animal origin (with restrictions);
- non-ruminant blood meal and blood products (with restrictions);
- milk, milk-based products and colostrums (without restriction);
- eggs and egg products (without restriction);
- hydrolysed protein from ruminant hides/skin (without restriction);
- hydrolysed protein from non-ruminants (without restriction);
- gelatine from non-ruminants (without restriction);
- animal fats (without restriction); and
- collagen from non-ruminants (without restriction).

## 4.3 CONTINUED AND INCREASED USE OF PLANT PROTEIN MEALS AND OILS AS DIETARY NUTRIENT SOURCES

Plant proteins represent the major dietary protein source used within feeds for lower trophic level fish species (tilapias, carps, catfishes) and the second major source of dietary protein and lipid source after fishmeal and fish oil for shrimps and European high trophic level fish species (Table 10), for example:

- *tilapias* – soybean meal (20–60 percent), corn gluten meal (5–10 percent); rapeseed/canola meal (20–40 percent); cottonseed meal (1–25 percent); soybean oil (1–8 percent);
- *carps* – soybean meal (5–25 percent); rapeseed/canola meal (20–40 percent); groundnut/peanut meal (30 percent); mustard seed cake (10 percent),
- *marine shrimps* – soybean meal (5–40 percent); wheat gluten meal (2–10 percent); corn gluten meal (2–4 percent); rapeseed/canola meal (3–20 percent); lupin kernel meal (5–15 percent);
- *marine fishes* – soybean meal (10–25 percent); soybean oil (3–6 percent); wheat gluten meal (2–13 percent); corn gluten meal (4–18 percent); sunflower seed meal (5–8 percent); rapeseed/canola meal (7–20 percent); canola protein concentrate (10–15 percent);
- *trouts* – soybean meal (3–35 percent); wheat gluten meal (2–10 percent); sunflower seed meal (5–9 percent); corn gluten meal (3–40 percent); rapeseed/canola meal (2–10 percent); lupin kernel meal (5–15 percent); faba bean meal (8 percent); field pea meal (3–10 percent); rapeseed/canola oil (5–15 percent); soybean oil (5–10 percent);
- *salmons* – soybean meal (3–12 percent); wheat gluten meal (2–10 percent); sunflower seed meal (5–9 percent); corn gluten meal (10–40 percent); rapeseed/

canola meal (3–10 percent); lupin kernel meal (5–15 percent); faba bean meal (5 percent); field pea meal (3 percent); rapeseed/canola oil (5–15 percent); soybean oil (5–10 percent);
- *milkfish* – soybean meal (35–40 percent);
- *grey mullets* – soybean meal (20–25 percent);
- *freshwater prawns* – soybean meal (15–25 percent);
- *cachama* – soybean meal (13 percent); corn gluten meal (6 percent);
- *freshwater crayfishes* – wheat gluten meal (2–10 percent); lupin kernel meal (5–30 percent); and
- *eels* – soybean meal (8–10 percent).

Soybean meal is the most common source of plant protein used in compound aquafeeds and the most prominent protein ingredient substitute for fishmeal in aquaculture feeds (Manomaitis, 2009), with feeds for herbivorous and omnivorous fish species and crustaceans usually containing (depending upon species, country, price and availability) from 15 to 45 percent soybean meal, with a mean of 25 percent in 2008 (Table 10). In global usage terms, and based on a total compound aquafeed production of 29.3 million tonnes in 2008 (Table 3), it is estimated that the aquaculture feed sector is consuming about 6.8 million tonnes of soybean meal; China alone is currently consuming an estimated 6.0 million tonnes of soybean meal within compound aquafeeds (Mike Cremer, American Soybean Association, personal communication, December 2009).

At present, plant protein/oil choice and selection are based upon a combination of local market availability and cost (Figure 40), and the nutritional profile (including antinutrient content and level) of the protein meal and/or plant oil in question (Davis and Sookying, 2009; Gatlin *et al.*, 2007; Krogdahl *et al.*, 2010). With the continued rise in the price of fishmeal, plant protein concentrates will gain more and more prominence over regular plant protein meals within aquafeeds for high trophic level cultured species and crustaceans (includes soybean protein concentrate, canola protein concentrate, pea protein concentrate and corn/wheat gluten meals; for review see Tacon, Metian and Hasan, 2009). For example, according to Manomaitis (2009), the forecast demand for soybean protein concentrates within aquafeeds is over 2.8 million tonnes by 2020.

## 4.4 INGREDIENT COMPETITION WITH OTHER USERS

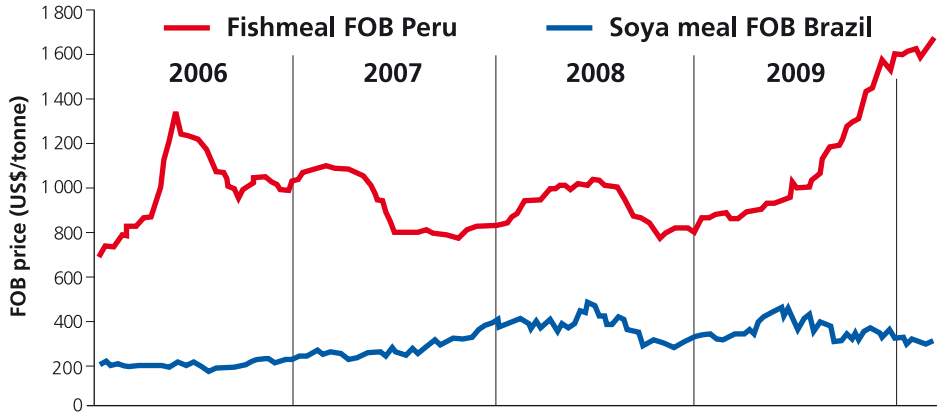
Aquaculture, like any other animal production system, has to compete with other users for nutrient inputs, including specific feed ingredients and fresh food items.

### 4.4.1 Competition with livestock

Livestock are an integral part of the agricultural food production process within all of the countries where aquaculture is practised. They are also a major consumer of feed ingredients and feeds: total global livestock and animal feed production is estimated at 708 million tonnes in 2009 (poultry 41.5 percent; pig 30.0 percent; ruminant 25 percent) (Peter Best, personal communication, March 2010); total global feed production increased by 20 percent since 1995, growing at an average annual compound rate of 1.3 percent (Best, 2010b).

Although contribution of aquafeed to global animal feed production is currently less than 4 percent by volume, aquaculture has emerged as a major competitor and consumer for several key ingredient sources, including fishmeal and fish oil. It is estimated that the aquaculture sector consumed over 4.5 million tonnes of fishmeal and fish oil in 2008, or about 70.3 percent of the total global production of these commodities (Table 11; Figure 38). Despite this, in China (the world's largest producer of pigs and aquaculture products), the largest consumer of fishmeal remains the livestock and poultry sector (52 percent of total Chinese fishmeal demand in 2008); the

FIGURE 40
**Variation in price (US$/tonne) of FAQ fishmeal and soybean meal, January 2006 to March 2010**




*Note*: FOB = free on board.
*Source*: J. F. Mittaine (International Fishmeal and Fish Oil Organization, personal communication, 2009).

estimated demand for fishmeal within pig starter/piglet diets alone is 612 000 tonnes (Wang, 2009). For example, according to the same author, animal feed production in China during the first half of 2009 was reported as follows: total national feed production 64.63 million tonnes (down by 5.4 percent from the previous year); pig feed 23.3 million tonnes (up 1.8 percent); poultry feed (meat) 18.5 million tonnes (down 12 percent); poultry feed (egg) 11.123 million tonnes (down 15.8 percent); aquatic feed 7.85 million tonnes (up 17.3 percent); ruminant feed 2.15 million tonnes (down 24.6 percent); and others 1.6 million tonnes (up 5.7 percent; Wang, 2009). According to Shepherd (2009), the major consumers of fishmeal in 2008 were aquaculture 58.8 percent, pig 30.9 percent, poultry 9.1 percent; and of fish oil (2010 estimate), aquaculture 80 percent, refined edible 12 percent, and industrial 7 percent. Aquaculture currently uses 760 000 tonnes of fishmeal, equivalent to 76 percent of Europe's fishmeal consumption (Thomsen, 2009).

### 4.4.2 Competition with pet food

The pet food industry represents a relatively new and rapidly growing non-food animal sector, with dog and cat feed sales totalling US$49 billion in 2008 (Gianni Carniglia, personal communication, December 2009). Despite this, the dog and cat feed sector is one of the largest consumer of terrestrial animal protein meals and fats, including poultry by-product meal and meat and bone meal; the pet-food industry representing 45 percent of the processed animal protein outlets in the EU (Nielsen, 2009) and 9 percent of rendered meal usage in Australia (Palmer, 2009). Moreover, compared with the other conventional animal feed sectors (including the aquaculture sector), the high-value and lucrative pet food sector is willing to pay top price for "pet food grade" low-ash poultry by-product meals, which results in many of these products being out of the economic grasp of other users, including aquatic feed producers (for review, see Aldrich, 2006). A similar situation exists for the competition for fresh fish and aquaculture by-product meals for use within tinned cat foods and dog foods (De Silva and Turchini, 2008).

### 4.4.3 Competition with biofuels

Increasing petroleum costs and concern for the climate and the need to reduce greenhouse gas emissions have placed renewed efforts to identify alternative renewable sources of energy, including the use of conventional food grains and oilseeds, plant

and animal oils and by-products, and/or low-value cellulosic wastes as substrates for the production of biofuels, including ethanol and biodiesel. Notwithstanding the ecological, environmental, economic and/or ethical merits or not of biofuel production, it is suffice to say that many countries/governments have now adopted biofuel production as a national priority, with the sector in some countries enjoying a variety of government subsidies and incentives (for review, see FAO, 2008a).

On the negative side of the biofuel production is the diversion of potential existing food grains and crops (including the land and other resources used to produce them) from direct human consumption to more profitable (owing to government subsidies and incentives) biofuel production for use as a "greener" petroleum substitute; the latter leading to less grains and crops being available for direct human consumption and increased demand for these commodities and consequent increased food prices.

For example, Figure 41 shows the rapid growth and development of biodiesel production (based on the use of vegetable oil and animal fat as organic carbon inputs and typically made by chemically reacting these lipids with an alcohol) by the world's two top producers – the EU and the United States of America – with a total combined production of 8 million tonnes out of a world total of about 13 million tonnes (Swisher, 2009b). The majority of feedstock used is soybean oil, rapeseed oil and palm oil, but the use of animal fats and greases from the rendering industry is gaining ground, accounting for over 20 percent of the total raw materials used for biodiesel production in the United States of America in 2008. Rendered fats and oils also accounted for approximately 15 percent in Brazil, 67 percent in Paraguay, 60 percent in Uruguay, and for the majority of raw material used in Canada (Swisher, 2009b).

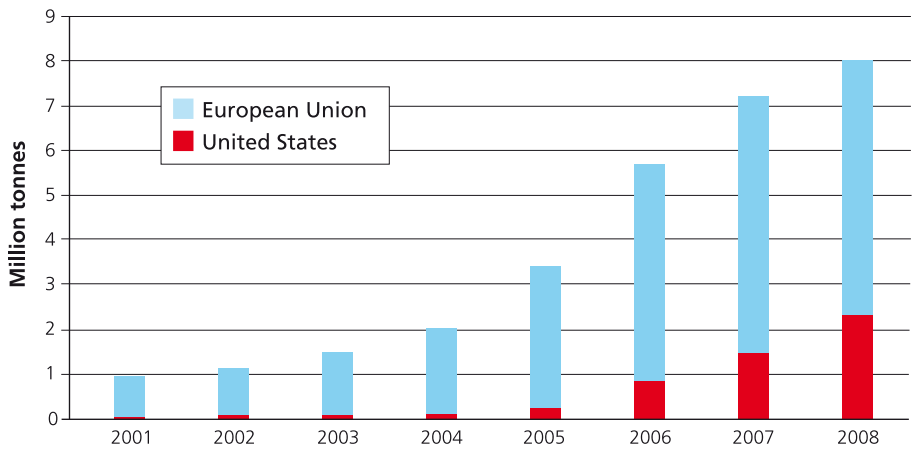
In the case of the other major biofuels, ethanol or bioethanol, they are usually produced through the microbial fermentation of sugars or starches present in food crops such as corn, wheat, sugar beets, sugar cane and molasses. Table 12 shows the total global production of biofuels according to FAO (2008a). Figure 42 shows the proportion of the United States of America corn crop destined for biofuel production.

On the positive side, as mentioned previously, a variety of new feed by-product meals will be produced and be available from ethanol biorefineries, including distillers grains, corn gluten feed and corn gluten meal (Figures 21 and 42).

### 4.4.4 Competition with humans

Last but not least, there is the direct competition between aquaculture and humans for fish, either in the form of fresh/frozen fish used as a direct feed source (estimated usage

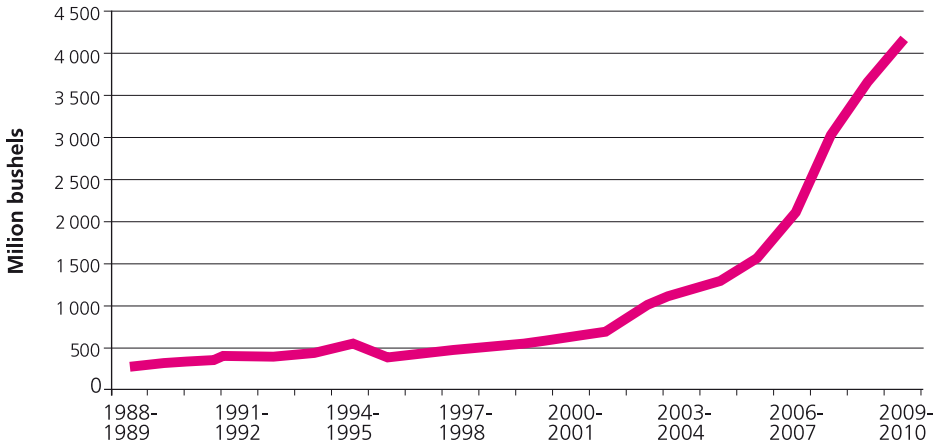
FIGURE 41
**United States and European Union production of biodiesel, 2001–2008**




*Source*: Swisher (2009b).

by aquaculture in China being between 6 and 8 million tonnes in 2008), or indirectly in the form of fishmeal and fish oil produced from whole fish suitable for direct human consumption (for review, see FAO, 2008b; FAO, 2011a; Funge-Smith, Lindebo and Staples, 2005; Hasan and Halwart, 2009; Tacon and Metian, 2008a, 2009a, 2009b).

FIGURE 42
**United States corn destined for ethanol production, 1988/89 to 2009/10**




*Note*: 1 bushel = 25.4 kg.
*Source*: USDA (2010b).

TABLE 12
**Biofuel production by country, 2007**

| Country/country grouping | Ethanol | | Biodiesel | | Total | |
|---|---|---|---|---|---|---|
| | Million litres | Mtoe* | Million litres | Mtoe* | Million litres | Mtoe* |
| Brazil | 19 000 | 10.44 | 227 | 0.17 | 19 227 | 10.60 |
| Canada | 1 000 | 0.55 | 97 | 0.07 | 1 097 | 0.62 |
| China | 1 840 | 1.01 | 114 | 0.08 | 1 954 | 1.09 |
| India | 400 | 0.22 | 45 | 0.03 | 445 | 0.25 |
| Indonesia | 0 | 0.00 | 409 | 0.30 | 409 | 0.30 |
| Malaysia | 0 | 0.00 | 330 | 0.24 | 330 | 0.24 |
| European Union | 2 253 | 1.24 | 6 109 | 4.52 | 8 362 | 5.76 |
| Others | 1 017 | 0.56 | 1 186 | 0.88 | 2 203 | 1.44 |
| World | 52 009 | 28.57 | 10 204 | 7.56 | 62 213 | 36.12 |

* Mtoe = million tonnes of oil equivalent.
*Source*: FAO (2008a).

## 4.5 GROWING IMPORTANCE OF FEED AND FOOD SAFETY

Reported food safety risks associated with the use of aquaculture feeds may result from the possible presence of contaminants, either within the feed ingredients used or from the external contamination of the finished feed on prolonged storage. For example, major animal feed contaminants reported to date have included salmonellae, mycotoxins, veterinary drug residues, persistent organic pollutants, agricultural and other chemicals (solvent residues, melamine), heavy metals (mercury, lead, cadmium) and excess mineral salts (arsenic, hexavalent chromium, selenium, fluorine), and possible transmissible spongiform encephalopathies. Apart from the direct negative effect of these possible contaminants on the health of the cultured target species, there is also a risk that some of these feed contaminants may be passed along the food chain via contaminated aquaculture produce to consumers.

Public concern regarding food safety has increased as a consequence of the increasing prevalence of antibiotic residues, persistent organic pollutants and chemicals in farmed seafood (for review, see Berntssen and Lundebye, 2008; Karunasagar, 2009; Lie, 2008; Lightner *et al.*, 2009; Tacon and Metian, 2008b).

*Harvest of striped catfish* (Pangasianodon hypophthalmus), *Mekong Delta, Viet Nam. Striped catfish are fed both farm-made and commercial aquafeeds in Viet Nam.*

*Courtesy of FAO/Nguyen Thanh Phuong*

# 5. Recommended approaches to feed ingredient selection and use

## 5.1 REDUCE COUNTRY DEPENDENCE UPON IMPORTED FEED INGREDIENT SOURCES

On the basis of the results obtained from the feed ingredient survey conducted for this report, it is clear that many aquaculture producing countries are highly dependent upon imports for sourcing the feed ingredients used in their aquaculture feeds. The results of this survey should be treated with caution as they are based on the best guesses of individual country respondents rather than official government statistics (and comparative advantage could very well favour importation over domestic production). All in all they do indicate some significant findings, as follows:

- Countries that reportedly import less than 25 percent of their feed ingredients used in compound aquafeeds: Argentina (0–10 percent), Brazil (0–10 percent), the United States of America (5–10 percent).
- Countries that reportedly import 25–50 percent of their feed ingredients used in compound aquafeeds: Australia (25–35 percent), Canada (40 percent), Denmark (30 percent), India (0–44 percent), Mexico (20–45 percent). In the case of India, feed ingredient imports can vary from 0 percent for freshwater Indian major carp feeds using locally available feed ingredient sources to as high as 44 percent for shrimp feeds.
- Countries and territories that reportedly import 50–75 percent of their feed ingredients used in compound aquafeeds: Chile (30–80 percent), China (>50 percent), Ecuador (60–70 percent), Egypt (54–75 percent), France (50–78 percent), Italy (70–75 percent), Turkey (70 percent), the United Kingdom of Great Britain and Northern Ireland (60–90 percent), Viet Nam (30–70 percent).
- Countries and areas that reportedly import 75–100 percent of their feed ingredients used in compound aquafeeds: Greece (90 percent), Republic of Korea (90–100 percent), Norway (80–90 percent), Peru (70–90 percent), Taiwan Province of China (50–100 percent), Tahiti (100 percent), the United Kingdom of Great Britain and Northern Ireland (60–90 percent).
- According to a recent statistic concerning the animal feed manufacturing sector in Mexico (CONAFAB, 2008), Mexico was ranked fourth in the world in terms of total animal feed production (26.2 million tonnes in 2008 – with aquaculture representing less than 1 percent of total feed production, or 230 000 tonnes), with the country importing over 55 percent of all the ingredients used within the animal feed sector, including over 90 percent of all plant oilseeds.
- Although no information was forthcoming from several other major aquaculture producers in Asia (including Bangladesh, Indonesia, Japan, the Philippines and Thailand), published information suggests that in the Philippines 40–60 percent and 85–95 percent of the feed ingredients used for fish feeds and shrimp feeds are imported, respectively (Sevilla, 2007). A similar situation to the Philippines is expected to exist in Indonesia, Malaysia and Thailand (see SES, 2009a, 2009b, 2009c).
- The current dependence of aquaculture producing countries upon the importation of major protein ingredient sources and lipids (i.e. fishmeal, soybean meal, fish oil)

is strongest within those countries where production is focused on exports and/or the production of high trophic level fish and shrimp (SES, 2009a).
- In general, the demand for imported feed ingredient sources is highest within those developing countries with a strong commercial animal feed manufacturing sector and dominated by larger integrated farms and larger independent farms (SES, 2009c).
- In-country feed ingredient availability and usage within most developing countries is usually biased toward energy-rich rather than protein-rich ingredient sources, with greatest usage of local non-imported ingredients being within compound feeds intended for the production of freshwater and brackishwater fish feeds targeted for domestic consumption (SES, 2009a, 2009b) and within farm-made aquafeeds produced by smallholder farmers (SES, 2009c).
- The active promotion by many governments to reduce the current dependency of their national animal feed manufacturing industries upon imported feed ingredient sources by developing more competitive protein and energy sources from locally available agricultural products, including cassava, rice, oil palm and copra (SES, 2009a, 2009b, 2009c, 2009d).

## 5.2 SELECT FEED INGREDIENTS THAT CAN BE SUSTAINABLY PRODUCED AND GROW WITH THE SECTOR

As mentioned at the outset, for finfish and crustacean fed aquaculture production to maintain its current average annual growth rate of 8 to 10 percent to 2025, the external supply of nutrients and, therefore, feed ingredient sources will have to keep pace. Included within these ingredient sources are:

- fishery by-products and aquaculture by-product meals and oils;
- invertebrate fishery by-product meals and oils;
- terrestrial animal by-product meals and fats;
- cereals, including by-product meals and oils;
- oilseed meals and oils;
- pulses and protein concentrate meals; and
- microbial ingredient sources.

Ingredient choice should be based, therefore, not only on nutrient level, digestibility, and cost, but also upon other criteria such as sustainability and environmental impact of production, and fish-in fish-out ratio (Jackson, 2010; Kaushik and Troell, 2010; Naylor *et al.*, 2009).

The limited supply of fishmeal and fish oil from wild fisheries and the continued strong demand for these products have led to concerns about the long-term sustainability of the fisheries and the level of responsible management of the fisheries. It is, therefore, important that care is taken to ensure that any fishmeal and fish oil made from wild fish comes from fisheries that have been managed according to the FAO Code of Conduct for Responsible Fisheries (FAO, 1995), and that countries follow the guidelines on the use of wild fish as feed in aquaculture (FAO, 2011a) that have been developed in support of Article 7 (Responsible fisheries management) and Article 9 (Aquaculture development) of the FAO *Code of Conduct for Responsible Fisheries*.

## 5.3 MINIMIZE ENVIRONMENTAL AND ECOSYSTEM IMPACT OF FEEDS AND FEEDING REGIMES

As mentioned earlier, one of major criteria for ingredient selection is nutrient density and nutrient digestibility. It follows, therefore, that the higher the nutrient digestibility of a particular ingredient (or complete feed containing the ingredient), the higher its nutrient utilization efficiency and resultant growth of the target species. Moreover, by using highly digestible feed ingredient sources and feeds, nutrient loss and feed wastage are kept to a minimum, thereby minimizing possible negative environmental and ecosystem impacts.

In addition to the direct selection of highly digestible feed ingredient sources, nutrient loss and nutrient impacts from feeds can also be negated by integrating production with other cultured species that can benefit from these nutrient waste streams (Duarte *et al.,* 2009; Soto, 2009) or by culturing the species under closed biofloc-based zero-water exchange culture conditions (Avnimelech, 2009).

Of particular note is the ability of biofloc-based zero-exchange production systems to essentially change the nutrition of the target species (usually either marine shrimps or tilapias) from a purely monogastric animal dependent upon the external supply of a nutritionally complete diet to an animal cultured within a nutrient-rich microbial soup capable of supplying nutrients to the cultured species (both shrimps and tilapias are able to filter out these microbial flocs) in addition to the diet being fed, with consequent cost-feed savings and ability to better utilize ingredient sources with inherent nutrient deficiencies or imbalances (Tacon *et al.,* 2002; Tacon, Nates and McNeil, 2006).

## 5.4 GIVE SPECIAL ATTENTION TO SMALL-SCALE FARMERS USING FARM-MADE/SEMI-COMMERCIAL AQUAFEEDS

Small-scale farmers still form the backbone of Asian aquaculture; they produce much of the cultured freshwater fish species for domestic consumption. One hallmark of this sector is the use of farm-made/semi-commercial aquafeeds. However, apart from the general absence of statistical information on the size and extent of this sector, little or no guidance and attention is given to better help small-scale farmers formulate and manage their feeds. To a large extent this has been due to the thrust by government agencies and feed manufacturers to move the sector away from the use of farm-made feeds to the purchase of commercially manufactured aquafeeds.

Merits and demerits aside of using farm-made aquafeeds (New, Tacon and Csavas, 1995; Hasan *et al.,* 2007), there is an urgent need to assist and train the resource-poor farmers using farm-made aquafeeds not only for improving feed formulation and minimizing the use of unnecessary feed additives and chemicals (including antibiotics), but also for improving feed management techniques (FAO, 2010d). The economic benefit is better returns from higher efficiency. The environmental benefit is less pollution from reduced wastage. There is also need for support services to build the capacity of small-scale aquafeed producers to improve their production processes as many small-scale farmers purchase feed from them.

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# ANNEX 1 – Global production of finfish and crustaceans

TABLE A1.1
**Total global production of the major cultivated finfish and crustacean species commonly fed on fresh food items, farm-made and/or commercially compounded aquafeeds**

| Major fed species | Production (tonnes) | Percent | Total value (US$) | Value (US$/kg) |
|---|---|---|---|---|
| **FRESHWATER FISHES** | | | | |
| **Fed carps** (Family *Cyprinidae*) | **14 426 803** | | **15 299 746** | **1.06** |
| **Chinese carps**[1] | **9 679 992** | **67.1** | **9 542 684** | **0.99** |
| Grass carp (*Ctenopharyngodon idellus*) | 3 775 267 | 26.2 | 4 797 279 | 1.27 |
| Common carp (*Cyprinus carpio*) | 2 987 433 | 20.7 | 3 696 415 | 1.24 |
| Crucian carp (*Carassius carassius*) | 1 957 337 | 13.6 | 2 135 857 | 1.09 |
| Wuchang bream (*Megalobrama amblycephala*) | 599 623 | 4.2 | 989 378 | 1.65 |
| Black carp (*Mylopharyngodon piceus*) | 360 332 | 2.5 | 835 610 | 2.32 |
| **Indian major carps** | **3 904 812** | **27.1** | **5 177 898** | **1.33** |
| Catla (*Catla catla*) | 2 281 838 | 15.8 | 3 303 124 | 1.45 |
| Rohu (*Labeo rohita*) | 1 159 454 | 8.0 | 1 334 193 | 1.15 |
| Mrigal (*Cirrhinus mrigala*) | 463 520 | 3.2 | 540 581 | 1.17 |
| **Other cyprinids** | **841 999** | **5.8** | **579 164** | **0.69** |
| Cyprinids nei[2] | 540 133 | 3.7 | 928 371 | 1.72 |
| Silver barb (*Barbonymus gonionotus*) | 106 457 | 0.7 | 99 033 | 0.93 |
| Others[3] | 195 409 | 1.4 | 273 458 | 1.40 |
| **Tilapias** (Family *Cichlidae*) | **2 797 819** | | **4 021 164** | **1.44** |
| Nile tilapia (*Oreochromis niloticus*) | 2 334 432 | 83.4 | 3 208 561 | 1.37 |
| Tilapias nei (*Oreochromis* spp.) | 419 982 | 15.0 | 766 946 | 1.83 |
| Java tilapia (*Oreochromis mossambicus*) | 38 140 | 1.4 | 32 476 | 0.85 |
| Blue tilapia (*Oreochromis aureus*) | 2 687 | 0.1 | 5 798 | 2.16 |
| Three spotted tilapia (*Oreochromis andersonii*) | 1 996 | 0.1 | 5 749 | 2.88 |
| Longfin tilapia (*Oreochromis macrochir*) | 187 | < 0.1 | 538.6 | 2.88 |
| Redbreast tilapia (*Tilapia rendalli*) | 160 | < 0.1 | 352 | 2.20 |
| Redbelly tilapia (*Tilapia zillii*) | 130 | < 0.1 | 325 | 2.50 |
| Sabaki tilapia (*Oreochromis spilurus*) | 105 | < 0.1 | 420 | 4.00 |

TABLE A1.1, continued

**Total global production of the major cultivated finfish and crustacean species commonly fed on fresh food items, farm-made and/or commercially compounded aquafeeds**

| Major fed species | Production (tonnes) | Percent | Total value (US$) | Value (US$/kg) |
|---|---|---|---|---|
| **Catfishes** (Order *Siluriformes*) | **2 780 897** | | **3 920 365** | **1.41** |
| **Family Pangasiidae** | **1 411 732** | **50.8** | **2 024 527** | **1.43** |
| Pangasiid catfishes nei (*Pangasius* spp.) | 1 380 702 | 49.6 | 1 994 685 | 1.44 |
| Striped catfish (*Pangasianodon hypophthalmus*) | 23 186 | 0.8 | 15 446 | 0.67 |
| Pangas catfish (*Pangasius pangasius*) | 7 844 | 0.3 | 14 396 | 1.84 |
| **Family Ictaluridae** | **463 638** | **16.7** | **692 552** | **1.49** |
| Channel catfish (*Ictalurus punctatus*) | 462 416 | 16.6 | 688 800 | 1.49 |
| Catfishes nei (*Ictalurus* spp.) | 1 022 | < 0.1 | 2 280 | 2.23 |
| Black bullhead (*Ameiurus melas*) | 200 | < 0.1 | 1 472 | 7.36 |
| **Family Claridae** | **407 075** | **14.6** | **539 017** | **1.32** |
| Torpedo-shaped catfishes nei (*Clarias* spp.) | 237 634 | 8.5 | 304 564 | 1.28 |
| Catfish, hybrid (*C. gariepinus x C. macrocephalus*) | 135 507 | 4.9 | 133 794 | 0.99 |
| North African catfish (*Clarias gariepinus*) | 33 924 | 1.2 | 100 593 | 2.97 |
| Asian catfish (*Clarias batrachus*) | 10 | < 0.1 | 66 | 6.60 |
| **Family Siluridae** | **322 551** | **11.6** | **430 378** | **1.33** |
| Amur catfish (*Silurus asotus*) | 321 071 | 11.5 | 422 931 | 1.32 |
| Wels catfish (*Silurus glanis*) | 1 480 | 0.1 | 7 448 | 5.03 |
| **Family Bagridae** | **152 728** | **5.5** | **199 564** | **1.31** |
| Yellow catfish (*Pelteobagrus fulvidraco*) | 134 448 | 4.8 | 174 782 | 1.30 |
| Chinese longsnout catfish (*Leiocassis longirostris*) | 15 347 | 0.6 | 19 951 | 1.30 |
| Asian redtail catfish (*Mystus nemurus*) | 2 513 | 0.1 | 4 132 | 1.64 |
| Bayad (*Bagrus bajad*) | 400 | < 0.1 | 608 | 1.52 |
| Bagrid catfish (*Chrysichthys nigrodigitatus*) | 20 | < 0.1 | 89.7 | 4.49 |
| **Others** | | | | |
| Freshwater siluroids nei (*Siluroidei*) | 19 700 | 0.7 | 26 410 | 1.34 |
| **Family Mochokidae** | | | | |
| Upsidedown catfishes (*Synodontis* spp.) | 2 772 | 0.1 | 6 376 | 2.30 |
| **Family Pimelodidae** | | | | |
| South American catfish (*Rhamdia sapo*) | 701 | < 0.1 | 1 542 | 2.20 |

TABLE A1.1, continued

**Total global production of the major cultivated finfish and crustacean species commonly fed on fresh food items, farm-made and/or commercially compounded aquafeeds**

| Major fed species | Production (tonnes) | Percent | Total value (US$) | Value (US$/kg) |
|---|---|---|---|---|
| **Miscellaneous freshwater fishes** | **1 334 135** | | **4 120 134** | **3.09** |
| **Family Channidae** | **376 480** | **28.2** | **475 844** | **1.26** |
| Snakehead (*Channa argus*) | 324 318 | 24.3 | 396 585 | 1.22 |
| Snakeheads nei (*Channa* spp.) | 22 300 | 1.7 | 31 860 | 1.43 |
| Indonesian snakehead (*Channa micropeltes*) | 15 831 | 1.2 | 18 153 | 1.15 |
| Striped snakehead (*Channa striata*) | 14 031 | 1.1 | 29 247 | 2.08 |
| **Family Percichthyidae** | **229 339** | **17.2** | **2 135 370** | **9.31** |
| Mandarin fish (*Siniperca chuatsi*) | 229 269 | 17.2 | 2 134 494 | 9.31 |
| Murray cod (*Maccullochella peelii*) | 70 | < 0.1 | 875.3 | 12.50 |
| **Family Synbranchidae** | | | | |
| Asian swamp eel (*Monopterus albus*) | 212 209 | 15.9 | 553 795 | 2.61 |
| **Family Characidae** | **170 381** | **12.8** | **316 319** | **1.86** |
| Pirapatinga (*Piaractus brachypomus*) | 91 951 | 6.9 | 134 166 | 1.46 |
| Cachama (*Colossoma macropomum*) | 44 219 | 3.3 | 101 728 | 2.30 |
| Characins nei (*Characidae*) | 18 186 | 1.4 | 39 645 | 2.18 |
| Pacu (*Piaractus mesopotamicus*) | 13 125 | 1.0 | 34 110 | 2.60 |
| *Brycon cephalus* | 2 900 | 0.2 | 6 670 | 2.30 |
| **Gouramis** | **82 844** | **6.2** | **127 818** | **1.54** |
| Snakeskin gourami (*Trichogaster pectoralis*) | 40 756 | 3.1 | 56 443 | 1.38 |
| Giant gourami (*Osphronemus goramy*) | 37 983 | 2.8 | 67 932 | 1.79 |
| Kissing gourami (*Helostoma temminckii*) | 3 955 | 0.3 | 3 362 | 0.85 |
| Gouramis nei (*Trichogaster* spp.) | 150 | < 0.1 | 81.2 | 0.54 |
| **Family Moronidae** | | | | |
| Striped bass, hybrid (*Morone chrysops x M. saxatilis*) | 5 725 | 0.4 | 32 154 | 5.62 |
| Striped bass (*Morone saxatilis*) | 5 | < 0.1 | 18.5 | 3.70 |
| **Family Centropomidae** | | | | |
| Nile perch (*Lates niloticus*) | 8 584 | 0.6 | 20 660 | 2.41 |
| **Others**[4] | **248 573** | **18.6** | **458 175** | **1.84** |

TABLE A1.1, continued

**Total global production of the major cultivated finfish and crustacean species commonly fed on fresh food items, farm-made and/or commercially compounded aquafeeds**

| Major fed species | Production (tonnes) | Percent | Total value (US$) | Value (US$/kg) |
|---|---|---|---|---|
| **DIADROMOUS FISHES** | | | | |
| **Salmons** (Family *Salmonidae*) | **1 570 990** | | **7 698 989** | **4.90** |
| Atlantic salmon (*Salmo salar*) | 1 456 721 | 91.9 | 7 204 152 | 4.95 |
| Coho salmon (*Oncorhynchus kisutch*) | 105 117 | 7.4 | 437 023 | 4.16 |
| Chinook salmon (*Oncorhynchus tshawytscha*) | 9 152 | 0.7 | 57 814 | 6.32 |
| **Trouts** (Family *Salmonidae*) | **676 730** | | **2 806 270** | **4.15** |
| Rainbow trout (*Oncorhynchus mykiss*) | 576 289 | 85.2 | 2 389 669 | 4.15 |
| Trouts nei (*Salmo* spp.) | 80 265 | 11.9 | 275 984 | 3.44 |
| Sea trout (*Salmo trutta*) | 19 432 | 2.9 | 135 601 | 6.98 |
| Brook trout (*Salvelinus fontinalis*) | 719 | 0.1 | 4 867 | 6.77 |
| Golden trout (*Oncorhynchus aguabonita*) | 25 | < 0.1 | 150 | 6.00 |
| **Eels** (Family *Anguillidae*) | **265 338** | | **1 230 852** | **4.64** |
| Japanese eel (*Anguilla japonica*) | 253 795 | 95.6 | 1 137 766 | 4.48 |
| European eel (*Anguilla anguilla*) | 7 264 | 2.7 | 100 055 | 13.77 |
| River eels nei (*Anguilla* spp.) | 4 279 | 1.6 | 4217.4 | 0.99 |
| **Milkfish** *(*Family *Chanidae)* | | | | |
| Milkfish *(Chanos chanos)* | 676 228 | 100 | 951 472 | 1.41 |
| **Miscellaneous diadromous fishes** | **70 642** | | **262 245** | **3.71** |
| **Family Centropomidae** | | | | |
| Barramundi (*Giant seaperch*; *Lates calcarifer*) | **44 959** | **63.6** | **156 906** | **3.49** |
| **Family Acipenseriformes** | **25 683** | **36.4** | **105 339** | **4.10** |
| Sturgeons nei (*Acipenseridae* | 25 123 | 35.6 | 97 279 | 3.87 |
| Adriatic sturgeon (*Acipenser naccarii*) | 220 | 0.3 | 3 885 | 17.66 |
| Siberian sturgeon (*Acipenser baerii*) | 169 | 0.2 | 2 379 | 14.08 |
| Danube sturgeon (*Acipenser gueldenstaedtii*) | 110 | 0.2 | 967 | 8.79 |
| Sterlet sturgeon (*Acipenser ruthenus*) | 31 | < 0.1 | 465.4 | 15.01 |
| Sturgeon (*Acipenser sturio*) | 30 | < 0.1 | 363.6 | 12.12 |

TABLE A1.1, continued

**Total global production of the major cultivated finfish and crustacean species commonly fed on fresh food items, farm-made and/or commercially compounded aquafeeds**

| Major fed species | Production (tonnes) | Percent | Total value (US$) | Value (US$/kg) |
|---|---|---|---|---|
| **MARINE FISHES** | | | | |
| **Seabass** | **213 762** | | **909 744** | **4.26** |
| Japanese seabass (*Lateolabrax japonicus*) | 97 754 | 45.7 | 132 007 | 1.35 |
| European seabass (*Dicentrarchus labrax*) | 66 738 | 31.2 | 496 898 | 7.45 |
| Seabasses nei (*Dicentrarchus* spp.) | 49 270 | 23.0 | 280 839 | 5.70 |
| **Mullets** (Family *Mugilidae*) | **234 686** | | **667 651** | **2.84** |
| Flathead grey mullet (*Mugil cephalus*) | 220 932 | 94.1 | 647 709 | 2.93 |
| Mullets nei (*Mugilidae*) | 13 420 | 5.7 | 19 081 | 1.42 |
| So-iuy mullet (*Mugil soiuy*) | 329 | 0.1 | 855.4 | 2.60 |
| Squaretail mullet (*Liza vaigiensis*) | 5 | < 0.1 | 5.3 | 1.06 |
| **Porgies, seabreams** (Family *Sparidae*) | **253 273** | | **1 285 642** | **5.08** |
| Gilthead seabream (*Sparus aurata*) | 133 026 | 47.7 | 718 866 | 5.40 |
| Silver seabream (*Pagrus auratus*) | 78 515 | 28.3 | 479 058 | 6.10 |
| Porgies, seabreams nei (*Sparidae*) | 39 143 | 22.4 | 65 705 | 1.68 |
| Blackhead seabream (*Acanthopagrus schlegeli*) | 2 003 | 1.3 | 17 022 | 8.50 |
| Others[5] | 586 | 0.3 | 4 991 | 8.52 |
| **Jacks, crevalles** (Family *Carangidae*) | **184 051** | | **1 398 890** | **7.60** |
| Japanese amberjack (*Seriola quinqueradiata*) | 158 508 | 86.1 | 1 346 684 | 8.50 |
| Amberjacks nei (*Seriola* spp.) | 20 792 | 11.3 | 30 916 | 1.49 |
| White trevally (*Pseudocaranx dentex*) | 2 700 | 1.5 | 6 750 | 2.50 |
| Japanese jack mackerel (*Trachurus japonicus*) | 1 762 | 1.0 | 13 702 | 7.78 |
| Jacks, crevalles nei (*Caranx* spp.) | 273 | 0.1 | 725 | 2.65 |
| Snubnose pompano (*Trachinotus blochii*) | 13 | < 0.1 | 87.6 | 6.74 |
| Greater amberjack (*Seriola dumerili*) | 2 | < 0.1 | 19 | 9.50 |
| Golden trevally (*Gnathanodon speciosus*) | 1 | < 0.1 | 5.7 | 5.70 |
| **Flounders, halibuts, soles** | **148 526** | | **647 736** | **4.36** |
| Lefteye flounders nei (*Bothidae*) | 78 141 | 52.6 | 92 988 | 1.19 |
| Bastard halibut (*Paralichthys olivaceus*) | 50 632 | 34.1 | 444 803 | 8.79 |
| Turbot (*Psetta maxima*) | 9 573 | 6.4 | 76 749 | 8.02 |
| Righteye flounders nei (*Pleuronectidae*) | 8 274 | 5.6 | 9 846 | 1.19 |
| Atlantic halibut (*Hippoglossus hippoglossus*) | 1 832 | 1.2 | 22 332 | 12.19 |
| Senegalese sole (*Solea senegalensis*) | 60 | < 0.1 | 792.9 | 13.22 |
| Common sole (*Solea solea*) | 13 | < 0.1 | 220.6 | 16.97 |
| European flounder (*Platichthys flesus*) | 1 | < 0.1 | 4 | 4.00 |

TABLE A1.1, continued
**Total global production of the major cultivated finfish and crustacean species commonly fed on fresh food items, farm-made and/or commercially compounded aquafeeds**

| Major fed species | Production (tonnes) | Percent | Total value (US$) | Value (US$/kg) |
|---|---|---|---|---|
| **Croakers, drums** (Family *Sciaenidae*) | **123 257** | | **168 314** | **1.37** |
| Large yellow croaker (*Larimichthys croceus*) | 65 977 | 53.5 | 78 513 | 1.19 |
| Red drum (*Sciaenops ocellatus*) | 53 511 | 43.4 | 74 588 | 1.39 |
| Meagre (*Argyrosomus regius*) | 3 769 | 3.1 | 15 214 | 4.04 |
| **Groupers** (Family *Serranidae*) | **78 425** | | **373 018** | **4.76** |
| Groupers nei (*Epinephelus* spp.) | 70 232 | 89.6 | 240 793 | 3.43 |
| Greasy grouper (*Epinephelus tauvina*) | 5 222 | 6.7 | 48 049 | 9.20 |
| Groupers, seabasses nei (*Serranidae*) | 2 612 | 3.3 | 79 285 | 30.35 |
| Orange-spotted grouper (*Epinephelus coioides*) | 195 | 0.2 | 2 188 | 11.22 |
| Areolate grouper (*Epinephelus areolatus*) | 96 | 0.1 | 1 664.4 | 17.34 |
| Brown-marbled grouper (*Epinephelus fuscoguttatus*) | 64 | 0.1 | 931.2 | 14.55 |
| Spotted coral grouper (*Plectropomus maculates*) | 3 | < 0.1 | 72 | 24.00 |
| Humpback grouper (*Cromileptes altivelis*) | 1 | < 0.1 | 36.7 | 36.70 |
| **Cods, hakes, haddocks** | **21 387** | | **83 831** | **3.92** |
| Atlantic cod (*Gadus morhua*) | 21 381 | 100.0 | 83 798 | 3.92 |
| Pollack (*Pollachius pollachius*) | 6 | < 0.1 | 33 | 5.50 |
| **Tunas, bonitos, billfishes** | **8 926** | | **123 094** | **13.79** |
| Southern bluefin tuna (*Thunnus maccoyii*) | 4 532 | 50.8 | 74 188 | 16.37 |
| Pacific bluefin tuna (*Thunnus orientalis*) | 2 193 | 24.6 | 14 117 | 6.44 |
| Atlantic bluefin tuna (*Thunnus thynnus*) | 1 471 | 16.5 | 30 091 | 20.46 |
| Yellowfin tuna (*Thunnus albacares*) | 730 | 8.2 | 4 699 | 6.44 |
| **Miscellaneous marine fishes** | **499 214** | | **957 805** | **1.92** |
| Marine fishes nei (*Osteichthyes*) | 394 236 | 79.0 | 525 331 | 1.33 |
| Korean rockfish (*Sebastes schlegeli*) | 32 992 | 6.6 | 191 715 | 5.81 |
| Cobia (*Rachycentron canadum*) | 24 860 | 5.0 | 38 637 | 1.55 |
| Puffers nei (*Tetraodontidae*) | 21 733 | 4.4 | 112 121 | 5.16 |
| Eastern pomfred (*Schuettea scalaripinnis*) | 11 749 | 2.4 | 11 867 | 1.01 |
| Mangrove red snapper (*Lutjanus argentimaculatus*) | 3 502 | 0.7 | 17 563 | 5.02 |
| Finfishes nei (*Osteichthyes*) | 3 286 | 0.7 | 14 467 | 4.40 |
| Others[6] | 6 856 | 1.4 | 46 104 | 6.72 |

TABLE A1.1, continued

**Total global production of the major cultivated finfish and crustacean species commonly fed on fresh food items, farm-made and/or commercially compounded aquafeeds**

| Major fed species | Production (tonnes) | Percent | Total value (US$) | Value (US$/kg) |
|---|---|---|---|---|
| **MARINE CRUSTACEANS** | | | | |
| **Marine shrimps** (Family *Penaeidae*) | **3 398 844** | | **14 290 444** | **4.20** |
| Whiteleg shrimp (*Litopenaeus vannamei*) | 2 259 183 | 66.5 | 8 985 289 | 3.98 |
| Giant tiger prawn (*Penaeus monodon*) | 721 867 | 21.2 | 3 349 552 | 4.64 |
| Penaeus shrimps nei (*Penaeus* spp.) | 167 908 | 4.9 | 754 035 | 4.49 |
| Banana prawn (*Penaeus merguiensis*) | 80 165 | 2.4 | 335 029 | 4.18 |
| Kuruma prawn (*Penaeus japonicus*) | 49 512 | 1.5 | 206 026 | 4.16 |
| Fleshy prawn (*Penaeus chinensis*) | 42 682 | 1.3 | 172 163 | 4.03 |
| Indian white prawn (*Penaeus indicus*) | 40 714 | 1.2 | 315 654 | 7.75 |
| Metapenaeus shrimps nei (*Metapenaeus* spp.) | 33 234 | 1.0 | 140 006 | 4.21 |
| Blue shrimp (*Penaeus stylirostris*) | 2 727 | 0.1 | 27 173 | 9.96 |
| Greasyback shrimp (*Metapenaeus ensis*) | 671 | < 0.1 | 5 057 | 7.54 |
| Akiami paste shrimp (*Acetes japonicus*) | 100 | < 0.1 | 130 | 1.30 |
| Palaemonid shrimps nei (*Palaemonidae*) | 69 | < 0.1 | 270 | 3.91 |
| Redtail prawn (*Penaeus penicillatus*) | 10 | < 0.1 | 52 | 5.24 |
| Atlantic ditch shrimp (*Palaemonetes varians*) | 1 | < 0.1 | 2 | 1.50 |
| Baltic prawn (*Palaemon adspersus*) | 1 | < 0.1 | 4 | 4.00 |
| **Marine crabs** (Family *Portunidae*) | **241 042** | | **749 047** | **3.11** |
| Indo-Pacific swamp crab (*Scylla serrata*) | 138 032 | 57.3 | 376 767 | 2.73 |
| Swimming crabs nei (*Portunidae*) | 83 803 | 34.8 | 294 149 | 3.51 |
| Marine crabs nei (*Brachyura*) | 18 759 | 7.8 | 75 899 | 4.05 |
| Swimcrabs nei (*Callinectes* spp.) | 261 | 0.1 | 1024.8 | 3.93 |
| Portunus swimcrabs nei (*Portunus* spp.) | 187 | 0.1 | 1207 | 6.45 |
| **Lobsters** | **372** | | **5 491** | **14.76** |
| Tropical spiny lobsters nei (*Panulirus* spp.) | 364 | 97.8 | 5 324 | 14.63 |
| Flathead lobster (*Thenus orientalis*) | 4 | 1.1 | 52 | 13.08 |
| Mud spiny lobster (*Panulirus polyphagus*) | 4 | 1.1 | 115 | 28.68 |
| **Others** | | | | |
| Marine crustaceans nei (*Crustacea*) | 109 | | 714 | 6.55 |

TABLE A1.1, continued

**Total global production of the major cultivated finfish and crustacean species commonly fed on fresh food items, farm-made and/or commercially compounded aquafeeds**

| Major fed species | Production (tonnes) | Percent | Total value (US$) | Value (US$/kg) |
|---|---|---|---|---|
| **FRESHWATER CRUSTACEANS** | | | | |
| **Freshwater crabs** (Family *Grapsidae*) | | | | |
| Chinese mitten crab (*Eriocheir sinensis*) | 518 365 | 100 | 3 608 126 | 6.96 |
| **Crawfishes, crayfishes** | **418 256** | | **1 867 527** | **4.47** |
| Red swamp crawfish (*Procambarus clarkia*) | 417 904 | 99.9 | 1 862 938 | 4.46 |
| Red claw crayfish (*Cherax quadricarinatus*) | 119 | < 0.1 | 1 552 | 13.04 |
| Yabby crayfish (*Cherax destructor*) | 84 | < 0.1 | 1 158 | 13.79 |
| Euro-American crayfishes nei (*Astacidae, Cambaridae*) | 76 | < 0.1 | 282.5 | 3.72 |
| Marron crayfish (*Cherax tenuimanus*) | 61 | < 0.1 | 1 419 | 23.26 |
| Noble crayfish (*Astacus astacus*) | 12 | < 0.1 | 177.3 | 14.78 |
| **River prawns** | **425 885** | | **2 140 938** | **5.03** |
| Giant river prawn (*Macrobrachium rosenbergii*) | 207 749 | 48.8 | 1 102 642 | 5.31 |
| Oriental river prawn (*Macrobrachium nipponense*) | 205 010 | 48.1 | 975 848 | 4.76 |
| Freshwater prawns, shrimps nei (*Palaemonidae*) | 13 096 | 3.1 | 62 337 | 4.76 |
| River prawns nei (*Macrobrachium* spp.) | 30 | < 0.1 | 110.8 | 3.69 |
| **Others** | **7 120** | | **49 943** | |
| Freshwater crustaceans nei (Crustacea) | 7 116 | 99,9 | 49 740 | 6.99 |
| Sawtooth caridina (*Caridina denticulate*) | 4 | < 0.1 | 203 | 50.75 |

[1] Excludes the filter-feeding species silver carp (3 558 923 tonnes in 2008) and bighead carp (2 299 391 tonnes in 2008; FAO, 2010a).
[2] Species not reported.
[3] Others include pond loach, nilem carp, small-scale mud carp, hoven's carp, lsok barb, mud carp, goldfish, roach, tench, Algerian barb, freshwater bream, roaches nei, bleak, white bream, asp, barbel, rudd, chub.
[4] Others include largemouth black bass, Kafue pike, Reticulate knifefish, netted prochilod, grass-eaters nei, Citharinus nei, aba, prochilods nei, climbing perch, bonytongues nei, Pacific fat sleeper, marble goby, northern pike, pike-perch, silver perch, European perch, African bonytongue, bluegill, American yellow perch, freshwater drum, white crappie, arapaima, knifefishes, Argentinian silverside, gudgeons, sleepers nei.
[5] Others include blackspot (= red) seabream, Sobaity seabream, common pandora, sharpsnout seabream, white seabream, common dentex, goldlined seabream, sargo breams nei.
[6] Others include John's snapper, fourfinger threadfin, filefishes, leatherjackets nei, flatfishes nei, scorpionfishes nei, spinefeet (= rabbitfishes) nei, mackerels nei, trumpet emperor, snappers nei, snappers, jobfishes nei, gobies nei, Russell's snapper, rice-paddy eel, snooks (= robalos) nei, silversides (= sand smelts) nei, streaked spinefoot, marbled spinefoot, spotted rose snapper, Waigieu seaperch, papuan black snapper, sixfinger threadfin (FAO, 2010a).
*Source*: FAO (2010a).

# ANNEX 2 – Fed cultured species production by country

TABLE A2.1
**Total fed cultured species production by major producing country in 2008 (tonnes)[1]**

| | | | |
|---|---|---|---|
| China | 15 670 948 | Guatemala | 18 727 |
| India | 3 080 161 | Bolivarian Republic of Venezuela | 18 627 |
| Viet Nam | 2 124 400 | Iraq | 16 746 |
| Indonesia | 1 642 957 | Nepal | 16 086 |
| Thailand | 1 032 387 | Nicaragua | 16 078 |
| Norway | 841 786 | Finland | 13 367 |
| Philippines | 697 903 | Hungary | 13 232 |
| Egypt | 693 815 | Ukraine | 12 584 |
| Myanmar | 653 696 | Ireland | 11 350 |
| Chile | 630 929 | Madagascar | 9 580 |
| Bangladesh | 621 605 | Belize | 9 549 |
| United States | 344 819 | New Zealand | 9 080 |
| Japan | 303 986 | Netherlands | 8 650 |
| Brazil | 267 156 | Syrian Arab Republic | 8 595 |
| Taiwan Province of China | 216 971 | Croatia | 8 356 |
| Ecuador | 172 120 | Panama | 8 224 |
| Malaysia | 166 590 | Sri Lanka | 7 468 |
| Turkey | 152 064 | Romania | 7 260 |
| United Kingdom | 144 314 | Bosnia and Herzegovina | 7 220 |
| Mexico | 143 321 | Cuba | 6 786 |
| Nigeria | 142 477 | Serbia | 6 351 |
| Pakistan | 135 098 | Jamaica | 5 948 |
| Republic of Korea | 115 591 | Sweden | 5 684 |
| Canada | 109 913 | Zambia | 5 640 |
| Iran, Islamic Republic of | 102 372 | Ghana | 5 594 |
| Russian Federation | 96 345 | Iceland | 5 088 |
| Greece | 93 486 | Kenya | 4 452 |
| Colombia | 66 400 | Portugal | 4 050 |
| Spain | 63 875 | Belarus | 3 960 |
| Lao People's Democratic Republic | 63 530 | Bulgaria | 3 810 |
| Italy | 58 459 | El Salvador | 3 766 |
| Uganda | 52 250 | Cyprus | 3 403 |
| France | 48 263 | Tunisia | 3 199 |
| Honduras | 47 080 | China, Hong Kong Special Administrative Region | 3 119 |
| Faroe Islands | 45 929 | Lithuania | 2 997 |
| Australia | 38 603 | Democratic Republic of the Congo | 2 970 |
| Cambodia | 38 505 | Argentina | 2 452 |
| Poland | 36 413 | Zimbabwe | 2 450 |
| Germany | 33 875 | Algeria | 2 384 |
| Denmark | 33 600 | Democratic People's Republic of Korea | 2 200 |
| Peru | 28 176 | Paraguay | 2 100 |
| Costa Rica | 27 034 | Austria | 2 086 |
| Saudi Arabia | 22 253 | New Caledonia | 2 041 |
| Israel | 19 762 | Sudan | 2 000 |
| Czech Republic | 19 260 | Other countries (<2 000) | 30 458 |
| | | **Total fed species** | **31 486 244** |

[1]Total fed species country production excludes data for silver carp (3 558 923 tonnes in 2008), bighead carp (2 299 391 tonnes in 2008), and freshwater fishes nei; total global production of freshwater fishes nei (species not given) was reported as 1 244 258 tonnes in 2008 (FAO, 2010a).
*Source*: FAO (2010a).

The rise into global prominence and rapid growth of finfish and crustacean aquaculture has been due, in part, to the availability and on-farm provision of feed inputs within the major producing countries. More than 46 percent of the total global aquaculture production in 2008 was dependent upon the supply of external feed inputs. For the aquaculture sector to maintain its current average growth rate of 8 to 10 percent per year to 2025, the supply of nutrient and feed inputs will have to grow at a similar rate. This had been readily attainable when the industry was young, but it may not be the case anymore as the sector has grown into a major consumer of and competitor for feed resources.

This paper reviews the dietary feeding practices employed for the production of the major cultured fed species, the total global production and market availability of the major feed ingredient sources used and the major constraints to feed ingredient usage, and recommends approaches to feed ingredient selection and usage for the major species of cultivated fish and crustaceans. Emphasis is placed on the need for major producing countries to maximize the use of locally available feed-grade ingredient sources, and, in particular, to select and use those nutritionally sound and safe feed ingredient sources whose production and growth can keep pace with the 8 to 10 percent annual average annual growth of the fed finfish and crustacean aquaculture sector.

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