techniques for fish disease prevention and control, taking into account the various preventive measures that are now being advanced that could inhibit the use of chemical inputs in aquaculture.

More importantly, AQD would continue to focus its activities in addressing the areas of concern of responsible aquaculture development guided by the priorities especially on the development of responsible aquaculture technologies and practices, responsible use of genetic resources for the purpose of aquaculture, adoption of measures to avoid environmental degradation, and promotion of environmentally sound culture methods and commodities. There is certainty that if uncontrolled, irresponsible practices in aquaculture would continue to threaten food safety and create negative impacts on the ecosystem. It is for this reason that AQD has been promoting the concept of healthy and wholesome aquaculture, which is a holistic approach to fish disease management for food safety and security. This concept also promotes the use of efficient feeds which are cost effective and low-polluting in order to optimize production and healthy famed aquatic animals with the least negative impact to the environment (Toledo *et al*., 2011).

5.4 Development of Sustainable Aquaculture Feeds

Southeast Asia is a major producer of aquaculture products and aquaculture production has been steadily increasing with concomitant increase in the demand for aquafeeds in the region. Fishmeal (FM) and fish derived products (FPs) such as fish oil (FO), fish hydrolysates, fish protein concentrates, fish processing by-products, and fish soluble, are the major components of aquafeeds that would satisfy nutrient requirements and acceptability. However, FM and FPs are not always available and market prices could be unstable. Hence, these have big impacts on aquaculture activity and its sustainability.

Aquaculture feeds with lesser dependence on these feedstuffs are being developed to sustain growth of aquaculture in the Southeast Asian region. Decreasing the levels of FM and FPs in aquafeeds has been the objective of many feed formulators and feed millers. Therefore, research effort should emphasize on determining the lowest levels of FM and FPs in feeds formulated for specific aquaculture species in their stages of growth without loss in efficacy and on protein production. This has been achieved to a certain extent, for example in the compounded feeds for some species using alternative protein sources and nutritional interventions. Improvement and refinement of formulations, however, should be continued together with technologies that make alternative protein sources commercially available and cheap. Moreover, the culture of species with low requirement for FM and FPs such as the low value with high volume aquaculture species should be encouraged and to a certain extent environment regulations should be put in place. In addition, there is a need for greater involvement of governments to expand the market and promote consumer acceptance of low value species.

5.4.1 Use of Fishmeals and Fish-based Products for Aquafeeds

Production from fed aquaculture is 54% of total production in Asia (FAO, 2008). In 2009, the Southeast Asian region which is a major producer of aquaculture products, the volume of production was 12.5 million MT valued at US$ 14.8 billion (FAO, 2010). The amount of raw materials that goes into aquafeed production in the region is significant and the impact is tremendous on non-renewable resources or on the raw materials with limited supply. The collective impact of market forces, research results, and pressures of environmental issues lowered the inclusion levels of FM as a source of high quality protein and minerals as well as that of FO as a source of omega fatty acids, the second most valuable among the FPs in compounded feeds for aquaculture. Global reported data showed that these ingredients are expected to decline from 1995 to 2010 in the levels of FM and FO in compounded feed of milkfish (*Chanos chanos*) from 15% to 3% and 3% to 1%, respectively.

Except for catfish, a similar trend is also reported for shrimps, marine fish and tilapia. The compounded feeds for these species have become less dependent on FM and FO as lesser amounts are used, and are also increasingly efficient as shown by lower average FCR values from 1995 to 2010. The decreased levels of FM and FO in aquafeed imply that there is now less pressure on the manufacture of FM and FO. However, fish production from aquaculture in the Southeast Asian region has increased and more fish farmers are using efficient compounded feeds in aquaculture, increasing the demand for aquafeed production and thus, increasing also the total requirements for FM and FPs. For instance, the volume of aquafeeds used in the culture of milkfish between 1995 and 2007 has more than doubled while that for the other species groups has quadrupled (**Table 59**). In 2010, the estimated volumes of total feeds for the culture of these species also increased. Thus, with increased aquafeed use in aquaculture production in the Southeast Asian region, the demand for FM and FPs will continue to increase.

5.4.2 Issues and Concerns

Aquaculture production in the Southeast Asian region has been increasingly dependent on aquafeeds and this trend will continue as long as resources for the feed poduction are available. However, FM and FPs which are significant components of aquafeeds are finite resources, and as such feed producers and feed formulators are optimizing the use of these feedstuffs in aquafeeds. There is a lower limit to the inclusion of these feedstuffs in compounded feeds for specific species for culture without loss of efficiency. The pressure on FM and FPs would be greatly alleviated by finding the right resources as alternatives for protein and oils in aquafeeds. These alternative resources should come in adequate supply, cheap, effective, and acceptable to consumers. The use of alternative protein sources in aquafeeds has been done successfully to a certain percentage of the protein coming from FM. The common sources are those coming from plants which are high in fiber and contain some anti-nutrients. Soybean which is the most important plant protein source in aquafeed is highly digestible to most species for culture. However, its use in aquafeeds is constrained by its application in the livestock industry, for human consumption, and for the production of ethanol and biodiesel. The importance and acceptability of soybean meal, however, as a major plant protein source (also a source of lecithin and oil) has long been recognized.

As a result, products with soybean as the base component are coming out in the market with enhanced protein level and amino acid profile. These enhanced products are not cheap and so their utilization is constrained by the economics of aquafeed manufacturing. The use of genetically modified soya and corn in aquafeed is also a concern for some sectors of the industry. Plant protein sources such as corn, peas, Leucaena leaf meal, the leguminous meals, and copra meal are commonly found in the region and these have been increasingly used in fish diets, thus, decreasing reliance on the use of protein from FM. The other plant sources such as rice bran, wheat, palm kernel meal, ground nut cake which are used mainly as sources of carbohydrates in aquafeed contains small amounts of proteins and thus, FM protein is substituted to a lesser extent. Through fermentation processes, the nutrients in these plant sources can be made more available, however, constraints in the use of these feedstuffs could include keeping their quality and acceptance by fish.

Agricultural by-products including rendered products of terrestrial animal origin and dried grains as by-products of fermentation and distilleries have also been effectively

Table 59. Fishmeal (FM) and fish oil (FO) uses and efficiencies (1995), and estimates based on expected growth (2007-2010) in milkfish and four species groups

Species/ Group	Percentage on feed[a]	Average Feed Conversion Ratio (FCR)	Average FM level in feed (%)	Average FO level in feed (%)	Total feeds used[b] (Thousand Tonnes)
Milkfish					
1995	30	2	15	3	220
2007	41	2	3	1	499
2010	44	1.9	3	1	572
Shrimp					
1995	75	2	28	2	1,392
2007	93	1.7	18	2	5,603
2010	95	1.6	12	2	7,170
Marine fish					
1995	50	2	50	15	498
2007	72	1.9	30	7	2,311
2010	73	1.8	24	6	2,797
Tilapia					
1995	70	2	14	1	984
2007	82	1.7	5	0	3,590
2010	85	1.7	3	0	4,953
Catfish					
1995	85	2	5	1	345
2007	72	1.5	8	1.7	2,080
2010	73	1.5	6	1.7	2,923

Source: *Data from Tacon and Metian, 2008.*
[a] *Estimated percentage of milkfish and total species group fed on aquafeeds*
[b] *Estimated total aquafeed used*

used in aquafeed formulations but the inclusion level is limited. Rendered by-products are cheaper and those that have been successfully used in aquafeeds production as protein sources are blood meal, meat and bone meal, feather meal, and poultry by-product meal. Furthermore, dried grains have high fiber content but may not be always palatable to fish. Many studies have shown the use of these by-products in aquafeeds, but the reduced digestibility of these products in fish is a constraint. In addition, poor market acceptance has limited the use of rendered products.

Plant-based oil which is cheaper than marine fish oils have also been used in aquafeeds. The sources of plant oils are sunflower, olive, coconut, corn, and palm, but the use of these oils is limited by their fatty acid profiles and degree of un-saturation. Nevertheless, these characteristics benefit most freshwater species for culture. The combination of plant-based oils with marine oils has been known to improve feed utilization by cultivable marine species. Other feed ingredients that can be used as FM and FPs substitutes include fermented plant protein, single cell protein, krill, and by-products of seafood processing (Naylor *et al*., 2009). These are good and suitable substitutes but they are not yet produced in commercial quantities and, in the case of krill, the adverse ecosystem impacts. Numerous fishery products are used as feed ingredients in aquafeed and probably not all can be substituted by alternative sources. The most important ones are FM and FO, and these are the focus of much research effort for many species. These investigations also include other rich sources of DHA and EPA such as marine algal resources.

Research had also been done on the use of leaf meals as alternative protein sources in commonly cultured fish in the region. Although substitution of FM is possible to a certain level but processing leaf meals would be expensive and, in addition, contain anti-nutritional factors. In the continuing efforts to develop new formulations using non-traditional feed ingredients, the use of beneficial microorganisms in the gut of aquaculture species have been explored to ferment common feedstuffs to increase their suitability for use in aquafeeds, while other fermentation methods such as solid state fermentation, are also being explored to process non-traditional feed ingredients.

The cultivation of low-value with high-volume fish species is being promoted because they require lesser amount of FM and FPs in the feeds compared with the high-value with low-volume species which are mostly marine carnivores. In this case, farmers prefer to grow such species because of the profitability of farm operations or incentives given by the government. However, the use of high amounts of FM can be limited to the larval feeds and lesser amounts can be included in the feed for later stages of aquaculture. The fast growth of aquaculture sector has spurred a great demand for aquafeed and most importantly on FPs as important ingredients in aquafeed production. This has resulted in some cases in the adulteration and indiscriminate addition of chemicals in these commodities to avoid spoilage, increase bulk weight, retain freshness, and to improve fish health and growth. Adulterations in fishmeal had been reported and governments of the Southeast Asian countries should take important steps to curtail this activity since it undermines the use of FM, the efficiency of the aquafeeds, and the safety of aquaculture products.

The use or application of basic nutritional information in the formulation of aquafeeds by formulators in the aquafeed industry is critical in improving the efficiency of the feeds and sustaining aquaculture. However, more research still needs to be done to improve the understanding of fish nutrition and feeding management, as for example in the use of enzyme complexes to reduce FM required in aquafeeds to give the same or even improved performance in fishes which seems to be feasible. Much research efforts on FM and FPs substitutions in aquafeed have been done and presently being done, where valuable results should be made accessible to people who are responsible for the adaptation and use of such information.

5.4.3 Challenges and Future Direction

More efficient compounded feeds with lesser inclusion of FM and FPs are presently produced compared with the situation a decade ago. Therefore, efforts to continue such initiatives should be sustained through the involvement of other sectors of the industry. For the sustainability of the industry in the region, a more aggressive and multidisciplinary effort in finding adequate substitutes in aquaculture feeds should be pursued, while the various challenges should be addressed. The major challenge in the use of conventional feed ingredients for aquafeed formulations are commercial availability, quality, and the adequacy of nutrients to meet the requirements of specific species. In addition to cost, there is competition for these resources from other users such as the food producing sector. Government subsidies and incentives will help bring down the cost, but, stringent regulations should be in place to safeguard quality. Furthermore, for effective FM and FPs substitution in aquafeeds, research should be conducted on feedstuff digestibility for important species for culture, as well as intervention should be in place in order to achieve nutrient balance, palatability, and stability in compounded feeds to enhance the FCR.

Commercial quantity is also a constraint for the non-traditional feed ingredients. However, it is crucial to establish efficacy through research to enable the other sectors of the industry to follow with the commercial production of these feed ingredients. Aquaculture products grown on non-traditional feedstuffs should also be assessed for acceptable sensory characteristics such as odor, color, taste, and texture. Traceability, effect on human health, and impact on the environment are significant issues to be addressed in the use of non-traditional ingredients. Databases are available on feed ingredients that include their nutrition composition, usage in industrially- and farm-made aquafeeds, quality criteria, limitation of use, as well as documented feeding studies (Tacon *et al*., 2009; Hertrampf and Pascual, 2000). Databases should be updated to contain the current information on feed ingredient including those on non-traditional feed ingredients, and should be made available to feed manufacturers, researchers, fish farmers, policy makers, and other stakeholders.

The use of alternative substitutes for FM and FPs has some setbacks such as poor palatability, poor digestibility, essential amino acids deficiency, high fiber content, and limited inclusion level. Technological innovations are therefore needed to effectively use these in aquafeeds. Genetic engineering can improve amino acid profile in legumes and increase DHA/EPA levels of plant-derived oils. In addition, with technological innovations, concentrated and hydrolyzed protein products can be made cheaper and bone content in meat and bone meal can be adjusted to reduce calcium levels. In addition, genetic selection can be done for strains/stocks that can efficiently utilize plant derived non-traditional ingredients. It is apparent that the demand for aquafeed will continue to increase in the region as more aquaculture operations will be producing fish through fed aquaculture. The development of efficient aquafeeds with less dependence on FM and FPs should be pursued aggressively and with more multidisciplinary research efforts. Some feed ingredients with potentials for use as substitutes for these resources are already found in the market. Their efficacy to substitute FM and FPs in aquafeed including those of non-traditional feed ingredients can be increased through technological innovations.

5.5 Minimizing Impacts of Aquaculture on the Environment

Aquaculture is the fastest-growing food production system globally, with about 9% increase in production per year since 1985 (Diana, 2009). On the average, Asia which is known as the birthplace of aquaculture (Tacon *et al*., 1995) provides 83% (range: 59-91%) of the total world aquaculture production, 14% of which comes from Southeast Asia (**Fig. 38**). Indonesia and the Philippines contribute the most to aquaculture production in Southeast Asia at 23-42% and 20-45% of the total production from aquaculture, respectively (**Fig. 39**). With the increasing demand for fish and fishery products coupled with the dwindling supply of wild aquatic resources, aquaculture has been projected to compensate the declining fishery production and considered a reliable solution to food security problems. However, as aquaculture production intensifies, a lot of problems have been linked with it.

The phenomenal growth of aquaculture in the recent years has caused modification, destruction or complete loss of habitat; unregulated collection of wild broodstocks and seeds; translocation or introduction of exotic species; loss of biodiversity; introduction of antibiotics and chemicals to the environment; discharge of aquaculture wastewater, thus coastal pollution; salinization of soil and water; and dependence on fishmeal and fish oil as aquaculture feed ingredients, to name a few (Chua *et al*., 1989; Iwama 1991; Beveridge *et al*., 1994; Naylor *et al*., 2000; Primavera, 2006). Efforts have been done by the countries in the region to increase production and at the same time minimize impacts of aquaculture on the environment.

5.5.1 *Status, Issues and Concerns*

The many advantages of aquaculture provide a strong and credible argument for its continued implementation. Aquaculture continues to provide valuable food supply and economic support for many countries. However, the industry has its own share of problems that need to be addressed, the most important of which is its impact on the environment. In order to limit the potential negative

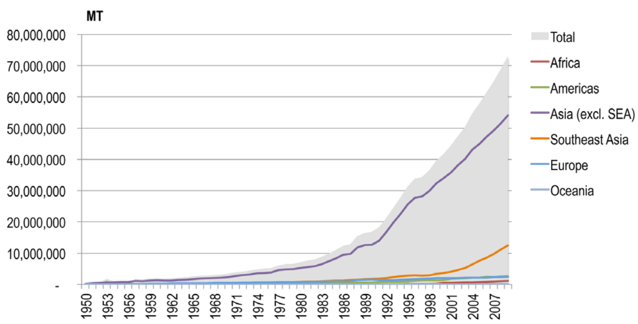

Figure 38. Aquaculture production from 1950 to 2009
*(**Source:** FAO database)*

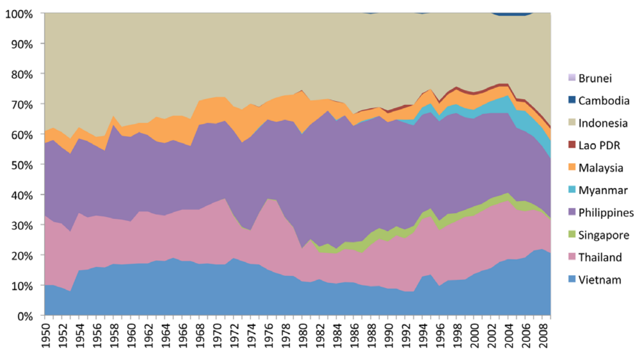

Figure 39. Contribution (%) of Southeast Asian countries to aquaculture production of the region from 1950 to 2009
*(**Source:** FAO database)*