Strengthening R&D Mechanisms to Advocate Effective Feed Management in Aquaculture and Reduce Dependence on Fish Meal: Impact on Myanmar Fisheries

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Aquaculture plays an important role in the sustainable development of the Southeast Asian region considering its significant contribution to food security, poverty alleviation and socio-economic well-being of the people. However, the development of aquaculture is highly constrained by the insufficient and inconsistent supply of fish meal and other fish-based products leading to the rising cost of aquaculture feeds. Since a large portion of fish meal supply also goes to terrestrial animal feeds, the use of fish-based products for animal feeds had been questioned because it conflicts with the use of the same resources for direct human consumption of the region's growing population. In order to ensure the sustainable development of aquaculture, countries in the region should understand such situation and explore options in the production of aquaculture feeds using suitable and cost-effective substitutes for fish meal and fishery products.

It has often been declared that aquaculture has great potentials to fill the gap between supply and demand for food fish, especially in the Southeast Asian region where aquaculture has been developing faster than could be imagined. In 2008, the Southeast Asian countries produced about 11.1 million mt of fish from aquaculture accounting for 21% of the world's fish production from aquaculture of 52.6 million mt (FAO, 2010). The top five aquaculture producing countries in Southeast Asia in 2008 (**Table 1**) were: Indonesia contributing 35% of the region's total production from aquaculture followed by Vietnam accounting for 22.3%, Philippines by 21.8%, Thailand by 12.0%, and Myanmar about 6.0% (SEAFDEC, 2010).

Nevertheless, the growth of the region's aquaculture industry has been confronted with various challenges including oil price fluctuation, unstable and inconsistent production, impacts of climate change, and disease outbreaks. In

Table 1. Aquaculture production of the Southeast Asian countries (Qty in '000 mt, Val in '000 000 US$)

Southeast Asian countries	2004		2005		2006		2007		2008	
	Qty	Val	Qty	Val	Qty	Val	Qty	Val	Qty	Val
Indonesia	1,354.5	1,967.0	1,941.1	2,168.7	2,377.5	2,341.5	2,466.0	2,447.5	3,855.3	4,222.5
Vietnam	1,198.6	2,357.0	1,467.3	2,945.7	1,687.7	-	2,194.5	4,544.8	2,468.3	4,617.7
Philippines	1,717.0	799.8	1,895.9	892.5	2,092.3	1,085.0	2,214.8	1,334.7	2,407.7	1,718.6
Thailand	1,301.5	1,714.5	1,318.5	1,353.2	1,353.0	1,990.0	1,370.4	2,134.6	1,330.8	2,165.3
Myanmar	426.0	-	575.0	-	575.0	-	604.7	1,862.4	653.9	782.6
Malaysia	202.2	309.8	188.2	341.1	212.0	352.0	268.5	353.0	240.1	462.9
Lao PDR	64.9	-	78.0	-	78.0	-	63.3	81.3	64.3	91.2
Cambodia	37.7	-	42.0	-	41.4	-	50.2	-	39.7	61.8
Singapore	5.4	8.5	5.9	10.0	8.6	9.5	4.5	9.0	3.5	9.3
Brunei Darussalam	0.7	-	0.7	-	0.7	-	0.7	3.2	0.4	0.4
TOTAL (Aqua)	**6,243.7**	**7,201.8**	**7,434.5**	**7,711.2**	**8,348.2**	**5,778.0**	**9,174.3**	**12,747.3**	**11,064.0**	**14,032.2**
Region's Total Fish Production	**21,053.7**	**15,148.5**	**22,880.0**	**16,417.0**	**24,394.1**	**15,466.2**	**25,211.2**	**23,937.9**	**27,260.1**	**28,583.6**

Source: *SEAFDEC (2010)*

addition, the demand for eco-labeling of aquatic products and traceability documentation requirements of importing countries has made aquaculture operations in the region becoming more complex. Furthermore, other constraints continue to hound the development of aquaculture in Southeast Asia, especially in terms of limited land and insufficient supply of freshwater, shortage and rising prices of good quality feeds, inadequate power supply for processing and the continuing rising cost of oil, pollution and environmental degradation problems, and limited expertise among government officials (Hishamunda *et al.*, 2009). One very crucial factor that impedes the sustainable development of aquaculture is the over-reliance of aquafeed processing on fish meal and fishery products as main ingredients. In order to address such concern, the use of fish meal and fishery products as principal source of nutritional protein should be minimized, in which case there is a need to look for suitable and cost-effective substitutes for fish meal and fishery products in fish diets.

This concern was reiterated by Ekmaharaj (2009) who suggested that research on alternative ingredients as substitute to fish meal in aquafeeds should be intensified to reduce the use of fish food which in turn could reduce fisheries by-catch. In this regard, Lymer *et al.* (2008) reported that FAO has set the general principles on the use of fish as feeds in order to avoid the high demand of fish to be transformed into feeds. Platon *et al.* (2007) also suggested that any aquaculture system should also aim to decrease feed conversion ratio and reduce the quantity of feeds used through better feed management. In addition, Funge-Smith *et al.* (2005) further suggested that since the supply of low-value/trash fish in the Asia-Pacific countries have diminished but with prices that continue to increase, there might be a need to increase imports of fish meal from the global market for the region's aquaculture industry otherwise, fish meal should be replaced with other feed ingredients. Thus, the replacement of fish meal with alternative ingredients in aquaculture diets has become a major concern in international nutrition research. Since the use of low-value fish/trash and fish meal in aquaculture sector has already been unsustainable, the aquaculture industry should continue to exert efforts to reduce its dependence on fish as feeds through effective feed management practices and the development of better quality feeds using alternative ingredients (De Silva and Turchini, 2009).

In Southeast Asia, increased incomes led to increased consumption of meat and higher-value fish products especially those from aquaculture. Consequently, the need for aquafeeds also increased in order to sustain the aquaculture industry. Therefore, it is critical that effective regulation be established on the need to balance global forage fish supplies and trash fish consumption. Naylor *et al.* (2009) suggested that balancing the demand-side regulation on feeds and supply-side management of forage fisheries should be promoted in order to create appropriate incentive for sustainable growth of the aquaculture industry. The Resolution on Sustainable Fisheries for Food Security for the ASEAN Region adopted in November 2001 provided the need to: "*Increase aquaculture production in a sustainable and environment-friendly manner by ensuring a stable supply of quality seeds and feeds, effectively controlling disease, promoting good farm management and transferring appropriate technology*". Similarly, the adopted Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region emphasized on the need to develop programs to "*Improve the efficient use of aquatic feeds by regulating the quality of manufactured feed and feed ingredients, providing guidelines on farm-level food conversion ratios and levels of aquaculture effluents and supporting research into developing suitable alternative protein sources to reduce dependence on fish meal and other fish based products*". Thus, to ensure the sustainable development of aquaculture *vis-à-vis* the efficient use of aquafeeds, countries in the region should understand the current status of its aquaculture vs. the aquafeed industry.

Aquaculture Development in Myanmar

The fisheries sector, which is one of the most important economic sectors after the agriculture, largely contributes to the protein requirement of the people of Myanmar and is an important contributor to the improvement of the socio-economic condition of Myanmar. Among the fishery sub-sectors, aquaculture has played a major role by contributing 21% to the country's total fish production of 3,147,600 mt in 2008, with production from marine capture sharing 53% (1,679,000 mt) and inland capture fisheries accounting for 26% (814,700 mt). In Myanmar, aquaculture is mainly conducted in ponds, and in 2008-2009 the total pond area was 176,852.2 ha consisting of 86,491.2 ha fishponds and 89,862.0 ha shrimp ponds. Freshwater pond fish culture is the major source of the country's aquaculture production with rohu (*Labeo rohita*) as the dominant species cultured.

In Myanmar, most farmers adapt the polyculture system by rationally utilizing all strata and the natural food in the pond water, especially for the culture of the Indian major carps, Chinese carps, common carps, tilapia, catfish (*Pangasianodon hypophthalmus*), and freshwater prawn (*Macrobrachium rosenbergii*). While farming of shrimps (*Penaeus monodon*) is mainly conducted in Rakhine State adopting the extensive plus and extensive or traditional culture methods, marine fish culture which is still in its initial development stage, focuses on grouper (*Epinephelus* spp.) and sea bass (*Lates calcarifer*) cultured in net cages

Above: Culture of soft-shelled crabs in Myanmar; and
Below: Trash fish being chopped to feed soft-shelled crabs in Myanmar

using seeds from the wild, and is operated in the southern coastal area of Myeik.

Recently, soft-shell crab farming has become popular in Myanmar because of the high price and demand for soft-shelled crabs in the export market. Under marketable sized mud crabs are collected from the wild and reared individually in small boxes for a couple of weeks where the crabs are fed with trash fish chopped into suitable sizes, depending on the size of the stock. On the other hand, wild-caught crablets are farmed in intensive operations in which one or two crablets are held together and checked every other day for molting, since soft-shelled crabs could be ready for the market after two molts. The rapid progress of the country's aquaculture industry had made Myanmar one of the emerging important Southeast Asian countries with substantial growth in aquaculture both in freshwater and marine environments (De Silva and Turchini, 2009).

Development of Aquaculture Feeds in Myanmar

Freshwater fish farming in Myanmar utilizes farm-made feeds from locally available ingredients such as rice bran, ground-nut cake, and cotton seed cake, among others. The procedure involves cooking broken rice, ground-nut cake or cotton seed cake and rice bran (1:2:7) and fed to fish as a moist mash. Nonetheless, some large commercial fish farm owners operate their own feed mills to produce feed pellets for their farms on an experimental basis while fish farmers are already using the formula of rice bran and ground-nut cake (4:1) in feeds that are directly put in feeding bags made from mosquito netting materials and placed in the ponds. For tilapia and *Pangasianodon* catfish culture however, formulated feed pellets which are manufactured by private feed mills are used. Although there is no reliable source of feed formula and feed conversion ratio in the production of feed pellets by private feed mills, it is roughly known that the feed ingredients include broken rice, rice bran, ground-nut cake, soybean cake, and locally available fish meal added with vitamin premix.

Nevertheless, many fish farmers have shifted from the use of farm-made feeds to factory made feeds (sinking pellets) because of the existence of aquafeed mills owned by private companies as well as government-run. For feeding, some fish farmers use feeding bags with appropriate mesh size to contain the sinking pellets while others manually broadcast the pellets from feeding platforms in the ponds. Commercial feed manufacturers most often go out of their way to convince freshwater fish farmers to use their manufactured pellet feeds without assessing the need and economics of the use of such feeds in their fish farms.

There are now 27 fish feed production plants in Myanmar, seven of which are producing mainly freshwater fish feeds. The raw materials include a mixture of 60% rice bran, 14% peanut cake, 4% prawn shell dust, 12% wheat flour, and 10% soya bean, in which case manufacturing of the feeds makes use of plant protein instead of fish meal (**Table 2**).

Table 2. Freshwater fish feed plants and daily production of feeds

Fish feed production plants	Fish feed produced per day (tons)
Livestock Food Stuff and Milk Product Enterprise	250
Htoo Thit	200
Shwe Taung Ngwe Taung	150
Phyo Ayer	120
Myan Swan Htet	70
Shwe Myanmar	60
Ngwe Pin Lae	60

On the other hand, marine shrimps and freshwater prawns are fed factory-made pellets produced by local private feed mills but due to the decreasing number of semi-intensive and intensive shrimp and prawn farms, the demand for pellet feed had also been reduced. However, trash fish/ low-value fish are the main food source for most cultured marine species such as grouper, *Epinephelus* spp. as well as mud crab (*Scylla* spp.). It is therefore very noticeable that the country's soft-shelled crab and marine fish farming thoroughly depend on trash fish as feeds. Considering that the country has huge potentials for aquaculture development, therefore there is a need to improve the quality of farm-made and commercial pellet feeds, and at the same time also reduce the use of trash fish for feeds for the sustainability of its aquaculture development. Along this rationale, the Department of Fisheries (DoF) of Myanmar had facilitated the conduct of workshops and seminars on aquaculture giving many of its staff the chance to attend high level training and graduate studies programs through scholarships. In 2010, the SEAFDEC Aquaculture Department (AQD) conducted two on-site training sessions of "farm-based feed preparation" and "fish health management" in Myanmar for the staff of DoF and members of the fish farmers' association, the Fisheries Federation of Myanmar. In addition, the DoF and Myanmar Fisheries Federation also conduct several regular training courses on various aspects of aquaculture. Moreover, the development of small-scale aquaculture emphasizing on the production of low-cost fish species and improvement of aquaculture techniques for food security of the local communities has been promoted by DoF in collaboration with Japan International Cooperation Agency (JICA) through the project on Small-scale Aquaculture Extension for Promotion of Livelihood of Rural Communities (SAEP) which was implemented from 2009 to 2011.

Issues and Concerns

In Southeast Asia, the development of sustainable aquaculture which is an important source of aquatic protein for the region's growing population is being constrained by the insufficient supply and high cost of nutrients, and inadequate feed ingredients and formulated feeds. In many Southeast Asian countries, the specific problem on aquaculture feeds and feeding management varies greatly according to the status of development of aquaculture and the culture systems adopted. While some countries are still using traditional feeding practices such as feeding unprocessed feeds which are available from near farm sources as well as agricultural by-products, and using small marine fish or trash fish, the other countries have already developed advanced feeding management for aquaculture through the use of manufactured pellet feeds. In order to minimize the disparity among the countries as far as aquaculture feed development is concerned, the 2nd Meeting of the AFCF in Brunei Darussalam in June 2010, had designated Myanmar as the lead country for the key cluster on "Fish for Aquaculture Feed in the Region" with the main objective of developing and promoting alternative feed production by reducing dependence on the use of low-value or trash fish in aquafeeds. Although a gigantic task for the country to undertake, but Myanmar is taking giant strides in this aspect through enhanced collaboration with the other countries in the region as well as with SEAFDEC through its Aquaculture Department.

It should be noted that in intensive aquaculture system, 60 to 80 percent of the operation costs account for feeds whereas in semi-intensive aquaculture system, it could only be 30 to 60 percent of the operations cost including fertilizers. In order to improve feeds and feeding strategies for aquaculture species, it is necessary to understand the basic principles of fish nutrition such as the nutritional requirements of the cultured species and the nutritional values of feed ingredients, among others. Nevertheless, feeds and feeding management had been noted to vary largely in many countries in the region especially in Cambodia, Lao PDR, Vietnam and Thailand (Edwards and Allan, 2004). Nonetheless, only very few farmers have high level of understanding of the nutritional requirements of the species being cultured in fish farms.

Moreover, in preparing farm-made feeds, the best combinations of feed ingredients for different cultured species and culture methods should be taken into consideration as well as the availability of feed ingredients which differs very widely both regionally and seasonally. In order to improve feed management and feed formulation, it is imperative that the environmental, social and economical impacts should be taken into account because feed management is a crucial factor that could affect water quality and subsequently fish production. Proper feeding is essential for survival and growth of cultured fish, while inappropriate selection of feed quality and poor feeding strategy could affect the poor utilization by the cultured species of the feeds resulting in high food conversion ratio (FCR). Thus, proper feed management could be promoted by improving the feed conversion ratio through the use of appropriate amount of feeds, maintaining proper feeding duration, proper feeding frequency and timing. Appropriate feed management techniques and/or improving feed quality would contribute to the appropriate utilization of feeds without increasing the operational costs of producing the desired fish (Hasan, 2010). Therefore, feed management strategies should aim for optimizing feed inputs, reducing feed conversion ratios and reducing the potential impact of the feeds in the culture water and the environment.

Dependence of aquaculture on fish meal

Feeds and feeding usually represent the largest operating cost items in most fish and crustacean farming operations. Industrially compounded and farm-made aquafeeds as well as trash fish have been used as feed inputs in aquaculture farming. In 2006, Thailand, Indonesia, Philippines and Vietnam were the only countries in the region included in the top ten compound aquafeed producers of the world, where Thailand, Indonesia, Vietnam and Philippines produced 1.10-1.30 million tons, 0.75-0.90 million tons, 0.65-0.85 million tons, and 0.35-0.40 million tons, respectively (Tacon and Metian, 2008). Worldwide, 40% of all aquaculture production is dependent on industrial manufactured pellet feeds with the major part of the ingredients coming from the marine and coastal ecosystems (New and Wijkström, 2002).

Globally, the percentage of farms using commercial feeds varies from 100% in salmon and trout to 93% in shrimps, 73% in catfish and marine fish, and 47% in carp farms. Major aquaculture commodities, particularly carps had seen increased usage of commercial feeds from 20% in 1995 to 47% in 2007, and the use of commercial feeds in carp farming is expected to increase to 60% in 2020. Tacon and Metian (2008) declared that presently, 82-93% of all farmed shrimps are grown on commercial feeds while 95% of shrimp farming industries will be using commercial feed in 2020. Furthermore, Deutsh *et al.* (2007) pointed out that although carp feeds accounted for 60% of all aquafeeds produced, this change could have the greatest impact on fish meal quantities needed to meet the large volume of feed production. For the manufacture of formulated pellet feeds for farming of carnivorous fish species and marine shrimps in the world, the feed industry is still highly dependent on marine capture fisheries for the dietary nutrient sources of the feeds including fish meal, fish oil and low-value trash fish (Tacon *et al.*, 2006). Thus, Deutsh *et al.* (2007) added that while aquaculture is developing as a highly globalized trade-dependent industry, it will continue to increase the use of the marine fishery resources as can be traced and mapped from the patterns of the global trade flows for fish meal. Nonetheless, it should also be considered that fish meal is used not only in aquafeeds production but also for domestic livestock feeds (poultry, pigs, cattle, among others), although aquafeeds are largely used for carnivorous aquatic species and also as taste attractant for omnivorous and herbivorous fish species.

Traditionally, fish meal and fish oil have been used extensively in aquafeeds especially in high valued fish feeds, mainly due to their excellent nutritional properties such as source of energy and essential fatty acids. As natural ingredients, fish meal and fish oil have very high protein contents, including well balanced essential amino acids, minerals and essential fatty acids (Omega-3 Highly Unsaturated Fatty Acids). The benefits of fish meal and fish oil in aquatic animal feeds could include higher survival and growth rates as these are highly digestible, increased appeal, promote fish health, and reduced incidence of deformities. Wide variation of the use of dietary fish meal and fish oil were observed within and between countries for the same species (**Table 3**). Moreover, the results of a survey conducted by Tacon *et al.* (2008) indicated that the major commercial culture fish species, compound feeds production, fish meal and fish oil used in Thailand, Indonesia, Vietnam and Philippines vary as shown in **Table 4**.

Table 3. Ranges of fish meal (FM) and fish oil (FO) used in the manufacture of aquafeeds for specific cultured species

Species cultured	FM	FO
Shrimps	5 - 40%	0.5 - 10.0%
Salmon	20 - 50%	9.0 - 35.0%
Trout	15 - 55%	3.0 - 40.0%
Eel	40 - 80%	0.0 - 24.0%
Marine fishes	7 - 70%	1.0 - 15.0%
Tilapia	0 - 20%	0.0 - 10.0%
Milkfish	1 - 5%	0.0 - 2.0%
Freshwater prawns	5 - 25%	0.0 - 3.0%
Chinese carps	0 - 20%	0.0 - 2.0%
Catfish	3 - 40%	0.0 - 15.0%

In 2006, the top global consumers of fish meal based on cultured fish species were marine shrimps, followed by marine fishes, salmon and Chinese carps whereas the top consumers of fish oil were salmon followed by marine fishes, trout and shrimps. Tacon and Metian (2008) predicted that the use of fish meal and fish oil (derived from wild capture fisheries) by the aquaculture sector in terms of compound aquafeeds will decrease in the long term. However, the use of fish meal and fish oil usage would still increase in high value starter and finisher in broodstock feeds. The reason for such scenario could be a variety of factors which include the static and/or diminishing global supply of wild forage fishes; increasing market price of small pelagic forage fishes; global increasing costs of energy, processing, and transportation; static and/or diminishing supply of fish meal and fish oil for export.

Rana (2009) pointed out that even though fish meal production has been stable, aquaculture output has been clearly expanding and thus, in looking at the challenges for stabilizing and increasing aquaculture growth one should also focus foresight beyond the fish meal debate, especially if forecasts for fish production are considered. Nevertheless, due to various reasons that include increasing

price and limited supply of fish meal and fish oil, many attempts have been made to replace fish meal and fish oil with alternative feed ingredients for the sustainability of the aquafeeds industry, an effort which has been pursued in the Southeast Asian region, where numerous protein and oil sources including animal by-products, plant proteins and oils, and marine products from lower trophic levels having potential uses in aquafeeds had been tried as substitutes for fish meal and fish oil. The use of plant origin ingredients as sustainable alternatives to marine fish meal and fish oil in aquafeeds has great potential because these ingredients are highly available globally at competitive prices and have nutritional properties that satisfy the nutritional requirements of some fish. However, plant derived ingredients could also present some problems and challenges to successfully complete the replacement of fish meal and fish oil especially in carnivorous marine fish diets. Many studies have shown that partial replacement of fish meal and oil by plant origin ingredients does not affect the health and growth of fish, but such replacement had been found to be considerably easier for herbivorous/omnivorous fish species than for the more nutritionally demanding carnivorous fish species (Hardy and Tacon, 2002). In fact, only a small amount of fish meal and fish oil could be used in the diets for omnivorous and herbivorous fish species which are dominantly cultured in the world, mainly to increase fish appeal.

Since most of the Southeast Asian countries are agriculture countries, these countries have a comparative advantage over other parts of the world in terms of producing both feeds and fish. However, the recent opening of export market to the Middle East and Europe has influenced the culture practices of freshwater carps in Myanmar which has shifted to using formulated feeds to increase production (Aye *et al.*, 2007). It was however noted that in spite of the increased export of Indian major carps especially rohu (*Labeo rohita*), the availability and affordability of the fish to the local communities had not been affected (De Silva and Turchini, 2009). Nonetheless, the shifting trend from extensive to semi-intensive carp culture in Myanmar could increase the demand for feed ingredients. In this regard, Ng *et al.* (2007) suggested that for development of cost-effective farm- and factory-made feeds in Myanmar, research on nutrient and feeding requirements of major cultured species should be conducted, using locally available agriculture by-products such as rice bran and ground-nut cake. Moreover, farmers should be taught how

Table 4. Production of compound feeds, fish meal and fish oil used in the culture of major commercial fish species of selected countries in Southeast Asia

Country	Feed Production (tons)	Reported FCR	% Fish meal (ave)	% Fish oil (ave)
Shrimps				
Indonesia	312,000-400,000	1.4 -1.8 (1.6)	8-20 (15)	1.0-3.0 (2.0)
Philippines	15,000-30,000	1.2 -1.8 (1.5)	10-30 (20)	4.0-6.0 (5.0)
Thailand	650,000-750,000	1.2- 2.0 (1.5)	5-35 (25)	0.5-3.0 (2.0)
Vietnam	260,000-310,000	1.2-1.8 (1.6)	10-30 (20)	1.0-3.0 (2.0)
Marine fish (Barramundi)				
Thailand	1173	1.4-3.0 (1.8)	20-50 (35)	2.5-6.0 (4.0)
Tilapia				
Indonesia	84,000	1.8	3-8 (5)	1.0-2.5 (1.5)
Philippines	175,000	1.4-1.8 (1.6)	7	-
Thailand	151,200	1.3-1.7 (1.5)	0-20 (6)	1.0-3.0 (1.5)
Milkfish				
Indonesia	30,000-50,000	1.8	2-5 (3)	0.5-2.0 (1.0)
Philippines	200,000	1.8-2.7 (2.2)	5	-
Freshwater prawn (*M. rosenbergii*)				
Thailand	21,420	1.5-2.5 (1.7)	5-20 (15)	1.0-3.0 (2.0)
Common carp				
Indonesia	185,000-360,000	1.4-2.0 (1.7)	2-7 (5)	0.50-2.0 (1.0)
Catfish (include *Pangasianodon* spp., *Clarias* spp.)				
Indonesia	60,000-70,000	1.0-1.3 (1.2)	5-10 (7)	1.0-3.0 (2.0)
Thailand	113,400	1.2-1.5 (1.4)	5-20 (10)	1.0-3.0 (2.0)
Vietnam	400,000-500,000	1.4-1.8 (1.6)	5-15 (10)	1.0-2.0 (1.5)

Note: *Adapted from Tacon and Metian (2008)*

Above: Trash fish/low-value fish to be processed into aquafeeds in a fish meal factory in Myanmar; and
Below: Fish meal powder products of Myanmar

to make good quality farm-made feeds and proper feeding techniques, while the government should establish and promote the guidelines for good aquafeed manufacturing practices to address sustainability and traceability issues.

Low fish meal content in formulated diet for aquaculture

The current growth in global aquaculture is paralleled by an equally significant increase in companies involved in aquafeeds manufacturing. Aquaculture industries raising particular economically valued species such as penaeid shrimps and some marine fishes would require feeds with high demands on feed ingredients resulting in significant acceleration in demand for properly formulated aquafeeds not only for the present aquaculture condition but also for the next decades. As requirements for aquafeeds increase, shortages are anticipated in various ingredients, especially the widely used protein sources such as fish meal. A variety of other protein sources have been considered as partial or complete replacement for fish meal, especially the plant protein sources such as soybean meal. In the past five years, vegetable protein meal production has increased by 10% while fish meal production has dropped over 50% since 1989, which has been largely attributed to overfishing and serious decline in wild fish stocks. Recently, waste product from fisheries processing industries had been explored as potential source of ingredient that could replace fish meal. Feed costs are a major consideration in aquaculture especially for marine fishes, where high protein containing feeds using quality fish meal, can account for as much as 40 to 60% of production costs with about 67% of the actual feed cost is attributed to the fish meal protein fraction. Clearly, this is an untenable situation since global aquaculture had been increasing in size as well as in diversity of aquatic species cultured. Therefore, considerations such as cost and availability of commonly utilized aquafeed ingredients should also be recognized as new feed formulation practices development. Moreover, innovative approaches must explore the wide variety of processing by-products potentially available as source of nutritionally valuable ingredients in specific aquafeeds. However, this must be correlated with the availability of such ingredients, especially the plant and animal proteins in the local setting and the dictates of economic pressures. Notwithstanding such concerns, the final processed aquafeed must meet the specific physical standards such as water stability and palatability as well as satisfying the nutritional needs of the aquatic species being cultured.

Therefore, research effort is needed that could contribute to the compilation of feed ingredients particularly for sole protein source (fish meal) together with relevant performance data. This would be a worthwhile contribution to global aquaculture. The conduct of such study could also contribute to the better understanding of locally available aquaculture feed ingredients and in finding useful information on other potential feedstuffs for aquaculture diets through experimental feeding trials based on the needs of present day aquaculture. Hopefully, outputs of this effort will serve as a catalyst for further compilation and ultimate critical analysis of basic and applied information on a wide range of specific ingredients for use in commercial aquaculture.

Trash fish/low-value fish for aquafeeds

Another issue that confronts the aquaculture industry is the direct feeding of low-value or trash fish to higher value aquaculture species especially in grouper and soft-shell crab farming. Such practice is unsustainable, and in many cases created conflicts between the use of low-value fish for human consumption and use as feed ingredient. Nevertheless, the use of trash fish/low-value fish and/or other animal protein sources in farm-made feeds is still a common practice in freshwater and marine carnivorous fish culture as well as in crab and lobster fattening in Asia (De Silva and Turchini, 2009). Therefore, there is a need to know the extent of usage of fresh trash fish or low quality dried fish or meal against their direct use for human food, considering that the use of low-value or trash fish as feeds for high-value fish species is seen to be swelling in support of the expansion of aquaculture. This would place much

Table 5. Soft-shell crab farming areas in Myanmar and monthly total trash fish used (2010-2011)

State/Regions	Farms	Cultured Area (ha)	Total Stocking	Total trash fish fed (tons/month)
Tanintharyi Region	3	42.82	1,048,091	208.81
Yangon Region	5	42.38	2,147,000	89.76
Ayeyarwaddy Region	2	9.55	400,000	16.39
Rakhine State	2	14.28	106,000	16.44
Total	**12**	**109.03**	**3,701,091**	**331.40**

Note: *1.0 acre = 0.405 ha*

pressure on the long-term sustainability of the fisheries in which trash fish are caught. Thus, while aquaculture production grows dramatically in the Southeast Asian region, development of improved diets that do not rely on low-value or trash fish to substantially increase its production without threatening wild stocks remains a key challenge in this region. In the case of Myanmar, trash fish is widely used in mariculture although the availability of commercial pellet feeds and its use in sea bass, grouper and soft-shell crab culture are still very limited. Soft-shell crab farmers in Myanmar are still using the trash fish/low-value fish because of the relatively low cost involved. Trash fish utilized for the feed of soft-shell crab production means that low value fish are transformed to high value products. Currently, there are 314 acres of soft-shell crab farms in Yangon, Tanintharyi, Rakhine and Ayeyarwaddy State and Regions and 331.4 tons/month of trash fish are used as feed for crab farming (**Table 5**). De Silva and Turchini (2009) suggested that pellet feeds can be more effective than feeding trash fish in which case soft-shell crab farms can significantly reduce the cost of production.

Reduced use of trash fish or low-value fish should be promoted in the manufacture the fish meal and fish oil. While in Asia, fish meal manufacture is based on species mix of marine trash fish and seafood industry waste, specifically Thailand, Indonesia and Vietnam are among the top 16 producers, importers and consumers of fish meal (IFFO, 2008). Fish meal consumption in Vietnam has increased to 82,000 tons in 2004 from almost zero in 1999 whereas the importations of Thailand decreased from 10,080 tons in 2004 to 4,800 tons in 2006 because of increased domestic fish meal production. Although the local production of fish meal in Thailand was insufficient, they were able to increase their supply for its increased fish meal consumption by expanding its supply network through the other countries in the region and increasing the supply from abroad (Deutsh *et al.*, 2007). In this regard, Deutsh *et al.* (2007) suggested that maintaining heavy fishing pressure at lower levels of food web, spurred in part by ever increasing demand for fish meal in the growing aquaculture sector, may make it difficult for marine fish species at higher trophic levels to recover even if fishing pressure on these stocks had been significantly decreased. De Silva and Turchini (2009) reported that since fish meal production in other countries of Asia is growing slowly, a nation such as Myanmar which produces nearly 12,000 tons of fish meal would be of utmost importance to the region. As reported, fish meals are produced in Myanmar using trash fish that are not suitable for direct human consumption. Aye *et al.* (2007) reported that through such industry, a potential waste is eliminated and employment is created, indirectly contributing to poverty alleviation and food security. There are 14 fish meal plants and 27 fish-feed production plants in Myanmar (De Silva and Turchini, 2009) and that a number of significant trends in feed development and management

Table 6. Fish meal production, exported and locally used in Myanmar

Year	Total production (tons)	Exported			Locally Used (tons)
		Amount (tons)	Value (US$ Millions)	Price (US$/ton)	
2006-2007	23,700.900	15,546.259	8.504	547.0	8,154.641
2007-2008	24,022.500	19,801.246	12.545	633.5	4,221.254
2008-2009	21,756.590	13,256.220	7.108	536.0	8,500.370
2009-2010	36,423.056	21,080.270	10.551	500.5	15,342.786

Table 7. Trash fish used, energy used and fish meal production by Division in Myanmar

Division	Years	Trash fish used (tons)	Fish meal production (tons)	Production rate (% of raw trash fish)
Thanintharyi	2006-2007	71,021.28	23,700.900	33.37
	2007-2008	76,206.94	24,022.500	31.52
	2008-2009	66,502.40	20,588.140	30.96
	2009-2010	108,802.77	35,561.850	32.68
Yangon	2008-2009	4,830.71	1,168.450	24.19
	2009-2010	3,613.08	861.206	23.84

that have a bearing on dependence on fish meal/low-value fish or fish meal from external sources are taking place in Myanmar. However, there is very limited quality control in the commercial fish feeds produced in Myanmar.

Fish Meal Production in Myanmar

Of the number of fish meal plants in Myanmar, two are in Yangon Division, two in Mon State, and the rest are in the Thanintharyi Division. At present, two fish meal plants in Yangon and six plants in Thanintharyi Division are in full operation. Most of the fish meal manufacturing plants are located near the major fish landing sites. The produce of the fish meal plants is mostly exported as well as used by local poultry feed factories and to a lesser extent used in aquafeed factories.

Normally, to produce one ton fish meal, 3-4 tons of trash fish would be required. Fish meal plants in Yangon Division are using 4,221.895 tons of trash fish to produce 1,014.848 tons of fish meal while factories in Thannintheryi Division are producing 25,968.34 tons of fish meal by using 80,633.34 tons of trash fish. Fish meals produced in Myanmar contain 50-60 percent protein contents. Myanmar fish meal is exported to Malaysia, Bangladesh, Singapore, China, India, Japan, Kuwait, Vietnam and Thailand. Some details of the fish meal production of Myanmar are described in **Table 6** and **Table 7**. However, owing to limited information the effect of fish meal production on the fish stocks could not be analyzed.

Way Forward

In order to expand the aquaculture industry of Myanmar, R&D mechanism should be strengthened advocating effective feed management and reduced dependence on fish meal. In addressing these concerns, approaches should be promoted such as the culture of herbivorous fish species or bivalves and the practice of an integrated aquaculture system to simultaneously produce fish and shellfish. Using locally available plant by-products would be promoted in the research on nutrients and feeding management of major culture species. In Myanmar, quality control on commercial fish feeds and establishment of guidelines for good aquafeed manufacturing practices are most essentially and urgently needed. Data collection and analyses of the effects of fish meal production on the development of the aquaculture industry (dependence on resources: heavy fishing pressure at the lower levels of the food web) and on fish stock should be conducted to respond to the environmental concerns. This is true not only for Myanmar but for the Southeast Asian region as a whole. The small pelagic fish resources should be conserved for food web support and not just targeted for human catch at the maximum sustainable yield. In addition, the uncertain impacts of climate change on small pelagic fisheries in the future are important points that should also be considered. Therefore, the implementation of an ecosystem approach to aquaculture and fisheries should be taken into consideration by the fisheries agencies in the region.

Fish for Aquaculture Feed

Based on the report of the 18th Meeting of the ASEAN Sectoral Working Group on Fisheries (ASWGFi) in June 2010 in Brunei Darussalam, each ASEAN member country has to lead the implementation of various measures that would enhance the development of the fisheries sector in the region. In this connection, Myanmar has been tasked to serve as the lead country for the cluster on Fish for Aquaculture Feed. In carrying out such responsibility, a Working Committee would be organized by DoF of Myanmar to take charge of the development of fish meal replacement feed for aquaculture, explore the alternative protein sources for aquaculture feed, and coordinate with other ASEAN countries and regional fisheries organizations during research and development processes. Thus, Myanmar had set up its plan of action to implement these measures as shown in **Box 1**. Data collection and information on fish meal applied in freshwater and seawater aquaculture sector by the ASEAN countries will be conducted through the assistance of the Department of Fisheries of Thailand, while research activities focusing on the use of soybean meal, green pea and by-products of clam meat will be carried out by the DoF of Myanmar.

Box 1. Myanmar's Plan of Action for the development of fish meal replacement for aquaculture

- Organize the National Task Force for Fish for Aquaculture Feed Project
- Collect and compile data and information from the ASEAN countries on fish meal used in the freshwater and seawater aquaculture sector, the fish meal quantity used for aquaculture, impact of fish meal production on fisheries resources, other alternative sources to substitute fish meal feed in consultation with Thailand, the Alternative Chairperson of the ASEAN Fisheries Consultative Forum (AFCF)
- Implement research and development process by utilizing agro-based products and other by-products potentially available from local areas, for nutritionally valuable ingredients in specific aquafeeds
- Evaluate fish meal replaced feed research activities in other ASEAN Member Countries
- Cooperate with other ASEAN countries and regional organizations for the conduct of relevant research activities
- Organize workshops with the participation of ASEAN countries and regional fisheries organizations
- Conduct pilot scale production of fish meal replaced aquafeeds
- Assess and evaluate the pilot scale production of fish meal replaced aquafeeds

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