Way forward

The diverse educational backgrounds of farmers and their perception of the different aspects of aquatic animal health could be one of the challenges in fish health management. This concern could be addressed through regular conduct of activities on capacity building, information dissemination, and regular field consultation with local health officers. IEC materials are an efficient mode of awareness building since it can be illustrated, translated to local languages, and can be taken home by farmers for future reference.

Problems with transboundary and emerging diseases necessitate the formulation of new trade requirements within the region. Laboratory diagnostic capabilities and disease surveillance and monitoring programs should therefore be boosted. The existing networks reporting to WAHIS and Quarterly Aquatic Animal Disease (QAAD), and the transparent and prompt trans-national notification of new disease situations should be strengthened. The OIE and WAHIS system and QAAD reports to NACA are excellent platforms for the transparent reporting of country disease status. These systems will facilitate the timely notification of significant pathogen detections and the implementation of mitigation measures within the region.

Incorporation of water quality and other environmental issues in training courses, IEC materials, and laboratory services would help mitigate the effect of aquatic diseases. Aquatic animal health practitioners, as well as farmers, should understand the effect of environmental conditions on the general health of aquatic animals.

The capabilities of laboratory personnel in disease diagnosis can be enhanced through the twinning program of OIE. Personnel in satellite laboratories should also be trained for Level III diagnosis and equipment should be also upgraded in these laboratories.

7.1.3 Overcoming Fishmeal Dependence in Aquaculture

Fishmeal has traditionally been used as a primary source of protein in aquaculture feeds because of its high digestibility and well-balanced amino acid profile. Although global consumption has declined since its peak in 1996 (6.3 million mt per year), current rates are roughly three times of those 57 years ago and have been on a gradual uptrend since 2012 as shown in **Figure 100** (Indexmundi.com, 2021). The fishmeal consumption of the AMSs similarly peaked in 1999 at 1.9 million mt per year, before it gradually declined in subsequent years. In 2020, the AMSs collectively utilized 966, 000 mt of fishmeal accounting for more than 20 % of the global consumption rate.

The leading sources of high-quality fishmeal (Peruvian, Chilean, Danish) produced from small pelagic fishes like anchovies, scads, mackerels, herrings, and menhadens are the Latin American and the Nordic region. In Southeast Asia, Thailand and Viet Nam are the largest producers and exporters of fishmeal made from multispecies bycatch and trimmings (*e.g.* tuna) from the fish processing industry (Leadbitter, 2019).

However, the aquaculture feed industry's overdependence on fishmeal has both economic and ecological implications. Fishmeal is becoming more expensive as the rapid growth of the aquaculture feed industry pushes prices up. In Southeast Asia, trash fish or low-value fish bycatch are used as raw materials for fishmeal production as well as for human consumption, intensifying the demand for this resource strains the wild fisheries.

The adoption of alternative feed ingredients, especially protein sources, in aquaculture feeds is recognized as a viable option to reduce fishmeal overdependence and consequently to make fish farming more sustainable. Fishmeal substitutes and the status of their utilization in the region had been the focus of a consultative gathering of representatives from the AMSs in Myanmar in 2014 (Catacutan *et al*., 2015). Besides utilizing alternative feed ingredients in feed development, feed management strategies should be taken into consideration as it can also affect the profitability of aquaculture operations.

Use of Aquaculture Feeds

Several commercially important species are cultured in the region and their feeding habits, dietary protein

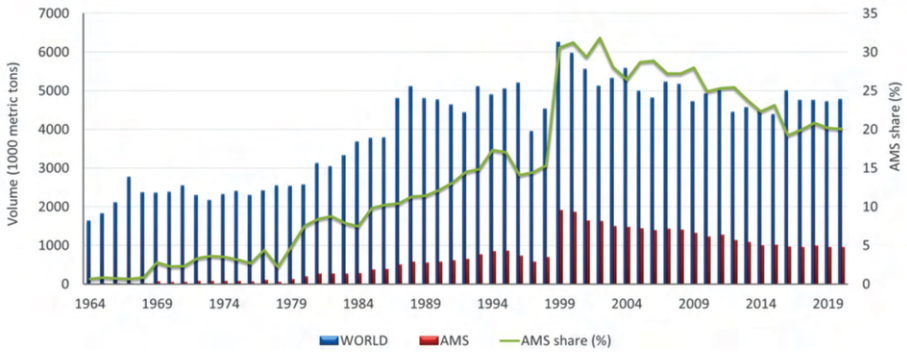

Figure 100. Fishmeal consumption of world and the AMSs from 1964 to 2020

requirements, and farming systems determine how much fishmeal is used in their diets. Herbivorous (*e.g.* milkfish, carps, and barbs) and omnivorous (*e.g. Pangasius* and tilapia) fishes require relatively lower dietary proteins (25–40 percent), therefore, the levels of fishmeal in formulated diets for these animals tend to be similarly low. On the other hand, carnivorous species (*e.g.* catfish, snakehead, sea bass, grouper, crabs, and shrimps) require high levels of dietary protein in their diets. These fishes are fed either raw low-value fish or aquaculture feeds which correspond to the nutrient requirement of the cultured fish species. Furthermore, low-value freshwater species are cultured in extensive or semi-intensive farming systems, relying mainly on natural food with occasional supplementation of plant-based feedstuffs such as rice bran. Species with higher commercial value, such as milkfish, tilapia, *Pangasius*, sea bass, and shrimps, are fed aquaculture feeds which are either manufactured domestically or imported from neighboring countries. Mangrove crabs and groupers are more often fed exclusively on fish bycatch.

Table 72. Aquaculture feed utilization of the ASEAN Member States

Country	Aquaculture feed utilization
Brunei Darussalam	With primary cultured species that include blue shrimp as well as groupers, Asian seabass, giant tiger prawn, pompano, snappers, jacks, tilapia, and milkfish (FAO, 2021) in intensive and semi-intensive types of culture in ponds, coastal and offshore cages, and recirculating aquaculture systems; most fish farmers require formulated feed inputs which are mainly imported
Cambodia	Freshwater aquaculture accounts for 90 percent of the total aquaculture production with *Pangasius* sp., snakehead, silver barb, cyprinids, gourami, and tilapia being the most cultivated species along with carps and catfishes as well as marine fishes such as Asian seabass and grouper (Somony, 2017; FAO, 2021); utilization of aquaculture feeds is limited due to high feed cost so farmers use farm wastes and by-products as well as "trash fish" either as sole feed or in combination with rice bran as a source of nutrition for the cultured fish (Joffre, 2019; Chankakada *et al.*, 2020)
Indonesia	Aquaculture production being dominated by Nile tilapia, milkfish, torpedo-shaped catfish, white leg shrimp, common carp, *Pangasius* sp., giant gourami, and giant river prawn (FAO, 2021) grown in ponds, paddy fields, and cages; demand for aquaculture feeds is large and continuously growing but the feed manufacturing industry relies significantly on imported materials such as fishmeal, soybean meal, corn meal, and blood meal driving up the cost of commercial feeds (Laining & Kristanto, 2015; Sarifin, 2017)
Lao PDR	Aquaculture is mainly centered on freshwater species such as tilapia, carps, barbs, catla, and rohu (FAO, 2021); requires commercial feeds for pond- and cage-cultured fish particularly tilapia while in other farming systems, supplemental feeding is done using local materials such as plant-based materials (rice bran, vegetables, corn, rice, cassava) and insects (Tammajedy, 2017)
Malaysia	With at least 40 cultured species that include whiteleg shrimp, tilapia, torpedo-head catfish, *Pangasius* sp., Asian sea bass, and giant tiger prawn that are being produced in significant volumes (FAO, 2021) in ponds, used mining pools, tanks, and cages; these commodities are fed locally-produced as well as imported formulated feeds (Yusoff, 2015; Manaf, 2017), but in hatchery operations, shrimp and fish broodstock are traditionally given raw, unprocessed maturation diets such as squid, polychaetes, fish, and bivalves
Myanmar	Aquaculture is dominated by rohu, silver barb, common carp, tilapia, and giant tiger prawn and at least 15 other species including catfishes, giant freshwater prawn, and marine fishes cultivated (FAO, 2021) in ponds and cages; fish farmers typically combine rice bran, peanut oil cake, sesame cake, cottonseed cake, rapeseed cake, soybean meal, mustard oil cake, and wheat bran to make daily feeds for most freshwater species, while tilapia, *Pangasius*, tiger shrimp, and sea bass are fed formulated feeds, and softshell mangrove crab and grouper are still heavily reliant on fish bycatch (Kyaw, 2015; Moe, 2017)
Philippines	The major cultured finfish and crustacean species such as milkfish, shrimp, tilapia, and mangrove crab with catfish, carp, siganid, grouper, freshwater prawn, and *Pangasius* sp. being produced in smaller volumes (Philippine Statistics Authority, 2020), are fed formulated feeds that are already commercially available for these species and are heavily used in cage culture and semi-intensive and intensive farming in ponds; some farmers rely on natural food while fish bycatch is still used in feeding mangrove crabs and grouper
Singapore	The majority of aquaculture production is from coastal farms with milkfish, mullet, Asian sea bass, grouper, snapper, and pompano as the favored species while land-based farms produce catfish, tilapia, snakehead, gourami, marble goby, and carps (Ong & Ong, 2015; FAO, 2021), which fed either "trash fish", commercial and farm-made formulated feeds, processed (confectionery) and by-products (plant waste, fish trimmings, poultry by-products); recent developments are now aimed at transforming fish farming into a more high-tech system (*e.g.* vertical aquaculture farm) to improve fish production (Shen *et al.*, 2020)
Thailand	The utilization rate of aquaculture feeds is high, with feeds for fish species comprising around 90 percent of the total aquaculture production costs (Krongpong, 2017) of cultured finfish and crustacean species that include whiteleg shrimp, giant tiger prawn, tilapia as well as catfish, carp, and giant freshwater prawn (Sampantamit *et al.*, 2020), which are fed four types of commercially accessible diets, *i.e.* for eight farmed species complete feed, concentrated feed, premixes, and supplemental, all of which are regulated by DOF Thailand
Viet Nam	The utilization rate of locally-produced aquaculture feeds is high given the intensive farming of the most economically important species, *Pangasius* sp. as well as black tiger shrimp, whiteleg shrimp, Asian sea bass, snakehead, carps, tilapia, and at least five more species in ponds, floating cages and rice-fish farming systems (Tuan, 2015; FAO, 2021), which are fed locally-produced feeds for all life stages of fish, particularly *Pangasius* sp., which are available commercially (Hasan *et al.*, 2019)

Table 73. Estimated feed demand (thousand mt) in 2017 and 2019 in selected ASEAN Member States

	2017			2019			Increase rate (%)
	Fish feeds*	Shrimp feeds	Total	Fish Feeds	Shrimp Feeds	Total	
Viet Nam	2,700	450	**3, 150**	4,560	1, 000	**5, 560**	76.51
Indonesia	1, 263	330	**1, 5963**	1, 460	352	**1, 812**	13.81
Thailand	495	450	**945**	613	478	**1, 091**	15.43
Philippines				275	100	**375**	
Malaysia	96	85	**181**	130	105	**235**	29.83

Source: *Merican, 2018; Merican, 2020*
**Includes feeds for freshwater and marine fishes*

The intensity of aquaculture feed utilization in the respective AMSs varies according to the level of aquaculture operations and the farming systems being practiced (**Table 72**). Some AMSs depend heavily on aquaculture feeds, particularly those engaged in intensive farming systems, while some have minimal usage.

The estimated feed utilization for species (*i.e.* Chinese carp, tilapia, catfish, shrimp, freshwater crustacean, milkfish, other marine and freshwater fish) typically grown in Southeast Asia increased dramatically from 2000 to 2017 posting an annual percentage rate (APR) of 8 percent per year (Tacon, 2020). From 2017 through 2025, this is expected to increase at a rate of 4.5 percent each year on average. Gains in feed utilization vary significantly among the AMSs (**Table 73**), with Viet Nam posting the largest rise between 2017 and 2019 (Merican, 2018; Merican, 2020). Overall, the feed consumption of the region's cultured commodities increased significantly, owing to the rapid rise of fed aquaculture.

Research and Development on Alternative Feed Ingredients

The Ministry of Maritime Affairs and Fisheries of Indonesia, in partnership with the FAO, launched the Aquafeed Self-sufficiency Movement from 2017 to 2019 to create an aquaculture feed supply chain that is independent of external inputs (FAO, 2020). The use of locally accessible ingredients had therefore been encouraged by the initiative to reduce production costs. Palm kernel meal (PKM), a byproduct of the country's massive palm oil industry, was investigated as a cost-effective aquaculture feed ingredient. This product can replace up to 20 percent of fishmeal in feeds. Other local ingredients utilized in farm-made feeds include copra meal, rice bran, duckweed, turi wheat (*Sesbania grandilflora*) leaf meal, detoxified *Jatropha curcas* kernel meal, and aquatic weed *Ceratophyllum* sp. Shrimp head meal and local fishmeal made from fish processing wastes had been particularly considered important as animal protein sources. Imported soybean meal is also widely used.

Malaysia has conducted extensive research into using fishmeal substitutes in aquaculture feeds (Manaf & Omar, 2015; Manaf, 2017). Agricultural resources and byproducts, as well as wastes from agro-industrial processing sectors like bone meal, blood meal, and chicken byproduct meal, are used as alternative protein sources in commercial and farm-made feeds. Plant protein sources (*e.g.* soybean, canola, wheat gluten, and pea) have been utilized successfully in omnivore fish diets, whereas poultry byproduct meal and shrimp head meal have been studied in carnivorous species diets. Single-cell proteins from microbial fermentation, food processing wastes, insect meal, bioethanol industry byproducts, and microalgae have also been investigated.

For several years, researchers in the Philippines have been studying alternative protein sources, including a wide range of locally available materials with the potential to replace fishmeal (Cruz *et al*., 2015, Mamauag, 2016; Aya, 2017). These include a variety of leaf and seed meals (*ipil ipil*, sweet potato, papaya, feed pea, and cowpea), aquatic weeds (water hyacinth, crinkle grass), food agricultural wastes (mango peels, citrus pulp, and peels), food processing byproducts (meat and bone meal, poultry byproduct and okara), processed raw materials (spray-dried hemoglobin meal, protein-enhanced copra meal and distiller's dried grains with solubles (DDGS)), microalgae (*Arthrospira platensis* and *Chlorella vulgaris*), and other unconventional feedstuffs (snail and earthworm). These ingredients had been tested in diets for marine and freshwater finfish and shrimp, giant freshwater prawn, and abalone.

In Singapore, studies on the use of food processing wastes such as okara (soybean curd residues) and fish trimmings revealed that feed made from these sources could complement commercial feeds for cost-effective snapper culture (Yihang & Ong, 2015). Recently, a commercial enterprise is pursuing large-scale production of the black soldier fly larvae meal as a source of protein for aquaculture feed and pet meals (The Fish Site, 2020). Because of its beneficial nutritional composition, insect meal is considered a good fishmeal alternative.

Research on the utilization of alternative ingredients in aquaculture feed in Thailand focused on replacing fishmeal with plant and animal protein sources in the diets of major cultured species (Kosutarak, 2015; Krongpong, 2017). These ingredients include soybean meal, sesame meal,

palm kernel meal, peanut meal, coconut meal, poultry meal, pig meal, meat and bone meal, feather meal, silkworm meal, snail meal, and fish and shrimp hydrolysates. Although locally available, these are also utilized by other sectors (*e.g.* livestock, pet food, fertilizer, and biofuel) or consumed directly as human food. Thus, aquaculture feed manufacturers remain reliant on imported ingredients. The country is also a key fishmeal producer in the region and globally, although the issue related to illegal, unreported, and unregulated (IUU) fishing had a severe influence on the country's aquaculture feed sector (Leadbitter, 2019), highlighting the need for alternative feed ingredients.

In Viet Nam, locally grown and imported soybeans are widely used in commercial feeds (Tuan, 2015). According to studies, soybean meal may replace up to 80 percent of fishmeal in catfish diets, 30 percent in snakehead and knife fish diets, and 50 percent in pompano diets. Other imported plant protein sources include canola meal, corn gluten, peanut meal, cottonseed meal, and sunflower seed meal.

Aside from using alternative feed ingredients, the cultivation of low-trophic level species that require low protein levels in their diets is also promoted, as non-animal protein sources are efficiently utilized by these species. Likewise, feed management strategies have been studied to reduce feed costs and address pressing water quality issues from culture production. Skip feeding has been suggested as an economically and environment-friendly practice in the cage culture of Nile tilapia in the Philippines (Cuvin-Aralar *et al*., 2012). In addition, a biofloc-based aquaculture system has been demonstrated as a sustainable approach in the production of various farmed species such as giant freshwater prawn, Pacific whiteleg shrimp, and catfish (Cuvin-Aralar, unpublished data; Ekasari *et al*., 2019).

Fishmeal Substitution in Diets of Aquaculture Species

SEAFDEC/AQD research efforts in recent years have concentrated on finding alternative protein sources in milkfish, grouper, tiger shrimp, tilapia, giant freshwater prawn, and abalone diets to reduce feed costs. However, few studies have been done on the inclusion of plant-derived feed additives in aquaculture feeds for these species.

Supplementation of soybean meal and soy protein concentrate at 40 percent in a low fishmeal milkfish diet gave excellent performance against commercial feeds (Coloso, unpublished data). Meat and bone meal, when supplemented at 30 percent in the milkfish diet, promoted good growth and survival, and also showed no histological alterations in milkfish tissues (Catacutan *et al*., 2015). A previous milkfish feeding experiment verified the beneficial use of DDGS in milkfish diet formulation (Mamauag *et al*., 2017). Feed efficiency and growth in fingerlings of other species, such as grouper (*Epinephelus fuscoguttatus*) increased when fed a diet containing 10 to 15 percent hydrolysate from milkfish offal (Mamauag & Ragaza, 2016). In addition, fermented copra meal (PECM®, protein-enhanced copra meal) can entirely replace soybean meal in the diets of grouper juveniles (Mamauag *et al*., 2019). Furthermore, spray-dried hemoglobin meal can be utilized in pompano diets (Mamauag *et al*., 2021).

Tank- and lake-based cage feeding studies showed the potential of replacing fishmeal with cowpea meal in giant freshwater prawn feeds at 30 to 45 percent inclusion level (Aya *et al*., 2015). Also, beneficial utilization of agricultural wastes and byproducts have been tested in diets for freshwater fish such as Nile tilapia (Aya *et al*., unpublished data). About 30 to 45 percent of okara meal could replace fishmeal in the diet, as well as supplementation of one percent each of citrus peel and citrus pulp as feed additives promoted better growth performance of tilapia fingerlings. Meanwhile, tilapia fry production increased when broodstock diets were supplemented with 50 percent ensiled mango peel. Moreover, the inclusion of up to 75 percent processed meal from invasive knife fish (*Chitala ornata*), an introduced species in the Philippines, in the diet of Nile tilapia juveniles resulted in higher growth performance (Abarra *et al*., 2017).

Diet development studies in land-based tanks for the tropical abalone, *Haliotis asinina*, revealed that with a good binder, the marine sources of protein in formulations could be reduced with a significant increase in shell length and weight gain, potentially shortening the culture period (Bautista-Teruel *et al*., 2016). Evaluation of enriched *Ulva pertusa* also showed that this seaweed species could partially replace fish and soybean components of formulated feeds for juvenile abalone (Santizo-Taan *et al*., 2019), while raw and fermented meals derived from *Chaetomorpha linum* can be included in the diet of black tiger shrimp at six percent and 12 percent inclusion levels, respectively (Biñas, unpublished data).

Polychaete production research has also begun at SEAFDEC/AQD (Alava *et al*., 2017; Mandario, 2020), in acknowledgment of their ability to improve crustacean maturation and their potential as an alternative protein source in aquaculture feeds.

Issues and Challenges

Several issues and challenges have been recognized regarding the use of alternative sources as fishmeal replacements in the diets of various aquaculture species. Information on anti-nutrient factors, nutrient composition, pesticide residues, and quality are key considerations in utilizing plant-based feed ingredients. While several local sources had been identified and tested, production volume remains insufficient to support commercial-scale feed manufacturing. There is also limited information on the digestibility, amino acid composition, and appropriate

dietary inclusion levels of many plant-based fishmeal substitutes. In addition, appropriate processing techniques to increase the nutritional composition of alternative ingredients that can be locally sourced needs further studies. Standards on the quality and safety of alternative feed ingredients specifically for use in aquaculture feeds have yet to be developed. Stakeholders interested in alternative protein sources have limited access to the results of feed development studies or the low adoption of these feed formulations by the commercial feed companies.

Way forward

Continued development of alternative feeds for economically important fish species in the region is necessary. Other raw materials that hold enormous potential in aquaculture feed formulation should be explored and evaluated under realistic farm conditions. These include biofloc meal, insect meal, aquatic weeds, and other agriculture and fisheries wastes and byproducts which could keep production costs down. Suitable equipment is also needed to process a huge amounts of these unconventional raw materials as feed ingredients. In this aspect, the collaboration between local government agencies, the academe, and research institutions is encouraged to develop low-cost equipment to process these materials into utilizable feed ingredients.

In 2018, SEAFDEC/AQD initiated the development of a database on alternative feed ingredients (http://afid.seafdec.org.ph). This initiative is a crucial step to collate and exchange information among the AMSs on the emerging alternative feed ingredients with promising use in aquaculture feeds. At present, the database covers information from at least 70 published papers. This will be constantly updated for there are many new and novel protein sources that are successfully applied to replace fishmeal in aquaculture feeds. In fact, a lot of alternative plant-based protein sources are continuously produced with the help of biotechnology. Research efforts should also address the application of emerging protein and lipid sources in aquaculture feeds and their effects not only on the biological performance but also on the fish health and quality of farmed species. Also, appropriate processing treatments to enrich the nutritional value of locally available indigenous protein sources should be applied and their suitability, viability, and profitability tested in diets of farmed species to promote cost-effective feeds for fish culture. Therefore, cooperation and collaboration among the AMSs, specifically the research and development institutions, private sector, and the academe both at the national and local levels, in several areas of research in fish nutrition and feed development should be strengthened, especially now that biotechnology is employed in producing cost-effective feeds. It is also of paramount importance that the promotion of alternative feed ingredients and sound feeding management practices be integrated or addressed in synergy in future feeds and feeding studies, the results of which should be disseminated to small-scale fish farmers engaged in fish culture. Other policies recommended for the AMSs on overcoming the dependence on fishmeal by development and use of alternative dietary ingredients in aquaculture feed are shown in **Box 34**.

Box 34. Recommended policies on the use of alternative dietary ingredients in aquaculture feeds

- Develop national standards on alternative feed ingredients, including the protocols for detecting contaminants in alternative feed ingredients and aquaculture feeds
- Increase regional and local awareness of the importance of reducing aquaculture's reliance on fishmeal and "trash fish" as major protein sources for aquaculture species
- Create a network involving food (fish and fruit) processors and aquaculture feed millers at the national and local levels to determine the volume of wastes and byproducts generated from the primary food processing industries and their potential use in aquaculture feed production
- Strengthen collaboration among the government sector (particularly the policymakers), research and development institutions, and the private sector (feed industry and farmers) on initiatives related to identification, development, promotion, and mass production of alternative protein sources
- Implement programs on the proper processing techniques of alternative feed ingredients to maximize their use in aquaculture feed formulations that small-scale fish farmers can adopt
- Compile and disseminate information on available alternative plant products through training programs as well as traditional and online information-sharing platforms
- Conduct field trials involving farmers, extension workers, and feed millers to demonstrate the effectiveness of using alternative ingredients in formulated feeds

7.1.4 Production and Dissemination of Good Quality Seedstocks

Aquaculture continues to lead aquatic food production globally (FAOa, 2019) with over 90 percent (102.9 million mt) of global aquaculture production is supplied by Asia in 2017. Southeast Asia plays a significant role in food security, with freshwater fish accounting for 30 percent of the aquaculture production. The region continues to move towards intensified farming of high-value aquaculture species (*e.g.* shrimp, mangrove crab, seabass, grouper, pompano, among others), which was previously dominated by low-trophic herbivorous fish (*e.g.*, milkfish, tilapia, siganid, carp).

With the diminishing production of capture fisheries over the years, the focus has shifted to the aquaculture industry in order to respond to the increasing demand for fish, thus, requiring increased area and intensified production. However, propelling this strategy has resulted in increased production cost from feed inputs, deterioration of the environment (land and water), an outbreak of viral and bacterial diseases, and reduced quality of seedstocks. Extensive research and development on replacing fish