economic losses are rationally precluded during the course of shrimp cultivation.

6.2 Overcoming the Fish Meal Dependence in Aquaculture

In recent years, the inclusion level of fish meal in commercial aquafeed formulations had decreased but in terms of quantity, fish meal usage actually increased due to increased production of aquaculture feeds in the Southeast Asian region. Fish meal or fish by-catch is a major source of protein in aquaculture feeds and its widespread use puts pressure on wild fisheries, an important source of food for the human population. The aquaculture industry's dependence on fish meal has long been recognized and the use of alternative protein sources as substitute for fish meal was the theme of the consultative meeting of representatives from the AMSs in Myanmar in 2014 (Catacutan *et al*., 2015).

Protein source in aquaculture feed is expensive because of its bulk in the feed formulae. For decades, researches on suitable alternative protein sources to overcome the dependence on fish meal had been conducted by many research agencies including the SEAFDEC Aquaculture Department (SEAFDEC/AQD). Nutrient levels in materials with potential as protein sources in aquafeed were analyzed and tested for acceptability or suitability in popular species for culture. These resources mostly come from plants, some from processing by-products, and few from unconventional sources. At SEAFDEC/AQD, the materials had been processed for testing in diets of culture species such as sea bass, abalone, milkfish, catfish, grouper, snapper, and shrimps.

6.2.1 Status on Use of Aquaculture Feeds

The level of use of alternative protein sources in aquaculture feeds is not of the same intensity in every AMS. Some countries are moderate to heavy users of aquaculture feeds, reflective of the level of their respective aquaculture operations. However, other countries use very minimal volumes of aquaculture feeds or none at all because their aquaculture operation is dependent on available fish by-catch coming from either fresh or marine waters.

Countries which are low to moderate users of aquaculture feeds have shown trends towards increasing their aquaculture production. Some countries are catching up to increase production from aquaculture by engaging the private sector and their governments to build bigger capacity aquafeed mills, modify tax on importation of materials such as fish meal, and train farmers on using aquafeed. Increase in aquaculture production is also triggered by the increasing human population and consequently demand for fish protein which can be supplied through aquaculture. Importation of aquaculture feed or feed ingredients has also increased in countries with common borders. Thus, it is clear that the demand for aquaculture feeds would continue to increase in the future.

6.2.1.1 Feed utilization of aquaculture species

Some aquaculture species are common to all AMSs, and classification of these species according to feeding habits will be helpful in obtaining information on the extent of fish meal use in aquafeed. These species vary in their dietary requirements for protein and subsequently the optimum dietary level contribution from fish meal. The species could be classified as herbivores (*e.g.* milkfish, carps, and barbs), carnivores (catfish, snakehead, sea bass, grouper, and black tiger shrimp), and omnivores (*Pangasius* and tilapia).

In most AMSs, farmed freshwater species generally consume less formulated feeds as such species are mostly low-value with culture systems that usually depend on fish by-catch or on natural food available in culture facilities during rainy months. For countries with access to sea water, there is an immense use of commercial feeds where high value species, such as sea bass and grouper, are cultured for export or for local consumption. Since this system of culture is expanding in the region, fish meal usage would surely continue to increase.

6.2.2 Research Efforts to Overcome Fish Meal Dependence in Aquaculture

Research and development efforts on fish meal and fish oil substitution in aquafeed with locally available ingredients are ongoing and being done by most AMSs. Agencies or entities engaged in this activity are their respective Departments of Fisheries, universities, and the private sector. For example in Thailand, a major aquaculture producing country, its Department of Fisheries oversees the production of commercial aquafeed for eight species. Also, there is an ongoing involvement by the Government, feed millers, and fish farmers to ensure the sustainable development and use of alternative dietary ingredients in aquafeed.

In Indonesia, production of local fish meal is high but only 5% of the total production goes to aquafeed and the rest is exported. Thus, the cost of commercial feed has increased because 70% of feed components is imported, the price of which continues to increase every year. Efforts towards reduction of fish meal in commercial diets have been done particularly for freshwater species where 5-11% is fish meal compared with that in marine fish species (> 30%) and shrimp (20-30%). Soybean meal is highly utilized to replace fish meal in commercial feed production but this is

entirely imported as local soybean is used for processing *tempeh* and *tofu*. The use of soybean in commercial feed for low-value species like carp, tilapia, catfish, *Pangasius*, and milkfish would not be competitive in terms of price. Hence, local ingredients like copra or palm cake meal, rice bran, and tapioca are utilized in farm-made feeds in areas where commercial feeds are not available. Local products from animal sources such as shrimp head meal, blood meal, golden snail, and vermi meal have been evaluated and could be used at 8-30% in diets of groupers. Plant ingredients containing > 20% protein (copra cake meal, rubber seed meal, *Leucaena* leaf meal, and aquatic weed meal) have been extensively evaluated and could be used at levels ranging from 10% to 60% depending on the species. Anti-nutrient substances limit the use of these plant sources and bio-processing using proper organisms is being developed to improve quality.

Extensive research to replace fish meal in aquafeed formulation has been conducted in Malaysia. Alternative sources used by commercial feed millers or at the farm include soybeans, canola, wheat gluten, pea, agricultural derived products and by-products, and also waste of agro-processing industries (bone meal, blood meal, poultry meal by-product, oilseed meal, cereals, and cereal by-products). However, research findings and current status of utilization of some materials such as microalgae, single cell proteins from microbial fermentation of waste materials, ento-protein from insect-based sources, and distillers dried grain soluble (DDGS) in commercial aquafeed have not been made known to the public. Replacement of fish meal in diets of omnivorous freshwater species to sustain fish production had been successful in the region, and the DOF of many countries had been promoting the farming and consumption of fish species such as tilapia, catfish, and grass carp.

Soybean is the most commonly used plant protein in commercial feeds in Viet Nam. Replacement of fish meal by soybean meal had been studied, and results indicated that such replacement in catfish diet could be 80%, for snakehead and knife fish diet at 30%, and pompano diet at 50%. In 2013, the country recorded high importation of plant sources (canola meal, corn gluten, palm seed meal, rice bran, peanut meal, cotton seed meal, and sunflower seed meal) but these might not have been all used in manufacturing aquafeed. In Singapore, research results conducted by a government agency showed that the residual fibrous part of soybean or okara mixed with minced fish trimmings could be used to supplement commercial feeds for red snapper.

Aquaculture in Cambodia and Lao PDR relies on available low value fish by-catch as feeds, but farmers have begun to import commercial feeds mostly for the hatchery operations because of increasing aquaculture activity. In Myanmar, the volume of export of fish meal to six countries decreased in 2013-2014 compared with that in 2010-2011. This is indicative of the increasing use of this commodity in the country where aquaculture is practiced in freshwater, brackishwater, and coastal areas. For freshwater species, the aquaculture feeds are made from locally-available agricultural by-products, *e.g.* rice bran, boiled broken rice, and oilseed cakes but feeds for tiger shrimp and sea bass are imported. The country also produced soybean meal but the quality has to be improved. Marine feed ingredients are also available such as shrimp shell and head meal, as well as dried fish powder which could be used as attractants.

6.2.3 Fish Meal Substitution in Diets of Aquaculture Species

Results of nutritional studies on alternative protein sources have been published for many aquaculture species. In the last few years, the research efforts of SEAFDEC/AQD focused on diets of milkfish, abalone, and grouper. Soybean meal is the most popular or successful plant protein source to substitute fish meal in diets of almost all aquaculture species. This plant source and its derived products such as soy protein concentrate are utilized by milkfish at 40% of the diet at a lowest fish meal level of 15% with no negative effects on growth and survival (Coloso, unpublished). Since soy bean meal is an imported product, other cheaper sources were tried such as the DDGS to replace a portion of soybean meal in feed formulations for milkfish fingerlings (Mamauag *et al*., 2017). Milkfish digest the protein in formulations with DDGS at 91%, and at 45% DDGS dietary inclusion, and the growth performance parameters and intestinal morphology are not affected. Currently, formulation with DDGS is being tested in the grow-out feed of milkfish in sea cages. For other species such as grouper, *Epinephelus fuscoguttatus*, a carnivore, feed efficiency and growth increased in fingerlings when fed diet with the hydrolysate from milkfish offal at 10-15% (Mamauag and Ragaza, 2016).

For the tropical abalone, *Haliotis asinina*, diet development studies conducted in land-based tanks, showed that with a good binder the marine sources of protein in formulations could be decreased with a significant increase in shell length and weight gain showing potential to shorten the culture period (Bautista-Teruel *et al*., 2016). Currently being evaluated are enriched seaweeds (*Ulva lactuca* and *Gracilaria bailinae*) as feed ingredients in the tropical abalone diet.

6.2.4 Issues, Challenges and Constraints

Various issues and challenges and constraints have been raised on the use of alternative sources to replace

fish meal in the diet of aquaculture species classified under omnivores, carnivores, and herbivores species (refer to ***Appendix 2***), the vital one is information on suitable alternative sources for specific species and their availability. For alternative sources of plant origin, information on anti-nutrient factors, nutrient information and quality are crucial to their utilization. Soybean is the most common plant protein used to replace fish meal in aquafeed formulations, but due to its increasing cost as dictated by the market, local sources have been identified but production volume is limited. Furthermore, information is scant with regards to the digestibility, amino acid profile, and dietary inclusion level (suggested level) of plant protein sources with potential for use in aquafeed. Research results on alternative protein sources in aquafeed are not available to interested stakeholders.

6.2.5 Future Directions and Policy Recommendations

Strong collaboration is encouraged among AMSs in exchanging research information or joint research work between institutions with appropriate facilities and expertise. This is also true between local agencies especially with the agriculture sector for the mass production of identified plant protein sources suitable for aquafeed production and also among R&D institutions, the private sector, the academe, and donor agencies.

The policies recommended for AMSs on overcoming the dependence on fish meal by development and use of alternative dietary ingredients in aquaculture feed are shown in **Box 17**.

Box 17. Recommended policies on the use of alternative dietary ingredients in aquaculture feed

- Establish a national aquafeed quality control to ensure high compliance of feed milling companies to fisheries regulations and acts.
- Establish a focal agency of ASEAN Programs for this purpose. SEAFDEC/AQD could be given the role of focal agency and as such should work closely with ASEAN Member States, research institutions, academe, industry, and international organizations.
- Create an ASEAN Forum or network and include all stakeholders.
- Formulate the National Action Plan.
- Enhance awareness on the importance of reducing dependence of aquaculture on feed and ingredients of marine origin.

6.3 Production and Dissemination of Good Quality Seedstock

The world's total farmed food fish production in 2012 was approximately 66.6 million metric tons, of which 88.4% came from Asia (FAO, 2014a). China contributed 61.7% to the 88.4%, followed by Southeast Asia with 26.2% and the rest from Central and Western Asia. Farmed aquatic commodities include high volume of low value aquaculture species like tilapia, carps, as well as Clariid and Pangasiid catfishes that are easily traded. Freshwater fish species are easily produced for they have been successfully bred in captivity and farmed historically long enough in that their husbandry protocols are already well established and optimized. On the other hand, marine fishes especially those requiring years to mature and are often hormonally induced to breed, need extensive hatchery and nursery facilities and technical skills for seedstock production before these could be farmed in ponds or cages. Brackishwater and/or marine invertebrates like mud crabs, shrimps, and shellfishes are among the commercially valuable species from marine aquaculture. Mariculture necessitates higher investment inputs from feeds to technical farm operations and maintenance, hence marine fish products are inevitably sold at higher market prices.

With regards to farmed aquatic plants, Indonesia, Philippines and Malaysia are recognized as among the major producers with an estimated combined production of 8.6 million metric tons or 36.0% of the total world production of aquatic plants mainly comprising seaweeds (FAO, 2014a).

For both inland and mariculture systems, farming methods have progressively evolved and many have resorted to intensification to achieve higher outputs. This has led to problems such as poor quality broodstock and seedstock, deterioration of culture environments as well as the proliferation of aquatic fish disease-causing agents that pose challenges in sustainable aquaculture production in the Southeast Asian region. Such issues continue to occur despite the initiatives to: a) find solutions to nutrition, water quality, and health management concerns; b) develop sustainable intensive husbandry methods; and c) adopt genetic programs to produce genetically enhanced, quality seedstock that are on-grown to maximize farm yields for a short rearing period. Nonetheless, such concerns are gradually being addressed through policies as well as practical techniques and/or scientific interventions to enable the production of food fish that will not only support food security but also promote economic growth. Motivation to improve economic growth through fish production and trade is seen as an offshoot of the ASEAN integration where each Southeast Asian country must be ready to compete foremost against other regional market forces and ultimately contribute to global fish production.

6.3.1 Why Good Quality Seedstock?

Although aquaculture yields from the Southeast Asian countries are still high, a slight decline in the annual production was noted in recent years. This has clearly