

# Utilizing Alternative Ingredients in Aquafeeds for Sustainable Aquaculture

Frolan A. Aya

Aquaculture is considered as the key to ensuring enough food protein to feed the growing world population (FAO, 2014). It is expected that the global food demand will increase to 70% in 2050. Aquaculture is touted as the fastest growing food-producing sector in the world. The accelerated growth of the aquaculture sector has resulted in the expansion of aquaculture feed production. However, at present, the aquaculture feed industry is confronted with pressing issues such as the limited availability and escalating cost of dietary fishmeal (FM) and fish oil (FO). FM has traditionally been used in aquaculture feed due to its high protein quality and palatability. However, the success of the aquaculture industry will depend in part on the reduction or replacement of FM use in aquaculture feeds using less expensive alternative protein sources. Several alternative feed ingredients, including plant-derived materials, have been tested in aquaculture feeds for several fish species of economic importance. Meanwhile, other non-conventional protein sources such as agricultural wastes and byproducts have been found to hold enormous potentials in future fish feed formulations.

Since 2010, the Japanese Trust Fund (JTF) has been providing research funds to the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC/AQD), for the implementation of the regional program “Promotion of Sustainable Aquaculture and Resource Enhancement in Southeast Asia” under the ASEAN-SEAFDEC Fisheries Consultative Group mechanism. Under this program, one of the projects being aggressively carried out by SEAFDEC/AQD focuses on environment-friendly, sustainable utilization and management of fisheries and aquaculture resources, in short sustainable aquaculture. This is aimed at establishing environment-friendly aquaculture technologies that includes assessment of the potentials of locally available plant-derived products and agricultural wastes as feeds in order that food security through sustainable aquaculture could be assured.

## Need for alternative protein sources in aquafeeds

Feed is the one of the major contributing factors to the operational cost in fish farming, accounting for 50-70% of production cost. In most ASEAN Member States (AMSs), commercial feeds are too expensive for small-scale fish farmers, limiting their ability to intensify aquaculture production. The increasing cost of commercial feeds has therefore, prompted many fish farmers to search for alternative feeds. Since the aquaculture sector in many AMSs (e.g. Philippines) generally depends on the use of imported

fishmeal (Sumagaysay-Chavoso, 2007), utilization of locally available ingredients in formulating aquaculture feeds or aquafeeds could reduce production costs.

SEAFDEC/AQD has been conducting studies on the development of cost-effective practical feeds for many tropical species (Millamena, 1996), *i.e.* milkfish, tilapia, catfish, shrimps, grouper, mangrove crab, and pompano (Fig. 1), some of the major species cultured in the Philippines. Refinement of formulated diets focuses on the use of inexpensive and indigenous materials in diet development. Previously, a study was embarked by SEAFDEC/AQD with JTF funding, to determine the feasibility of using locally available feed ingredients such as cowpea (*Vigna unguiculata*) meal as an alternative protein source in diets (Fig. 2) for the giant freshwater prawn (*Macrobrachium rosenbergii*).

Results of the study showed that cowpea meal can replace fishmeal protein at 30-45% inclusion level with no adverse effects on growth and production of this species when reared under laboratory and lake-based conditions (Aya *et al.*, 2015). Recently, the utilization of fish processing wastes processed as hydrolysates, as fish-feed ingredients has also been tested in diets for grouper (Mamaug and Ragaza, 2016).



Fig. 1. Feeding of formulated feeds to pompano in net cages at AQD's Igang Marine Station in Igang, Guimaras



Fig. 2. Cowpea (*Vigna unguiculata*) meal as an alternative protein source in giant freshwater prawn *Macrobrachium rosenbergii* diets

The increasing world prices of dietary FM and FO has resulted in the search for alternative protein sources. This has been highlighted during the 2001 ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security in the New Millennium: “Fish for the People” and reinforced during the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security Towards 2020 “Fish for the People 2020: Adaptation to a Changing Environment” in 2011. The latter conference has crafted the Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region towards 2020, which enjoins the SEAFDEC Member Countries to improve the efficient use of aquatic feeds by strictly regulating the quality of manufactured feed and feed ingredients and to support continued research for developing suitable alternative protein sources that will reduce the dependence on fishmeal and other fish-based products. SEAFDEC/AQD has complemented this regional initiative through its program on Healthy and Wholesome Aquaculture, which aims to promote a holistic approach of improving aquaculture production through innovations in nutrition, feed development and fish health management.

In addition to contributing to the attainment of ASEAN’s long-term goal of achieving food security and maintaining a healthy environment through sustainable aquaculture practices in the region, the Government of Japan through the ASEAN Foundation (Japan-ASEAN Solidarity Fund), SEAFDEC and the Government of Myanmar spearheaded the conduct of the Regional Technical Consultation (RTC) on the Development and Use of Dietary Ingredients or Fishmeal Substitutes in Aquaculture Feed Formulations in December 2014 in Nay Pyi Taw, Myanmar. The RTC reviewed the status, challenges, and opportunities associated with developing alternative dietary ingredients for aquaculture feed in the ASEAN-SEAFDEC Member Countries; identified the specific advantages being made in the region with respect to the development of alternative aquaculture feed ingredients; and developed policy recommendations (regional and country-specific) relevant to feed formulations and development (Catacutan *et al.*, 2015).

The outputs of the RTC include a report on the status on the use of alternative feed ingredients in each AMS (**Table 1**). In such report for instance, Cruz *et al.* (2015) explained the status of development of aquaculture feeds in the Philippines using alternative dietary ingredients that include: a) legumes; b) ipil-ipil (*Leucaena leucocephala*) leaf meal; c) miscellaneous fodder plants, such as the leaves and other aerial parts of papaya, water hyacinth, Ipomea or sweet potato; d) roots and tubers like arrow root (*Maranta arundinacea*), sweet potato (*Ipomea batatas* L.), cassava (*Manihot esculenta* Crantz), taro (*Colocasia esculenta* L.), and elephant yam (*Amorphophallus campanulatus*); e) cereals and cereal byproducts like rice bran and maize; and f) oil cakes and oil meals. Similarly, animal protein sources such as the African snail meal, giant toad meal, fish silage, feather meal, maggot meal, green mussel meal, and superworm (*Zophobas morio*) have also been utilized

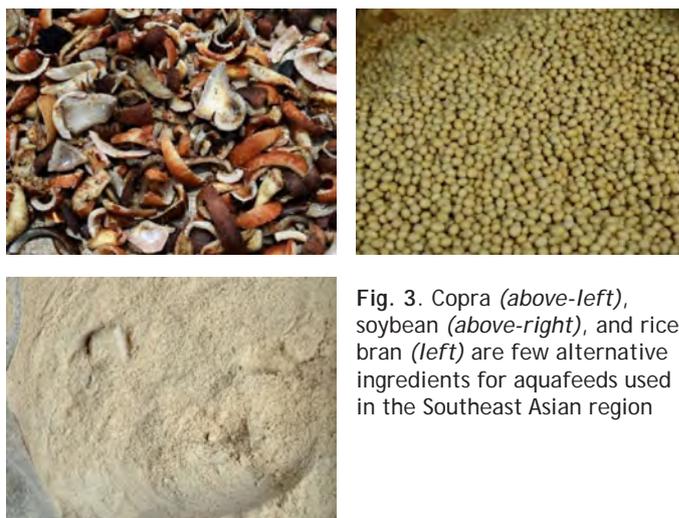


Fig. 3. Copra (above-left), soybean (above-right), and rice bran (left) are few alternative ingredients for aquafeeds used in the Southeast Asian region

(Cruz *et al.*, 2015).

In addition, the working group discussions at the abovementioned RTC identified the issues and strategies on the development of alternative aquaculture feed ingredients for selected commodities in the Southeast Asian region (**Table 2**), where it was also established that in the Southeast Asian region, copra meal, soy bean and rice bran have been commonly used as ingredients in the formulations of aquafeeds (**Fig. 3**). Moreover, the list of regional policy recommendations for the development and use of alternative dietary ingredients in aquaculture feed development in the Southeast Asian region that emanated from the RTC is summarized in **Box 1**.

### Agricultural wastes as feed ingredients in aquafeeds

As an agricultural country, the Philippines for instance, has vast land areas that are devoted to farming of agricultural crops. The country’s major crop plantations (*i.e.* mango, banana, pineapple, citrus, and other crops) produce large amounts of wastes and byproducts after processing, which if not disposed properly lead to environmental hazard. Therefore, ways to reutilize these wastes and byproducts in aquafeeds merit serious attention. Other agricultural byproducts such as sugarcane bagasse and soybean curd residues are untapped sources of energy and protein for aquaculture feeds, although some of these wastes and byproducts have been used for fertilization and livestock feeds, as well as in the production of functional ingredients or products.

In 2015, with another funding support from JTF, SEAFDEC/AQD implemented a study to explore the suitability of agricultural wastes and byproducts in aquaculture feeds for tilapia (**Fig. 4**). However, the presence of anti-nutritional factors (ANFs) in agricultural wastes and byproducts limits their use as fish feed ingredients. Processing of these agricultural wastes and byproducts using biological treatments (*i.e.* fungi solid state fermentation, inoculation with specific

**Table 1.** Status of development of alternative dietary ingredients for aquaculture feeds in the AMSs

Country	Status and Issues	Recommendations
Cambodia	<ul style="list-style-type: none"> <li>• Farmers perceived that low value fishes are available and feeding them would result in better taste and faster growth</li> <li>• The concept on the use of plant protein sources in aquafeed is new and it needs to be proven to farmers that plant protein can replace some fishmeal in feed formulation</li> <li>• Processing technology on the use of fish oil and plant oils is not available and also biotechnology R&amp;D for alternatives for fishmeal and fish oil</li> </ul>	<ul style="list-style-type: none"> <li>• Ensure sufficient amount of ice on boats and landing sites, and during transport to maintain the freshness of fish so that fish by-catch could be used in aquafeed production</li> <li>• Promote the use of fishmeal, plant protein sources and fish oil in commercial aquafeeds for grow-out and prove that aquafeeds for grow-out is profitable and provide better water quality for culture</li> <li>• Intensify information dissemination on best feeding practices and feed formulations to local hatcheries, networks, and grow-out farmers</li> <li>• Train farmers in using fishmeal and plant protein, fish oil, and plant oils in fish feed formulations</li> <li>• SEAFDEC and other agencies to provide technical and financial support to the Department of Aquaculture Development and Aquaculture Research Institute Centers that conduct trials with some volunteer farmers interested in producing homemade aquafeeds</li> <li>• Fisheries Administration of the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Cambodia to provide strong support to commercial feed companies who are keen to set up and operate aquafeed mills in Cambodia</li> <li>• Demonstrate and implement the 90% satiation feeding techniques developed by the United States Soybean Export Council (USSEC) to reduce feed wastes and financial expenditures</li> </ul>
Indonesia	<ul style="list-style-type: none"> <li>• The quality of feed produced by the farmers is not stable because of inconsistent quality of ingredients</li> <li>• Most of the ingredients are seasonally available (e.g. local fishmeal, rice bran, etc.) and farmers are not able to purchase them during off-season fish harvest</li> <li>• Presence of anti-nutritional compounds in plant ingredients</li> </ul>	<ul style="list-style-type: none"> <li>• Intensify in-depth research efforts on bioprocessing techniques to reduce anti-nutritional compounds in plant ingredients, as the application of microorganisms through bioprocessing such as fermentation could minimize the cost of improving the quality of alternative ingredients in particular byproducts and wastes from agriculture before being used in diet formulations</li> <li>• Develop the techniques for mass production of high quality alternative ingredients for aquafeed, which could be done through the provision of equipment such as hammer mill and bio-reactor to produce fermented feedstuffs</li> <li>• Institute government programs to centralize the supply of feed ingredients in each province in farming areas through the establishment of a central warehouse in several farming areas across the country to sustain the availability of the local ingredients</li> <li>• Continue providing technical support to improve farmers' knowledge on feed and feeding management, hygiene, and sanitation with the involvement of fisheries extension and fisheries department officials in the development of on-farm feed production</li> </ul>
Lao PDR	<ul style="list-style-type: none"> <li>• Lack of appropriate mass media for each particular area on aquaculture feed; extension officers need special training on feed and feeding</li> <li>• Farmers have very limited opportunities for training</li> <li>• Most training courses are, in general, aquaculture and do not emphasize feed and feeding</li> <li>• Most training courses are not held at the farm sites, so farmers cannot attend</li> </ul>	<ul style="list-style-type: none"> <li>• Establish cooperation on feed and feeding technologies through research and experimentation at the provincial, national, and inter-regional levels</li> <li>• Sustain capacity building of fisheries staff in aquaculture technology and management, with more focus on feeds and feeding technology</li> <li>• Enhance extension network and research collaboration between institutions dealing with inland aquaculture development and education, including feed and feeding technology</li> <li>• Determine the market demand for domestic consumption and processed fish for export</li> <li>• Promote sustainable aquaculture development to encourage aquaculture-industry investments</li> </ul>
Malaysia	<ul style="list-style-type: none"> <li>• Use of blacklisted antibiotics in aquafeed as prophylactic treatment</li> <li>• Most of freshwater aquaculturists feed unprocessed chicken intestine directly to freshwater catfish which brings the issue of hygiene</li> <li>• Concerns on the Halal status of fish diets containing raw materials such as products or byproducts from swine industry</li> <li>• Use of byproducts from farmed fish as feed ingredients for the diets of the same species (also called intra species recycling)</li> </ul>	<ul style="list-style-type: none"> <li>• Promote farming of omnivorous fish species such as tilapia and catfish</li> <li>• Promote consumption freshwater fish</li> <li>• Promote Good Aquaculture Practices (GAPs) to produce quality products certified by DOF Malaysia to increase consumer preferences</li> <li>• Enhance awareness programs for farmers and government officials to implement relevant rules and laws</li> <li>• Intensify R&amp;D on fishmeal and fish oil substitution in aquafeeds with locally available ingredients</li> <li>• Establish networking of suppliers of local ingredients</li> <li>• Put up more aquafeed mills in the country to supply 600,000 MT aquafeed by 2020</li> </ul>

**Table 1.** Status of development of alternative dietary ingredients for aquaculture feeds in the AMSs (Cont'd)

Country	Status and Issues	Recommendations
Myanmar	<ul style="list-style-type: none"> <li>• Presence of anti-nutrient factors in plant-based ingredients</li> </ul>	<ul style="list-style-type: none"> <li>• Use feed additives, attractants, and synthetic amino acid supplement</li> <li>• Improve processing methods for locally available agriculture byproducts</li> <li>• Review existing policies/regulations on the use of fish bycatch</li> <li>• Use of adulterants and preservatives such as anti-oxidant and mould inhibitor to prevent mycotoxins</li> <li>• Enhance postharvest technology for good quality raw material and improve feed milling technology such as trypsin (moist heat) inhibitor, dehulling, extruding, and pelletizing</li> </ul>
Philippines	<ul style="list-style-type: none"> <li>• Fishmeal are continued to be used as the major source of dietary protein in aquafeed</li> <li>• Invasive species (e.g. knife fish and blacklip tilapia) are used as trash fish for the production of mudcrab and shrimps</li> </ul>	<ul style="list-style-type: none"> <li>• Reduce the dependence on the use of fishmeal for aquafeed by active promotion and development of more competitive protein and energy sources from locally available products including cassava, rice, oil palm, and copra</li> <li>• Develop quality aquafeed out of invasive fish species such as knife fish and blacklip tilapia (<i>Sarotherodon melanotheron</i>)</li> <li>• Continue the Bureau of Fisheries and Aquatic Resources-initiated Philippine National Aquasilviculture Program that allows the use of the spaces in mangrove areas for aquaculture where stocks are usually mud crab and marine finfishes as well as use available natural food in the environment for their growth</li> <li>• Give special attention to small-scale farmers using farm-made aquafeeds as well as promote organically-formulated diets</li> <li>• Government to give utmost attention to organic agriculture where plant protein sources and byproducts are utilized as source of organic feeds for organic aquaculture</li> <li>• Disseminate technology that uses Green Water Technology in freshwater and inland fisheries, which is recommended not only to reduce cost on feeds but also to avoid possible disease outbreaks caused by viruses and bacteria</li> <li>• Promote tax liberation on imported plant-based protein sources by the government as incentives to feed millers</li> <li>• Continue R&amp;D activities for the production of aquafeeds for species that have low fishmeal requirements</li> </ul>
Singapore	<ul style="list-style-type: none"> <li>• Types of feed used for aqua-farming are natural (trash fish), dry formulated (commercial diet), farm-made (formulated), processed (confectionary), and byproducts (plant waste, fish trimmings, poultry byproducts)</li> <li>• Increasing cost of commercial fish feeds</li> </ul>	<ul style="list-style-type: none"> <li>• Reduce the cost of production from purchasing to converting of feed materials/ingredients into digestible form that involve specialized equipment to extract the desired components</li> <li>• Produce feeds ethically and should undergo stringent testing for any potential toxins that might be created in the process of feed development as this will not only affect the survival and growth of the cultured stocks but also the end users or consumers</li> <li>• Ensure that newly developed feed generate nutrients that will promote good growth and survival of the cultured stocks, and result in good quality fish (i.e. rich in omega 3 fatty acid that is beneficial to consumers)</li> <li>• Sustain the availability of materials used as feed ingredients to ensure continued production of fish feeds</li> </ul>
Thailand	<ul style="list-style-type: none"> <li>• Fishmeal can be replaced to a large extent but at higher cost (e.g. enzyme and amino acid supplementation)</li> <li>• Supply of fishmeal from local production not is enough, while production faced challenges from illegal, unreported and unregulated (IUU) fishing</li> <li>• Problems on the use of genetically modified (GM) plants</li> <li>• Fish oil considered as serious limiting factor</li> </ul>	<ul style="list-style-type: none"> <li>• Enhance the utilization of fish-by-catch or FBC (e.g. fish processing trimmings) as fishmeal, fish silage, and fish hydrolysates in aquafeed production</li> <li>• Give focus on the production of commodities for export or high value domestic aquatic animals to make the utilization of imported ingredients (e.g. fishmeal, soybean meal, fish oil) more feasible</li> <li>• Government sector to give attention to IUU fishing, environmental regulations, national aquafeed legislation, researches, and extension of information/knowledge to farmers and feed mills</li> <li>• Feed millers/manufacturers to improve feed quality, reduce leaching of nutrients, and improve digestibility of feeds to reflect the real feed cost</li> <li>• Farmers to understand feeding regimes, culture systems, and marketing (domestic or export)</li> </ul>

**Table 1.** Status of development of alternative dietary ingredients for aquaculture feeds in the AMSs (Cont'd)

Country	Status and Issues	Recommendations
Viet Nam	<ul style="list-style-type: none"> <li>• Little information on fish bycatch and the recent number of fishmeal plants</li> <li>• Certification of local fishmeal quality should meet international standards</li> <li>• Animal feed mills and aquafeed mills do not use local fishmeal of good quality; imported fishmeal is used while the local fishmeal is exported</li> <li>• Soybean production is small and utilized mostly for human consumption</li> <li>• Soybean for aquafeed use is imported</li> <li>• Few studies on fishmeal and fish oil replacement</li> <li>• Plant oil not used widely in aquafeed because plant oil contains less omega 3</li> </ul>	<ul style="list-style-type: none"> <li>• Government of Viet Nam to have a long-term policy to grow plant protein sources, particularly soybean</li> <li>• Government to issue regulation for harvestable size of any marine species for sustainable importation</li> <li>• Local fishmeal plants to show transparency of information regarding volume and quality of local fishmeal that can be accessed through website</li> <li>• Local fishmeal plant operators to work together to control the quality of trash fish from capture fishery</li> <li>• Private companies and government to develop a long-term program for replacement of marine animal ingredients with alternative sources, using bioactive products such as NOVAQ (aquaculture feed developed in Australia) or “like NOVAQ” or bioflocs system</li> <li>• Donors to support efforts to overcome the effects of climate change and value chain programs for fish by-catch and aquaculture products</li> </ul>

Source: Catacutan et al. (2015)



**Fig. 4.** Agricultural wastes and byproducts currently being converted into valuable protein sources in tilapia diets: (A-B) pineapple peels; (C) sugarcane bagasse; (D) okara meal or soybean curd residues; (E-F) citrus pulp and peels

**Table 2.** Issues and strategies on the development of alternative aquaculture feed ingredients for selected commodities in the Southeast Asian region

Issues/Gaps	Strategy/Recommendation
<b>Herbivores (e.g. milkfish, carps, barbs)</b>	
<ul style="list-style-type: none"> <li>• Inadequate information on alternative feed ingredients from plant-based sources</li> <li>• Some alternative ingredients are not available locally in many countries in the Southeast Asian region</li> <li>• Presence of anti-nutritional factors affect the nutritional value of many alternative feed ingredients from plant sources</li> <li>• Incomplete information on proximate composition of many alternative ingredients from plant sources</li> <li>• Limited study on the feeds and feeding of herbivorous species</li> <li>• Poor digestibility of many plant protein ingredients</li> <li>• Low efficiency of feeds (<i>i.e.</i> high feed conversion ratio)</li> </ul>	<ul style="list-style-type: none"> <li>• Compile and disseminate information on alternative plant products and facilitate exchange of information both within and outside the region</li> <li>• Define and apply strategies that will encourage production of locally available alternative ingredients</li> <li>• Create and implement policies that will facilitate the outsourcing of other alternative ingredients</li> <li>• Enhance R&amp;D efforts in processing to improve the nutritional value of the alternative ingredients</li> <li>• Conduct profiling or characterization of the alternative ingredients</li> <li>• Continue R&amp;D to improve the efficiency of feeds, particularly on the food conversion ratio or FCR</li> <li>• Strengthen collaboration among the government sector (particularly the policy makers), R&amp;D institutions, and the private sector</li> </ul>

**Table 2.** Issues and strategies on the development of alternative aquaculture feed ingredients for selected commodities in the Southeast Asian region (Cont'd)

Issues/Gaps	Strategy/Recommendation
<b>Omnivores (e.g. pangasius, tilapia)</b>	
<ul style="list-style-type: none"> <li>• Need of additional potential alternative protein sources</li> <li>• Limited information on quality of alternative ingredients</li> <li>• Lack of information on economic feasibility of using alternative ingredients that can replace fishmeal</li> <li>• Inclusion levels of peanut meal in feeds for tilapia are not known</li> <li>• Different strains of genetically improved tilapia have varying responses to alternative protein sources</li> <li>• Insufficient information/knowledge of small-scale farmers on proper utilization of feeds</li> </ul>	<ul style="list-style-type: none"> <li>• Improve post-harvest and/or processing technologies to enhance the quality and nutritional value of alternative feed ingredients (e.g. peanut meal), and strengthen research collaboration to address the issue on determining the nutritional value of the new or improved ingredients (e.g. amino acid analysis)</li> <li>• Conduct national assessment of ingredients in each country in terms of availability, sourcing, sustainability and cost effectiveness which will lead to selection of specific ingredients in the country</li> <li>• Promote mass production of protein sources/ingredients that are found appropriate after each assessment by country</li> <li>• Establish/enhance collaboration with the agriculture sector for the mass production of alternative protein source ingredients</li> <li>• Determine optimum inclusion levels (for peanut meal and also for soybean meal) and response of the species in terms of growth and meat quality</li> <li>• Generate information on nutrient digestibility of genetically improved strains of tilapia through joint efforts among institutions with appropriate facilities and expertise</li> <li>• Disseminate information to farmers through training programs for extension officers, distribution of information materials</li> <li>• Conduct demonstration of field trials on the use of traditional feeds, especially those with new alternative feed ingredients, involving the cooperation of farmers, extension workers and feed millers</li> </ul>
<b>Carnivore (e.g. catfish, snakehead, seabass, grouper, black tiger shrimp)</b>	
<b>Freshwater fishes: Catfish</b>	
<ul style="list-style-type: none"> <li>• Small-scale farmers are still dependent on on-farm feeds</li> <li>• Non-availability of data on actual utilization of imported and local fishmeal in feed formulations as feed companies usually do not release the detailed contents of fishmeal in commercial formulated diets</li> </ul>	<ul style="list-style-type: none"> <li>• Conduct research on feed development for catfish, particularly on nutrient requirements and protein source substitution (with emphasis on the use of alternatives to fishmeal)</li> <li>• Refine existing technology on formulation of catfish feeds</li> <li>• Facilitate sharing of information for further development of feeds</li> </ul>
<b>Freshwater fishes: Snakehead</b>	
<ul style="list-style-type: none"> <li>• Heavy reliance on trash fish as feed source (about 15% of fishmeal are included in aquafeeds)</li> <li>• Most feed ingredients are imported and some governments regulate the growing of plant-based protein sources such as soybean</li> </ul>	<ul style="list-style-type: none"> <li>• Promote the use of pellet feed instead of trash fish</li> <li>• Conduct further studies to clarify the requirements of fishmeal in snakehead diets</li> <li>• Encourage farmers to grow plants which have the potentials as feed ingredients</li> </ul>
<b>Marine fishes: Sea bass</b>	
<ul style="list-style-type: none"> <li>• Sea bass cultured in freshwater and seawater have varying nutrient requirements</li> <li>• Commercial feed (&gt;43% CP) for this species is readily available in some countries such as Thailand and Viet Nam but data on actual utilization of fishmeal are not available</li> <li>• Lack of diets for broodstock</li> <li>• Most feed ingredients used in feed formulations are imported</li> </ul>	
<b>Marine fishes: Grouper</b>	
<ul style="list-style-type: none"> <li>• Lack of research on suitable larval feeds</li> <li>• Commercial feed formulations use at least 30% imported fishmeal</li> <li>• Heavy reliance on trash fish in feeding grouper</li> <li>• Commercial feeds (46-50% CP) for grouper are readily available in Indonesia but data on actual utilization of fishmeal are not available</li> </ul>	<ul style="list-style-type: none"> <li>• Carry out research to determine suitable larval feed for grouper and suitable broodstock diets for sea bass cultured in freshwater and seawater</li> <li>• Conduct R&amp;D on fishmeal substitution for sea bass and grouper diets</li> <li>• Enhance collaboration among government, R&amp;D institutions, feed industry and farmers on initiatives related to development of good quality feed and protein source substitution</li> </ul>
<b>Crustaceans (e.g. black tiger shrimp)</b>	
<ul style="list-style-type: none"> <li>• Reliance on both local and imported feeds but dependence on imported fishmeal in shrimp feed production is increasing</li> <li>• Lack of diets specific for broodstocks</li> <li>• Lack of high quality alternative protein sources for use in aquafeed formulations</li> </ul>	<ul style="list-style-type: none"> <li>• Conduct R&amp;D on fishmeal substitution for shrimp diets</li> <li>• Carry out research to determine suitable diets specific to shrimp broodstock</li> </ul>

Source: Catacutan et al. (2015)

Box 1. Summary of relevant policy recommendations on feed formulations/development

Key Problems	Policy Recommendations
Inadequate knowledge and technology	<ul style="list-style-type: none"> <li>• Continue research and development activities for the production of aquafeeds with low or minimal fishmeal content</li> <li>• Provide focus on research and development on aquafeeds quality, improved formulation, and use of alternative dietary ingredients</li> <li>• Develop techniques for mass production of high quality ingredients to replace fishmeal and fish oil in aquaculture feeds</li> <li>• Create a network or a regional forum for exchanging and sharing of R&amp;D on feed formulation and efficiency, and feeding management practices</li> <li>• Provide technical support to improve farmer's knowledge on feeds and feeding management, hygiene, and sanitation</li> <li>• Facilitate exchange of information and cooperation with other regions</li> </ul>
Supply of fishmeal and feed ingredients from IUU fishing and genetically modified organism(GMO)	<ul style="list-style-type: none"> <li>• Assess the production capacity of feed milling plants, including the import- export volume of (the raw materials for feed ingredients</li> <li>• Establish and apply the traceability system of all raw materials used as feed ingredients through the application of the Catch Documentation System (CDS)</li> <li>• Create a government program in AMS to encourage the mass production of local feed ingredients and establish a centralized supply of feed ingredients in each local government</li> <li>• Establish the supplier networks of local ingredients</li> </ul>
Lack of regulations and/or fishery acts and cooperation to manage development of aquafeeds	<ul style="list-style-type: none"> <li>• Establish a national aquafeed quality control to ensure high compliance of feed milling companies to fisheries regulations</li> <li>• Establish SEAFDEC Aquaculture Department (AQD) as a focal agency of ASEAN programs on development and use of alternative dietary ingredients in aquaculture feed development. As the focal agency, AQD will work closely with AMSs, research institutions, academe, industry, and inter-regional organizations</li> <li>• Create an ASEAN forum or network that includes all stakeholders on development and use of alternative dietary ingredients in aquaculture feed development</li> <li>• Formulate the National Action Plan on development and use of alternative dietary ingredients in aquaculture feed development</li> <li>• Enhance awareness on the importance of reducing dependence of aquaculture on feed and ingredients of marine animal origin</li> </ul>

Source: Catacutan et al. (2015)

microorganisms, among others) to reduce their ANFs (e.g. tannin, phenol, saponin, lignin and alkaloid) would enable higher inclusion level in fish feeds. When developing feedstock from agricultural wastes, potential safety issues regarding pesticide residues (e.g. organochlorines, pyrethroids, and organophosphates) should also be identified. The nutritional quality, digestibility, and suitability as feeds, economic analysis should also be determined to assess the viability and profitability of using these agricultural wastes and byproducts in aquaculture feeds.

## Way Forward

Continuous research on alternative protein sources such as plant-derived feed ingredients, fish processing wastes, underutilized crops, and insect-based meal needs to be done. Development of cost-effective processing techniques to convert these alternative feed ingredients should also be addressed to make the aquaculture feed production in the Southeast Asian region sustainable. The Philippines is a major tuna producer in the Western and Central Pacific Ocean (Barut and Garvilles, 2015), and where tuna processing is also a major industry with landing areas located in the cities of General Santos and Zamboanga, in Mindanao.

Byproducts from canned tuna processing are utilized in fishmeal production (Sentina, 2013). Nevertheless, the beneficial use of tuna byproducts as fishmeal replacement in aquaculture feeds in the Philippines is an interesting area which remains to be studied to maximize its potential. Tuna byproducts appear to be a good protein substitute for fishmeal in aquaculture feeds because of its high nutritional quality, which could even be further improved by combining these with agricultural feed sources during the fermentation process.

Studies on the use of fisheries processing wastes blended with agricultural byproducts as complementary ingredients in diets for cultured fish species in Southeast Asia should therefore be conducted. Agricultural and fish processing wastes and byproducts have very low or no commercial value, and are readily available in large quantities, making them excellent alternative ingredients to aquaculture feeds. Appropriate and low-cost treatments to increase their nutritional value are likewise needed and their suitability should be tested in diets for farmed fish species (Mamauag, 2016).

Utilization of these agricultural and fish processing wastes and byproducts will provide cost-effective and more sustainable feed alternatives to increase farm productivity, and more importantly, reduce the negative impacts to the environment.

SEAFDEC/AQD will continue to conduct a wide array of research to improve the performance of aquaculture feeds, as well as explore the development of low fishmeal and/or plant-based aquaculture feeds derived from locally available ingredients to replace ingredients obtained from imported crops and fishmeal. In addition, SEAFDEC/AQD will spearhead the development of database of alternative feed ingredients for use in aquaculture feeds, and exchange of information among the AMSs on alternative feed ingredients would also be actively pursued.

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### About the Author

Dr. Frolan A. Aya is a Scientist of SEAFDEC Aquaculture Department based in Binangonan, Rizal, Philippines.