We appreciate the opportunity to respond to your questions on alternative feeds for aquaculture. Developing alternative feeds to reduce the amount of fishmeal and fish oil contained in aquaculture feeds while maintaining the important human health benefits of farmed seafood is critical to sustainability of aquaculture in the United States and abroad.

With regard to your specific questions, we offer the following:
(1) Groundbreaking research on alternative dietary ingredients (feedstuffs) for aquaculture, including plant based proteins, is expanding the United States and worldwide. Where should the federal government focus its research efforts in the area of alternative feeds for aquaculture? Are there specific areas that the federal government should not address?

- Science-based quality standards and processing procedures
  - The adoption of any new byproduct for use in feeds by industry will depend on confidence of quality of materials. Quality criteria by which commodities are traded are common for South American and European fishmeals. These quality criteria need to be meaningful and complete (i.e., not just crude protein, ether extract and ash) and geared toward use (e.g., shrimp in ponds have different needs than broodstock).
- Palatability, digestibility, complementary amino acids, n3 highly unsaturated fatty acids (HUFAs)
  - As aquaculture expands, its demand for nutrient sources will increasingly lead to further identification and development of non-traditional sources, some of which will have low palatability and digestibility, poor amino acid profile, and/or lack of essential fatty acids. These problems must be addressed in a variety of ways, such as: addition of attractants, modified processing methods, blending complementary amino acid sources, using alternate n3 HUFA sources.
- Anti-nutritional factors
  - Many alternative ingredients contain anti-nutritional factors (toxins, compounds that reduce digestibility, molds, etc.). The deleterious effects of some anti-nutrients can be mitigated by processing methods, and ensuring the initial high quality of ingredients.
- Other nutrients (e.g., minerals, probiotics)
  - Fishmeal provides more than just a good source of amino acids and fatty acids, it is also a good source of several minerals. As fishmeal is replaced by other ingredients, the balance and bio-availability of minerals needs to be considered.

(2) What are potential alternative sources of protein and oil for aquaculture feeds? For example, are there specific opportunities for greater use of seafood processing waste and other agricultural by-products in aquaculture feeds? Are there specific obstacles to using these alternatives as alternative dietary ingredients in aquaculture feed?

- Co-products of biofuel generation
  - Many of the byproducts of biofuel generation contain considerable quantities of protein, which may have application in aquatic feeds. Examples of these processes and their associated byproducts include: Biodiesel production (presscake, solvent extracted meal) and cell wall materials from oilseeds, nuts, fruits, and algae); ethanol production

[distiller?s dried grains with solubles (DDGS) from corn; stillage (yeast) from sugar juice; vinasse from molasses]. Prior to use, each of these will need to be characterized in terms of its proximate composition, mineral content, amino acid content, etc.

- Seafood processing byproducts
    - o Byproducts from seafood processing have great potential as alternative ingredients for use in aquaculture feeds, and are usually rich in n3 HUFAs, well balanced in AA profile, and highly palatable. However, there are serious impediments to utilization of these byproducts, including logistical issues dealing with remote locations (including the high seas), rapid spoilage, unpredictable and mixed by-catch species, transportation, and dewatering.
- Krill
    - o Southern krill (*Euphausia superba*) are reported to be the largest single species biomass on earth. They are high in amino acids, a good source of n3 HUFAs and carotenoid pigments, and are very palatable for aquatic animals. They autolyse rapidly after capture, which is generally not good, but could be used to advantage (rich in proteolytic enzymes). Some disadvantages include: harvesting sites are located far from market destinations (transportation is expensive); drying is expensive, as it is for all animal byproducts; fluoride content is high; and issues of disease transfer may exist if the krill is not properly processed (heated and/or dried).
- Meat and bone meal, Poultry byproduct meal
    - o These are available in significant quantities, but suffer from high variability and unpredictability in terms of product quality and nutritional composition.
    - o Reliable quality standards are needed, as described above. These meals are generally good sources of amino acids and minerals, but do not supply n3 HUFAs to an appreciable degree.
- n3 HUFAs from plant products (including algae)
    - o The main ?problem? here is that human consumption is the most lucrative target for HUFA products. It is likely that the extraction process from algal products is highly efficient, leaving little for aquaculture. This isn?t a significant problem, because the target of aquaculture is human food. It?s only a problem for aquaculture per se, since fish and shrimp need these n3 HUFAs.
    - o Potential also exists for obtaining HUFAs from algae grown for the biofuels industry. The biodiesel conversion process favors the shorter chain fatty acids, leaving the longer chain fatty acids available for extraction and subsequent use in human food supplements and aquaculture feeds.

(3) What type of treatments or processes show promise for improvement of existing aquaculture feedstuffs and for developing new feedstuffs? How soon could these technologies be commercialized?

- Enzymes (proteolytic, non-starch polysaccharides (NSP), phytase)
    - o Pretreatment of ingredients with specific enzymes could improve acceptability (palatability) and nutritional quality, but increases their cost of production**.** The best option is using enzyme-rich ingredients in combination with other ingredients. For example, co-processing krill or

arrowtooth flounder from Alaska (very high in proteolytic enzymes) with plant protein ingredients could result in highly digestible, nutrient-rich, cost-effective products. Of course, getting these products together in a way that makes sense is a challenge.

- Extrusion processing optimization of a wet protein co-product ingredient (e.g., stabilized high-moisture algal cell walls, raw seafood processing waste, etc.) can be used in place of the make up water that is normally added during the extrusion process, thereby reducing some of the high costs of drying.

(4) Fish meal and fish oil contribute important human nutritional components to aquaculture feeds such as n3 fatty acids. As the aquaculture feeds industry seeks to replace fish meal and fish oil with alternatives, how can the nutritional benefits of farmed seafood be maintained or enhanced? For example, what technologies exist for producing n3 fatty acids?

- Organisms can be bred to produce lipids that contain high levels of n3 HUFAs, a better amino acid balance, reduced anti-nutritional factors (e.g., phytase), etc.
- Single celled organisms (heterotrophs, autotrophs).
- Fractioning oils to concentrate n3 HUFA fatty acid.

Thank you for the opportunity to comment. If you have any questions, please contact me or Dr. Warren Dominy, Chief of the Feeds and Nutrition Department at Oceanic Institute.

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