Feed Ingredients

Working towards the removal of marine ingredients in aquafeeds

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There are a number of marine and freshwater finfish and crustacean aquaculture species that can be reared on production diets with minimal or no fisheries products (e.g. fishmeal).

Examples of freshwater fish species include carps and tilapia which are species that have been reared on diets composed primarily of plant ingredients for a number of years for which there are numerous examples in the literature. For these species, commercial grow-out diets generally have limited levels of animal protein and hence would be considered environmentally friendly or sustainable and organic diets (once defined by the local regulatory agency) can be easily produced. Even though production diets for these species have not had significant quantities of fish meal for a number of years, farmers still receive a need for fish meal in the diet.

On the other hand, production diets for marine species quite often have high (>15%) levels of fisheries products. For some species, this is due to palatability considerations but for most species the use of high levels of fisheries products is not warranted. Unfortunately, when feeds are first developed for a given species, fish meal is often put in at high levels to ensure nutritional adequacy of the diets. Then as the industry develops and nutrient requirements are better defined, fish meal is often reduced and often removed from diet formulations. Unfortunately, most farmers feed fisheries products must be in the diet and feed should have a good fish smell in order for them to work. This is unfortunate, as it makes the acceptance of diets without fisheries products quite difficult.

Replacement studies

The removal of marine meals does not work for all species; however, quite often if a suitable replacement strategy is employed marine proteins and oils can be reduced or removed from a practical diet formulation. However, the replacement strategy must take into account nutrient requirements of the culture species in terms of essential amino acids, fatty acids and minerals as well as potential palatability changes of the diets.

To provide several examples of marine species that do well on diets without fishery products, I have provided several examples of work that has been conducted in my laboratory.

Red drum

In research conducted by Karsey et al. (2000) we were able to set the stage for the development of practical diets for juvenile red drum (Sciaenops ocellatus) with limited levels of marine ingredients. These results were then applied to grow-out diets (Davis and Arnold 2004) for which I have provided an example of feed formulations in which soybean meal was used to replace fish meal (Table 1). In this example, we used nutrient requirement data that had been developed at a number of laboratories to maintain minimal nutrient requirements as the fish meal was replaced. It should also be noted, that in these diets, poultry by-product meal was included in the basal diet to help offset palatability problems as the fish meal was replaced with solvent extracted soybean meal.

The 14-week growth trial was conducted in a semi-closed recirculating system, consisting of a series of semi-square poly-
ethylenetanks (designed to hold 570 L of
water), a 970-L reservoir tank containing
two trickling towers and submerged biologi-
cal filtration, two 2.5-kW submersible
heaters, a circulation pump, and sand filtra-
tion. Supplemental aeration was provided
to each tank, and the system makeup water
was exchanged at a rate of approximately
19 L/min throughout the experiment. A 16-
hour light: 8-hour dark

photoperiod was established
using fluorescent
lamps with timers. Tanks
were stored with non-food fish (eight
fish/tank, three
tanks per treatment
having an initial
weight of 179 g.

Based on bi-
weekly measure-
ments, water quality parameters were
maintained at: mean + standard deviation
pH, 7.7 ± 0.1; TAN, 0.16 ± 0.06 ppm and
NO₂-N, 0.56 ± 0.02 ppm. Soluble and dis-
solved oxygen (DO) were monitored daily
and maintained at 29.6 ± 4.0 ppm and 6.1 ±
0.9 ppm, respectively. Temperature was also
maintained at 26.2 ± 0.7°C
during the first 12 days of the experiment
and 28.5 ± 1.0°C for the duration of the
experiment, resulting in an overall mean of
27.2°C.

As can be seen from Figure 1, the growth
response and feed conversion effi-
ciency (weight gain/feed offered × 100) was
very similar and there were no production
differences as fish meal was replaced.

In these diets, poultry byproduct meal and soy-
bean meal are the pri-
mary protein sources
each of which is less cost-
lier than fish meal.

Consequently, the overall diet formulation cost
is reduced without changing the performance of
the fish. However, in this
example we are still utiliz-
ing marine oils to meet
highly unsaturated fatty
acid (HUFA) require-
ments of the fish.

![Image of a fish food production facility]

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Pacific white shrimp
In the second example, we built off of previous research (see Davis and Arnold 2000, Samocha et al 2004) to produce diets with no marine proteins. This previous research demonstrated that we could replate fish meal with a variety of protein sources. In these examples we were using a co-extruded poultry by-product meal given the trade name ProfoundTM which is primarily soybean meal co-extruded with egg and poultry waste. However, for the presented data (see Davis et al 2004 for more detail) we have further refined this diet by replacing the menhaden fish oil with a combination of plant oils and algae meal products rich in Docosahexaenoic Acid (DHA) and Arachidonic Acid (ARA). Advanced BioNutrition, Columbia, MD, USA). As the lipids in these meals contain high levels (about 38%) of either DHA or ARA, they can be used to deliver very specific quantities of Highly Unsaturated Fatty Acids (HUFA) allowing for a precise blending of lipids. In Table 2 we present the diets from two separate outdoor tank experiments using the Pacific White Shrimp (Litopenaeus vannamei).

Growth trials for these experiments were conducted at the Shrimp Mariculture Research Facility, Texas Agricultural Experiment Station, Corpus Christi, Texas. Each study was conducted in replicated HDPE circular tanks positioned under a shade with roofing mode of clear and opaque panels. Each tank had a working volume of 650-L and bottom area of 0.85 m². Each tank was equipped with two airstones which delivered air at a rate of 8-10 Lpm and covered with 0.3 mm mesh resting to prevent shrimp from jumping out of the tanks. Natural seawater was used after initial chlorination with salinity adjusted to 30 ppt. One tank in each treatment was provided with a feed tray that covered about 45% of the tank's bottom (about 0.40 m²) to estimate feed consumption. Five shrimp from each of these tanks were collected weekly to estimate growth (group weights) and to adjust daily feed rations. Weekly rations were calculated assuming 100% survival, FCR of 1.15 and an estimated growth between 1 and 1.2 g per week. Daily rations were then calculated based on expected growth and offered four times per day. Each tank was run as a static system with a municipal freshwater added to offset evaporation losses. Dissolved oxygen, temperature, salinity and pH were monitored twice a day (morning and afternoon) in each tank. Total ammonia-nitrogen and nitrite-nitrogen were monitored once a week in all tanks. At the conclusion of the growth trials, all shrimp were harvested, counted, and weighed. Average final weight and survival for each dietary treatment were determined. Feed conversion ratio values were estimated based on feed inputs. Differences in final average weights, survival (arcsine transformed), and FCR were analyzed using an analysis of variance.

Juvenile Pacific white shrimp Litopenaeus vannamei

Table 2: Diet formulations expressed as g/100g (as is) for practical shrimp diets designed to contain 35% protein and 8% lipid using dietary microalgae fishmeal and oil replacement strategies

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variance to determine if significant (p <.05) differences existed among treatment means. The Student-Newman-Keuls multiple comparison test was used to determine where significant differences existed between treatment means.

As can be seen from Figure 2, in the first experiment the final weight were similar across all treatments. In this experiment P3HAs were similar and ranged from 1.40-1.52. These results indicate that the use of algae meals or MFO produced similar results and that the production was equal to that of a high quality commercial feed. In the second growth trial we removed the menhaden fish oil (w/f MFO) which resulted in a significant reduction in growth (Figure 2) and other measured parameters. Thus, demonstrating that maintaining suitable lipid sources in the diet is a critical component of proper feed formulations when we are replacing marine ingredients.

**Concluding remarks**

Aquaculture is to be competitive with other food sectors, we must minimize production costs by maximizing the economic returns from investments in the feed. This means feed must use the most cost-effective sources of ingredients and maximize over fortification of nutrients. In most countries, this means a reduction of fisheries products in commercial feeds and a move towards the use of ingredients from animal by-products and plant sources. Although we do not have replacement strategies established for all species, a number of cultured species will perform as well on a properly formulated diet with minimal or no fishery products as those that are maintained on diet with high levels of fishery products. Replacement strategies will vary with price structures and the target market. In the case of organic or environmentally friendly markets, the formulation of diets with organic or sustainable ingredients allows for the marketing of products into what are often higher value markets. In all cases, we must move towards better, more cost-effective diets if the industry is to maintain its current growth rate and productivity.

**References**


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