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Aquafeeds

Practical diet formulation and adoption in tropical spiny lobster aquaculture

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More research needed to better understand nutritional requirements and industry drivers for the adoption of formulated feeds

Spiny lobsters (family *Palinuridae*) are among the world's most valuable seafood species, driven by **strong demand and limited global supply** (https://doi.org/10.1007/978-981-32-9094-5_12). In Southeast Asia, the ornate rock or spiny lobster (*Panulirus ornatus*) and the spiny lobster (*Panulirus homarus*), are both farmed in Indonesia and Vietnam, while commercial production of *P. ornatus* has begun in Australia with recent commercial hatchery work focusing on *P. ornatus*. There is nascent lobster aquaculture development using these same two species in the Philippines and India, although both lack government support and commercial investment. These species are marketed differently, with the higher-value *P. ornatus* exported to China, while *P. homarus* are marketed domestically within Vietnam.

Most aquaculture production of tropical lobsters is based on wild-caught pueruli [the puerulus is the free-swimming, developing phase of spiny lobsters that settles out of the plankton and to bottom



This review of recent advances and future directions in practical diet formulation and adoption in tropical Palinurid lobster aquaculture shows that lobster aquaculture development across Vietnam, Indonesia and Australia is an incentive for the development of commercial feeds, but more research is needed to better understand lobster nutritional requirements and industry drivers for the adoption of formulated feeds. Photos of ornate rock or spiny lobster (*Panulirus ornatus*) by Dr. Donald Lightner.

(benthic) habitats]. Until recently, *P. ornatus* comprised 90 percent of Vietnamese production with the remaining 10 percent attributable to *P. homarus*. Puerulus capture in Indonesia is dominated by *P. homarus* and the export of this species has provided the basis for recent increase of lobster aquaculture volumes in Vietnam, which is now comprised of approximately 1500 tons of *P. ornatus* production and 2000 tons of *P. homarus*. Both species will feature prominently in the future of tropical lobster aquaculture, requiring better understanding of their relative growth dynamics and feed requirements.

Lobster farming relies heavily on wild-caught seafood as the major source of nutrition. In Vietnam this includes fish, crabs, mussels and sea urchins, reflecting the natural food preferences of these lobsters. While this practice ensures that feeds are palatable and largely nutritionally complete, it has led to considerable water quality degradation that in turn can make the environment less suitable for lobster culture and lead to disease.

Water quality and access to appropriate and affordable feed have been identified as major perceived constraints to the lobster aquaculture industry; both lead the industry toward the development and implementation of formulated feeds. With the expansion of the lobster industry in Vietnam and emerging industry in Indonesia, it is increasingly important to develop formulated feeds to ensure sustainable development.



(<https://www.globalseafood.org/goal/>).

This article – adapted and summarized from the **original publication** (<https://doi.org/10.1111/raq.12675>) (Nankervis, L. and C. Jones. 2022. Recent advances and future directions in practical diet formulation and adoption in tropical Palinurid lobster aquaculture. *Rev. Aquac.* 2022:1-13) – critically reviews and evaluates available data on nutrient and feed requirements in the context of spiny lobster biology and industry development, identifies barriers to implementation of formulated feeds and suggests future research focus areas.

For detailed information on some sections not included in this article summary – like lobster species farmed in the Pacific Ocean region; feeding behavior; feed ingestion and digestion; and physical properties of feed – and in-depth data on nutrition and nutrient requirements, access the original publication.



View of lobster net cages in Vietnam for the culture of ornate rock or spiny lobster (*Panulirus ornatus*). Photo by Dr. Donald Lightner.

Nutrition and nutrient requirements

Little is known about differences in nutrient requirements in relation to lobster age or size. While many species of fish have decreasing protein requirement as a percentage of the feed as the fish increase in size, it appears that some lobster species have the opposite trend, although data is lacking for our review. Excess protein is unnecessarily expensive and leads to nitrogen waste, contributing to existing

water quality issues with lobster aquaculture. Therefore, optimal nutrient levels, particularly for protein, need to be confirmed and elaborated for the future of sustainable economic aquafeeds for spiny lobsters.

Growth of *P. ornatus* appears to increase linearly with increasing digestible protein in the feed, at least for feed containing up to 56 percent digestible protein (61 percent crude protein). This is consistent with some lobster species that have the best growth and feed conversion from the highest protein and lowest fat feeds tested, but is not consistent with other species. This indicates that generalizing nutrient criteria across genera of spiny lobsters may be misleading.

Crustaceans generally do not grow well on feeds containing more than 10 percent lipid, and lobsters fed “trash” fish also appear to perform better on lower lipid fish species. Some species of lobsters prefer carbohydrate over lipid energy, although it is not clear if this represents positive aspects of dietary carbohydrates, or an aversion to diets with excessive lipids, consistent with other farmed crustaceans. Data on optimum lipid content for *P. ornatus* is limited, however, the species appears to grow better at 10 percent lipid rather than lower levels and appears to be better able to take advantage of higher-protein feeds at this dietary lipid level. Research reports that there may be an optimal level of lipid above 10 percent in feeds for *P. ornatus*, which must be elucidated for appropriate feed formulation.

Lobster aquaculture in eastern Indonesia, part 1



Lobster cage culture has great potential in Indonesia. The current industry consists of about 1,000 small-scale farm units, many of which raise lobsters in polyculture with seaweed and grouper.



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Limited information is available on carbohydrate sources on growth characteristics of lobsters. There is evidence for differences in the speed of digestion or glucose utilization from different carbohydrate sources. Carbohydrate source may also impact intermolt period, which will be reflected in growth rates. Carbohydrates are likely to be a major component of lobster feeds in order to effectively maintain water stability, requiring an understanding of growth impacts and dose-optimization of carbohydrate sources.

Little is known about the fatty acids requirements of spiny lobsters. Omega-3 fatty acids are generally considered to be essential for crustaceans, and some data suggest a requirement for EPA + DHA of 1.8 percent of the feed for *P. ornatus*, which remains our sole guidance on likely fatty acids requirements for Palinurid lobsters.

Cholesterol is one of the key differences between the nutrient requirements of fish and crustaceans. While fish can synthesize sufficient cholesterol to meet their needs, crustaceans require certain levels in their feeds in order to meet their cholesterol requirements for steroid hormone synthesis and other physiological processes. Some research has reported that 3 grams per kg cholesterol supplementation

supported greater growth and survival than higher levels, although lower supplementation levels were not investigated. Further refinement of cholesterol requirements and the need for supplementation will be important for more economical development of lobster feeds in the future, and to avoid negative effects of over-supplementation.

Regarding ingredient quality, a major focus of spiny lobster feed development to date has been to support sufficient feed intake and growth, which has generally fallen short of that provided by feeding fresh mussels. Lobsters appear to be very sensitive to certain tastants [taste-provoking chemical molecules] or other feed quality traits that are lost on freezing, with poorer growth results reported when using frozen mussels as food compared to fresh ones. Different fishmeal types can affect the growth and potentially survival of some species, which may be due to freshness, heating processes or other, yet to be defined, quality criteria. Developing raw material quality criteria will be important for the production of formulated lobster feeds of consistently high quality.

Storage conditions and processing freshness impact the quality of raw materials in aquafeeds, typically measured by total volatile nitrogen (TVN) and biogenic amines in the raw material. Quantification of the impact of these quality parameters in so-called trash fish and raw materials for formulated feed will be critical for the future development of lobster feed formulations.

The mineral requirements of spiny lobsters have not been studied to date, with the presumption that requirements are satisfied by the culture water and feed without the necessity for supplementation. Calcium, copper, phosphorous, potassium, magnesium, selenium and zinc are all required by crustaceans; however, it is unclear to what extent they need to be supplemented in practical feeds. Loss of minerals through molting may impart a periodic necessity for supplementation, and therefore some level of all of these minerals is recommended in practical feeds.

Phosphorous and calcium play important structural and functional roles in crustaceans and their requirements are interrelated. Phosphorous is typically in poor supply from adequate quality seawater, whereas calcium is abundant and able to be absorbed from the water. While calcium is not required in the feed for marine crustaceans, it is generally present in raw materials, which can inhibit phosphorous availability leading to recommendations of calcium:phosphorus ratios of less than 2:1, and in some cases less than 0.5:1. Phosphorous requirement values for crustaceans range from 1 to 2 percent of the feed, which leaves a broad range of potential minimum requirement values for phosphorous and maximum requirement values for calcium.

Vitamins are required for optimal growth, metabolic function and survival, and lobsters are no exception, although their requirements have yet to be quantified. Requirements for all vitamins have been quantified for various shrimp species, and lobsters are hypothesized to have similar requirements. Vitamin supplementation is required for optimum growth and feed conversion of lobsters given feed containing predominantly wild fish, fishmeal and wheat, which would imply that wild fish are, or can be, insufficient in vitamins for optimum production. While many vitamin requirements are relatively conserved between crustacean species, those for vitamin C, choline and inositol vary widely between species.

For the carotenoid pigment astaxanthin, its accumulation in lobster tissues indicates a potential antioxidant and health function which may increase resistance to stressors, as has been shown for penaeid shrimp. Astaxanthin is required at 50 ppm for optimal carapace color, although the benefits of higher supplementation levels remain unclear. Research found that a feed containing 800 mg per kg astaxanthin provided 55 percent higher growth than a feed containing 100 mg per kg. And anecdotal evidence further suggests that 100 mg per kg of carotenoids reduces oxidative stress in the clawed

lobster (*Homarus gammarus*), increasing growth and survival. Future research should elucidate whether this effect is consistent and whether it is specific to astaxanthin or whether it can be replaced by more cost-effective antioxidants.

Manipulation of gut microflora appears to be important for the optimization of growth and health of spiny lobsters. For example, dietary supplementation with health promoters can support gut health, microbial community and growth rates of both *P. ornatus* and *P. homarus*, and improved survival, particularly after a *Vibrio* challenge. Probiotics have been investigated for *P. ornatus*, largely focused on bacterial disease resistance rather than growth effects. It is important to optimize methods of manipulating gut microflora for optimal growth and health benefits.

Reference feeds

Feeds for lobster research to date have been developed in two clearly different directions, but with the common focus of forming a matrix that supports sufficient feed intake. The more traditional method of feed development was started with a fishmeal base and a starch binder, aided by a synthetic commercial pelleting agent to improve pellet binding and produced as a semi-moist pellet. Mixed fresh seafood has been included for palatability; however, it was recently reported that krill meal is more effective in supporting growth and survival of *P. ornatus*.

An alternative approach has been used for other lobster species, based on sodium caseinate, presumably for its highly concentrated water-soluble protein, and with a different binder. The protein content and palatability are delivered through green shell mussel (GSM) meal and betaine, while lipid is increased through krill oil, which combines with lecithin to deliver 1.39 percent of the feed as phospholipid.

Both reference feeds have identified the need for high levels of protein and moderate lipid. While both of these feeds are appropriate references for future development and incorporate various aspects of knowledge gained to date, they both contain ingredients that are not common in commercial formulations, or at least not at the same inclusion levels, due to the cost of the ingredients.

Implementation and adoption of feed formulations for lobsters are likely to require significant cost-optimization before their commercialization is possible. While these reference feeds both currently support inferior growth compared to fresh mussels, their potential for implementation appears promising in areas where fresh seafood bycatch is not readily available. Both feeds represent the product of the research that has gone into lobster grow-out feed development to date and provide a basis for further development.

Young lobsters ready for stocking in net cages in Vietnam. Photo by Dr. Donald Lightner.

Adoption of formulated feeds

Feed for lobsters cultured in Indonesia is entirely “trash” fish, generally consisting of just one or two species of small fish, predominantly sardines. In the locations where lobster farming is established, such as Lombok, there is very limited availability and low diversity of low-value seafoods that might be used as lobster feed. This in contrast to Vietnam where multiple fisheries, using a wide variety of gear, generate significant production of a wide diversity of seafood species including fish, crustaceans and molluscs. The smallest of these have limited human food value and are set aside for lobster farming. They are fresh (daily landings), nutritionally diverse and relatively inexpensive (\leq US\$1.00 per kg), and therefore provide effective nutrition for lobsters. Indonesia appears not to have an equivalent resource, and this has driven strong interest in development of manufactured feeds. In Australia there is limited history and culture of using trash fish for aquaculture grow-out and it is an unlikely development due to cost, environmental and biosecurity concerns.

Vietnamese farmers perceive that lobsters do not adapt easily to manufactured diets (pellets), and that manufactured diets are generally more expensive and lead to slower growth rates than traditional diets. This perception is not based on experience, as manufactured pellets for lobster have not been available. It appears that feed companies have been reluctant to embrace production of lobster feed due to the small volumes that might be involved, as well as the perception of poorer performance.

But economic analysis suggests a lobster feed would fetch a higher price and have a better FCR than those used in traditional aquaculture (shrimp and fish), and therefore profitability may be strong even with smaller volumes. Despite this, there has been no push from Vietnamese lobster farmers to access

a manufactured diet. The fledgling industry in Vietnam suffered a significant impact from a typhoon in 2017 that reduced production by 50 percent, and in turn reduced demand for the fresh seafood feed. Lower demand resulted in reduced cost of these feed sources, which may have lessened interest from aquafeed companies to produce a lobster feed.

Because Indonesia has limited access to the equivalent variety of small seafood species that Vietnam utilizes for lobster feed, the impetus for uptake of manufactured feeds is much stronger. The Indonesian government has an expectation that lobster aquaculture will transition to a manufactured feed, although they have not specified a requirement to do so in the new regulations concerning lobster aquaculture. The Directorate General of Aquaculture has proposed establishing demonstration farms using manufactured feeds to explicitly reveal the advantages of such feeds in terms of both economics and condition of the lobsters produced.

Potential for implementation of formulated feeds

Between 2010 and 2019, research and development interventions to promote lobster aquaculture in Indonesia focused on smallholders in impoverished coastal communities with limited opportunities other than fishing. This research revealed that the individuals and families involved were risk-averse and unwilling to farm lobsters over extended periods to achieve marketable size. Their preference was to sell the lobster seed they caught directly for cash, or on-grow the lobsters for only a short period and to a relatively small harvest size, which was uneconomic. Farmer's husbandry knowledge and financial capacity were very limited, resulting in the application of very poor nutrition to the lobsters they cultured. Although those operators on-growing lobsters expressed positive sentiment to accessing manufactured feeds, if and when they became available, their entire business model was not sustainable and most operations failed.

Subsequent consideration by researchers and government surmised that developmental interventions should focus on small and medium enterprises that were already involved in aquaculture. These existing businesses, with proven capacity in aquaculture, would more likely succeed in farming lobsters and have the financial capacity to apply best practice, including adoption of manufactured diets. Further, such operators are more likely to pro-actively advocate existing aquaculture feed suppliers and manufacturers to provide a lobster feed. From a business development perspective, the manufacture of lobster feeds and their adoption by lobster farmers in Indonesia is more likely with a market development strategy that focuses on small and medium-sized enterprises (SMEs) and business profitability. Conversely, aquafeed manufacturers may invest with greater confidence when SMEs are the driving force of industry development.

View of cage netting used for lobster culture in cages in Vietnam.

Photo by Dr. Donald Lightner.

Perspectives

The development of lobster aquaculture across Vietnam, Indonesia and Australia is providing an increasing motivation for the development of commercial tropical lobster feeds. Competition with “trash” fish and mixed fresh seafood feeds in Southeast Asia requires a cost-effective solution that also provides comparable growth. This is likely to be developed over a concerted effort to solve feed requirements in several areas, including nutrient requirements, raw material quality and value, physical aspects of feed, feeding methods, appetite and health.

Each of these aspects is important for the future development of commercially relevant feeds, which should be undertaken in consultation with the feed industry to ensure commercial relevance and implementation. Co-feeding commercial feeds and fresh ingredients show promise in its ability to spread the limited resource of trash fish and other bycatch further; however, it must be applied to commercial feeding conditions for successful implementation.

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