Improving the Cost Effectiveness of Shrimp Feeds

D. Allen Davis, Luke A. Roy and Daranee Sookying

Department of Fisheries and Allied Aquacultures

203 Swingle Hall

Auburn, Alabama 36849-5419 USA E-mail: DAVISDA@auburn.edu

Abstract

Currently aquaculture is supplying almost half of the world's seafood, making it a primary source of high quality nutrients for human consumption and an invaluable export item for many countries. Market prices have increased for many human food sectors; yet, the farm gate value for seafood products have declined or at best had marginal increases in price. Unfortunately, at the same time feed, fuel and processing costs are rapidly increasing pushing many of the world's producers to cut their production costs or go out of business. For those who would like to remain in the industry we must be willing to adapt to changing markets and adjust production processes to maximize investment returns. If we are to remain competitive, we must know our cost structures and re-evaluate production practices. It is time for the industry to review there production practices, confirm production values as well as costs so they can bet back to the basics of cost effective management and optimized feed formulations. There are no easy solutions to reducing production costs and there are no-magical solutions (that work) for sale on e-bay. Producers who know their system costs and inefficiencies can improve and have a chance of being cost competitive. Starting at the feed mill we must: 1) set nutrient restrictions for our feed formulations using the most up to date numbers and not rely on fish meal to make a good feed 2) select our ingredients based on cost effectiveness and quality 3) optimize mill processes to reduce production costs. At the farm, we must look at our management strategies in the light of economic efficiency and optimize feed inputs to provide the best overall return on our investment. By systematically improving the management of our systems we should be able to improve feed conversion, reduce our dependence on water exchanges and improve overall efficiencies.

Davis, A., Roy, L. and D. Sookying 2008. Improving the Cost Effectiveness of Shrimp Feeds. 271- 280 pp. Editores: L. Elizabeth Cruz Suárez, Denis Ricque Marie, Mireya Tapia Salazar, Martha G. Nieto López, David A. Villarreal Cavazos,Juan Pablo Lazo y Ma. Teresa Viana. Avances en Nutrición Acuícola IX. IX Simposio Internacional de Nutrición Acuícola. 24-27 Noviembre. Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, México.

Introduction

Capture fisheries and aquaculture are producing just over 100 million tons of food fish with commercial aquaculture supplying around half of this production. The commercial culture of shrimp has been one of the most successful sectors of the aquaculture industry. Based on online statistics from the Food and Agriculture Organization of the United Nations, cultured shrimp grew from a 10 billion dollar industry in 2000 to a 15.7 billion dollar industry in 2005. Over the same period the wild capture fishery produced around 3 million tons, whereas the aquaculture industry has grown from 1.2 to 2.6 million tons. Despite the continued expansion of commercial shrimp farming the industry faces a number of economic, social, and environmental challenges. Paralleling other agriculture markets, as the sector grows and matures the market price for the product often falls while costs of production often increase. This forces producers to improve their business practices and increase cost efficiency.

For shrimp farmers feed is one of the primary factors influencing cost efficiency of their farming operation (Tacon and Barg, 1998; Gonzalez-Rodriguez and Abdo de la Parra, 2004). One way to improve production economics is to improve the consistency, quality and economic value of the feed used at the farm level. In addition to the economic challenges, there are also questions regarding whether or not aquaculture is a sustainable practice from an environmental standpoint. In this regard, shrimp farming has been the subject of controversial debates which include the use of high levels of fish meal (and other marine ingredients) in shrimp feeds as well as excessive water use in pond based systems. Hence, there are social pressures to build both eco-friendly and profitable shrimp production systems.

Feed manufacturing

The value of seafood products are declining, stable or in some cases increasing only slightly which is wonderful news for the consumer. At the same time, feed, fuel and processing costs are rapidly increasing pushing commercial aquaculture operations to cut their production costs or go out of business. Given a fixed formulation, the cost of shrimp feeds has almost doubled in the last two years. This is in response to a wide number of factors but was first triggered by rising costs of fish meal which increased almost 50% over a two year period. The rapid increase in world fish meal prices was then followed by a moderate increase in the cost of other protein sources and more recently a rapid rise in cereal grain prices. This has resulted in a doubling of feed costs without subsequent increases in the value of the final product.

Albeit nutrition research can not influence world prices, it can provide alternative formulations to mediate price increases. Fortunately for the shrimp industry, researchers have been working towards the goal of quantifying nutrient requirements and providing information on the use of alternative feed ingredients for some time (Hardy, 1999). Traditional formulations for shrimp feed utilize 20 to 30% fish meal which is one of the most costly protein sources. Fish meal is also an ingredient for which world supply can not be expanded and is considered a limiting factor for the continued expansion of aquaculture. Most people agree that one of the first steps to reduce shrimp feed prices is to provide alternatives to the use of marine ingredients and develop plant based diets.

A number of research groups have been systematically identifying nutrient requirements and working to improve feed formulation technologies. This included a systematic approach to identifying limiting nutrients in the laboratory, testing diet formulations in outdoor tanks and then in research ponds. Using balanced formulations based on alternative protein sources, primarily of plant origin, has resulted in an improvement in the overall nutritional quality of practical diet formulations (e.g. Swick *et al.*, 1995; Davis and Arnold, 2000; Samocha *et al.*, 2004) as well as considerable reductions in formulations costs. These formulations were made possible by systematically identifying limiting nutrients and balancing the formulations as fish meal was removed. For this species, identifying the total sulfur amino acid requirement (< 2.8% dietary protein) was a key factor to removal of fish meal, which is one of the best protein sources for methionine. Once the fish meal was removed (or reduced), researchers identified limitations in essential fatty acids, cholesterol and phosphorus. Numerous studies have been conducted which have demonstrated the feasibility of reducing or completely replacing fish meal with no adverse effect on the productive performance of *L. vannamei* (Akiyama, 1988; Lim and Dominy, 1990; Piedad-Pascual *et al.*, 1990; Davis and Arnold, 2000; Mendoza *et al.*, 2001; Dersjant-Li, 2002; Davis *et al.*, 2004; Samocha *et al.*, 2004; Amaya *et al.*, 2007a, Amaya *et al.*, 2007b). These and current trials have demonstrated that practical diets can be formulated using soybean meal as the primary protein source. Other renewable protein sources such as distillers grain solubles, pea meal and corn gluten meal have been utilized in combination with soybean meal to enhance the amino acid balance and to diversify the ingredient base of these formulations (Hardy, 1999; Divakaran *et al.*, 2000; Cruz-Suarez *et al.*, 2001; Bautista-Teruel *et al.*, 2003; Gonzalez-Rodriguez and Abdo de la Parra, 2004; Roy *et al. In press)*.

Developing a feed that is nutritionally adequate and cost effective is not an easy practice and the formulations will vary from country to country as both prices and consumer preferences vary. The first restriction is that feed ingredient availability, cost and quality varies between regions. In most cases reducing the use of fish meal and replacing it with soybean meal and corn or wheat gluten (which provide a better balance of amino acids) often improve cost effectiveness. High quality local processing wastes such as tuna meal is often very effective and if properly processed it is of better quality than typical fish meals. The same applies to intermediate protein sources such as distillers grain solubles, as well as carbohydrate sources such as broken rice or wheat bran which are often by products of local processing. Unfortunately, the selection of ingredients is not simply based on cost effectiveness, availability and quality. As the farmer is the "purchaser", regional preference of the farmer must also be considered. Such requests often do not have anything to do with nutrition or feed quality. Examples include color, smell and taste. These are often critical characteristics requested by the farmer; yet, they are not likely to be perceived by the shrimp in the same fashion. As one of my friends put it, if you want to demand a specific smell from the feed then you should make sure you put your head underwater while you smell the feed, after all that is how the shrimp does it. Other requests such as low level of fines, sinking rate and stability are reasonable requests albeit quite often water stability is over emphasized.

Irrespective of local restrictions, once a feed formulation is established the feed must be properly processed for best results. Again there are numerous options but there are a few common areas that a feed mill can improve to reduce manufacturing costs and improve feed quality. The first is to ensure the quality of ingredients, which requires suitable specifications for each ingredient as well as suitable sampling and analyses. The second area of improvement can be through energy auditing, which is critical to identify energy wasting procedures. For example, hammer mills are often not optimized for operation and grind size. Quite often there is inadequate air moving through the system, hammers are worn and inappropriate screens are used (i.e. those purchase based on cost vs open area). Another area includes over drying of feeds which is often required because of high variation in moisture content . Remember, removing water uses energy and not selling water reduces profits. The third and most critical component is ensuring proper cooking (gelatinization) of the carbohydrates. This means maximizing the retention time in the pre-conditioner, using high quality dry steam, and maximizing post conditioning. These processes enhance carbohydrate digestibility and ensure good water stability of the feed.

Feed management

Once a quality feed is processed, stabilized and packaged it is of little value if it is not properly applied. Proper application of feeds in not an easy task and it goes hand in hand with proper stocking procedures, regular sampling for growth and health as well as the maintenance of suitable water quality parameters. Improving the economic return from the feed should be one of the primary goals of the farm manager, although it is far from an easy task.

In previous research (see Davis *et al.,* 2006) we have demonstrated a number of feed management concepts. One of the first considerations when planning feed management is to choose a nutrient density of the feed. When selecting a feed and applying it to a production system, one must understand that nutrient requirements are actually daily intakes. Hence nutrient density of the diet (e.g. protein and energy content) will affect how much you should feed as well as the feed conversion. Hence, feed inputs must be adjusted for the nutrient density of the diet; that is to say if we have higher concentrations of a nutrient in the feed we would offer less feed. As an example, a well balanced diet containing 40 % protein and fed at 75 % of the ration will deliver the same protein as a diet containing 30 % protein and offered at a 100 % ration. If the lower protein diet meets the nutritional requirements of the animal under a given set of conditions, increasing protein intake by increasing the daily ration (for this example 110%) does not lead to better growth. However, this overfeeding will in turn increase feed conversion ratios (feed offered per unit biomass gained) and increase pollution loading of the system. Similarly, if one chooses to increase the level of protein in the diet and feed the same quantity of feed (for this example feeding 100% ration of the 40% protein diet), growth would not improve, and feed conversion would stay the same. However, the efficiency of using the protein decreases and nitrogen waste (the metabolic by-product of protein metabolism) will increase. Of course over feeding any diet also reduces the economic returns from the feed.

Once a nutrient density of the diet is selected one must properly apply the feed, which is one of the biggest challenges to the commercial farmer. There are no set feeding rates that work on all farms as there are too many factors influencing growth rates and hence nutrient requirements. This means that each farm should use their own production data and experience to establish feed tables and feeding protocols that are appropriate for their conditions. Quite often when evaluating feed inputs we find that producers with poor feed conversion ratio's (FCR > 1.4 with a 35% protein diet) are overfed during the later portion of production. As feed conversions can only be determined after the fact there is no way to absolutely know what to do during a production cycle. However, if one knows historical results for growth and FCR, as well as current growth and a reasonable estimate of survival one can easily check if feed inputs are "reasonable". For example, if we know that the best FCR we have seen on the farm is 1.2, then we have a target FCR. Similarly, if historic averages for growth is 1.5 g/week then we have a target for growth. Remember, growth will vary from year to year so quite often we use both historical averages as well as current growth per week (averaged over at least two weeks) as guides. As an example, if our survival estimates indicate we have 300,000 shrimp per ha, a typical growth rate of 1.5 g/week and an ideal FCR of 1.2 then we can use this information to estimate daily feed input as follows:

300,000 shrimp/ha*1.5g/wk*1.2g feed/g shrimp*1wk/7days * 1kg/1000g = 77.1 kg/day/ha

Using the same formulation but solving for FCR, we can also estimate our FCR for intermediate periods which can also be used as a guide to indicate if we are over feeding or not. For example if we are feeding 90 kg/day/ha, growth of 1.5 g/wk and assumed population of 300,000 shrimp per ha we can estimate our FCR of 1.4 which is very good and not much off our target so we may keep it depending on where we think survival may be. However, if we were feeding 120 kg/day our calculated FCR would be 1.86 which would be considered high. By putting upper or lower limits on feed inputs one can quite often improve FCR as well as water quality parameters.

Another feed related consideration is that of water exchange. Quite often water exchange is used to control water quality (dissolved oxygen) by pushing out primary production to stabilize dissolved oxygen levels. This may be the best choice in some circumstances (e.g. where electricity is very costly or is not available) but from a cost standpoint aeration is more cost effective. Not only is aeration more cost effective but reducing water exchange improves the quantity of natural foods available to the shrimp. Natural foods are not only very nutritious but they are essentially free food. Hence, reducing feed inputs and water exchanges allows for a better use of natural productivity and reduces feed cost.

Conclusion

Currently the industry is under considerable stress from low shrimp prices and increased fixed and variable costs. If the industry is to continue to improve and expand production costs must be optimized for economic returns. This mean we have to objectively evaluate our production systems across all components from the feed to final harvest. Feed formulations must be improved to reduce the use of expensive ingredients and over formulation of nutrients must stop.

We must re-align our processing equipment to not only produce quality feeds but also reduce our energy use at the mill. At the farm we must critically evaluate our water and feed management to obtain the best return on our investments in feed.

References

Akiyama, D.M., 1988. Soybean meal utilization by marine shrimp. AOCS World Congress on Vegetable Protein Utilization in Human Food and Animal Feedstuffs, Singapore, October 2-7. American Soybean Association, Singapore.

Amaya, E. A., Davis, D. A., Rouse, D. B., 2007a. Replacement of fish meal in practical diets for the Pacific white shrimp (*Litopenaeus vannamei*) reared under pond conditions. Aquaculture 262, 393-401.

Amaya, E. A., Davis, D. A., Rouse, D. B., 2007b. Alternative diets for the Pacific white shrimp *Litopenaeus vannamei*. Aquaculture 262, 419-425.

Bautista-Teruel, M.N., Eusebio, P.S. and T.P. Welsh. 2003. Utilization of feed pea, *Pisum sativum*, meal as a protein source in practical diets for juvenile tiger shrimp, *Penaeus monodon*. Aquaculture 225, 121-131.

Cruz-Suarez, L.E., Ricque-Marie, D., Tapia-Salazar, M., McCallum, I.M. and D. Hickling. 2001. Assessment of differently processed feed pea (*Pisum sativum*) meals and canola meal (*Brassica* sp.) in diets for blue shrimp (*Litopenaeus stylirostris*). Aquaculture 196, 87-104.

Davis, D. A., Arnold, C. R., 2000. Replacement of fish meal in practical diets for the Pacific white shrimp, *Litopenaeus vannamei*. Aquaculture 185, 291-298.

Davis, D. A., Samocha, T. M., Bullis, R. A., Patnaik, S., Browdy, C., Stokes, A., Atwood, H., 2004. Practical diets for *Litopenaeus vannamei* (Boone, 1931): working towards organic and/or all plant production diets. Avances en Nutrición Acuícola VII. Memorias del Septimo Simposio Internacional de Nutrición Acuícola. 16-19 Noviembre, 2004. Hermosillo, Sonora, México. Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, México. ISBN 970-694-161-4.

Davis, D. A., Elkin Amaya, Jesus Venero, Oscar Zelaya and David B. Rouse. 2006. A case study on feed management to improving production and economic returns for the semi-intensive pond production of *Litopenaeus vannamei*. Avances en Nutrición Acuícola VIII. Memorias del Octavo Simposio Internacional de Nutrición Acuícola. 15 al 17 de Noviembre de 2006. Mazatlan, México. Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, México. ISBN 970-694-333-5.

Dersjant-Li, Y. 2002. The use of soy protein in aquafeeds. Avances en Nutricion Acuicola VI. Memorias del VI. Simposium Internacional de Nutrición Acuicola. 3 al 6 de Septiembre, 2002. Cancún, Quintana Roo, México. Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, México. ISBN 970-694090-1.

Divakaran, S., Velasco, M., Beyer, E., Forster, I. and A.G.J. Tacon. 2000. Soybean meal apparent digestibility for *Litopenaeus vannamei*, including a critique of methodology. Avances en Nutrición Acuicola V. Memorias del Simposium Internacional de Nutrición Acuicola. 19-22 Noviembre, 2000. Mérida, Yucatan, Mexico. Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, México. ISBN 970-694-52-9.

Gonzalez-Rodriguez, B. and I. Abdo de la Parra. 2004. Replacement of fish meal with co-extruded wet tuna viscera and corn meal in diets for white shrimp (*Litopenaeus vannamei*, Boone). Aquaculture Research 35, 1153-1157.

Hardy, R.W. 1999. Alternative protein sources. Feed Management 50, 25-28.

Lim, C. and W. Dominy. 1990. Evaluation of soybean meal as a replacement for marine animal protein in diets for shrimp (*Penaeus vannamei*). Aquaculture 87, 53-63.

Mendoza, R., De Dios, A., Vazquez, C., Cruz, E., Ricque, D., Aguilera, C. and J. Montemayor. 2001. Fishmeal replacement with feather-enzymatic hydrolyzates co-extruded with soya-bean meal in practical diets for the Pacific white shrimp (*Litopenaeus vannamei*). Aquaculture Nutrition 7, 143-151.

Piedad-Pascual, F., Cruz, E.M. and A. Sumalangcay. 1990. Supplemental feeding on *Penaeus monodon* juveniles with diets containing various levels of defatted soybean meal. Aquaculture 89, 183-191.

Roy, L.A., Bordinhon, A., Sookying, D., Davis, D.A., Brown, T.W. and G.N. Whitis. Demonstration of alternative feeds for the Pacific white shrimp, *Litopenaeus vannamei*, in low salinity waters of west Alabama. Aquaculture Research, *in press*.

Samocha, T. M., Davis, D. A., Saoud, I. P., DeBault, K. 2004. Substitution of fish meal by co-extruded soybean poultry by-product meal in practical diets for the Pacific white shrimp, *Litopenaeus vannamei*. Aquaculture 231, 197-203.

Swick, R.A., Akiyama, D.M., Boonyaratpalin, M. and D.C. Creswell. 1995. Use of soybean meal and synthetic methionine in shrimp feed. American Soybean Association, Technical Bulletin, vol. AQ43-1995.

Tacon, A.G.J. and U.C. Barg. 1998. Major challenges to feed development for marine and diadromous finfish and crustacean species. In: De Silva, S.S. (Ed.), Tropical Mariculture. Academic Press, San Diego, CA. USA, pp. 171-208.