Creation of Organic Feed Formulations for Rural Pennsylvania Aquafarms

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Executive Summary

Seafood industry analysts report that farm-raised fish will become the fastest-growing sector of the U.S. protein market, outpacing poultry and beef, within 15 years. Aquaculture technology that uses recirculating water tanks instead of larger indoor/outdoor operations that require acres of land may provide Pennsylvania farmers with a value-added opportunity to produce food fish for this burgeoning market.

Aquafarmers also could tap into more lucrative niche markets by producing organic aquacultured products. According to the United States Department of Agriculture's (USDA) Economic Research Service: "Consumers prefer organically produced food because of perceived health attributes and concern about pesticide residues, the environment, and farm worker safety."

When this research was conducted in 2006-2007, USDA and other state government certifying agencies had no rules for fish to be certified organic. The question of whether farmed fish could be labeled organic rested mostly in the source of feed, which often come from wild-grown fish products and oils that can be exposed to environmental toxins.

The researchers therefore worked under the premise that, to gain official USDA organic status, aquaculture feeds should be derived from organically-certified plant proteins and protein sources, relying less on traditional marine-based fish meal and fish oil.

This research looked to develop feeds for high-market-value aquaculture species, using only organically certified protein sources as the primary components. The research identified sources of organic feed ingredients, formulated and produced two experimental feeds, confirmed that these organic formulations support healthy and economic cultures of rainbow trout, and conducted a market analysis of the demand for organic aquaculture products in central and southeastern Pennsylvania.

The results offer strong evidence that there are opportunities to use organic products to lead the expansion of aquaculture opportunities and businesses in rural Pennsylvania.

Introduction

Based on the most recent survey data, aquaculture sales have remained relatively consistent over the past 7 years at approximately $950 million (National Oceanic and Atmospheric Administration, 2007). An analysis of future seafood demand in the U.S. market, however, notes that seafood will become the fastest-growing sector of the U.S. protein market, outpacing poultry and beef within 15 years, and that the seafood industry will require an additional 1.81 billion kilograms of product to meet the U.S. demand by the year 2020 (Johnson, 2003).

According to the U.S. Department of Agriculture's (USDA) Economic Research Service, organic farming became one of the fastest growing segments of U.S. agriculture during the 1990s. The Organic Trade Association (OTA) estimated the value of the organic food industry at $15 billion in 2005, with sales expected to reach more than $30 billion over the next 5 years.

The Center for Rural Pennsylvania
A Legislative Agency of the Pennsylvania General Assembly

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The Center for Rural Pennsylvania is a bipartisan, bicameral legislative agency that serves as a resource for rural policy within the Pennsylvania General Assembly. It was created in 1987 under Act 16, the Rural Revitalization Act, to promote and sustain the vitality of Pennsylvania's rural and small communities.

Aquaculture products are not currently covered under national or state certification processes for organic status, because the industry's traditional feed sources contain significant amounts of marine fish protein from wild sources whose backgrounds cannot be identified.[1]

Pennsylvania's aquaculture industry generates $9.94 million in sales annually. Sales of food fish (largely trout and bass) comprised 81 percent of the total aquaculture sales in Pennsylvania in 2008 (USDA National Agricultural Statistics Service, 2008a). In 2007, there were 70 aquaculture farms in the state with three major food fish enterprises.

A 2003 West Virginia aquaculture study provides an example of the potential economic contribution of aquaculture to Pennsylvania. According to the study, through linkages with other sectors of the economy, a $1 million increase in annual aquaculture production would increase total output in that state by an estimated $2 million annually, generate an additional $1 million in income and business taxes, and add 55 jobs (D'Souza, 2003).

Pennsylvania has long been recognized as a national leader in state-of-the-art trout farming for the food, recreation and stocking industries (Charlie Conklin, Pennsylvania State Aquaculture Coordinator, Personal Communication). The technology used for these enterprises is either river-based pens or indoor/outdoor water flow-through systems.

This research proposed that by developing organic feed sources for the aquaculture industry, and thereby moving fish species toward certified organic status, Pennsylvania could move to the forefront of the burgeoning market for certified-organic, high-market-value aquaculture species. New marketing strategies for aquaculture products and organic feed sources also could lead to industry expansion and additional income for farmers and businesses in rural Pennsylvania.

This project looked to develop feeds for Pennsylvania aquaculture using only organically certified plant and fish protein as the primary components.

The project proposed to employ recirculating technology, which uses tanks where fish are produced in a cost-effective manner through water treatment and recirculation. This technology eliminates the need for outdoor ponds, trough systems, significant water resources and large land requirements. Recirculating systems can use one-quarter of an acre to produce similar quantities of fish as could be produced using multiple acres in pond and flow-through operations (Westers, 2001).

Three Pennsylvania-based food fish enterprises (in central and eastern Pennsylvania) are now marketing trout, tilapia, striped bass, and other species to East Coast markets, to New York City and other metro areas for Asian and other ethnic populations. These operations are using river-based pens and indoor/outdoor flow-through fish systems. Recirculating tank technology has been successfully used for many years in the ornamental fish industry and one enterprise in Delaware is using the technology to grow freshwater shrimp (Charlie Conklin, Pennsylvania Aquaculture Coordinator, Personal Communication).

Cost efficiencies of recirculating aquaculture systems are currently under study, but it was estimated that an operation for the rural Pennsylvania producer would be approximately $200,000, which includes constructing new facilities, filter systems, and first-year costs. This cost would be lower in most cases as new buildings would not be necessary in all cases. Some current aquaculture operations use typical pole barn and metal agricultural buildings. Annual returns are estimated at $12,000 to $15,000. This compares to a new chicken production unit that costs $250,000 and generates an income of about $8,000 a year for Pennsylvania producers. (Handwerker, 2003; Garling, 1993).

While the cost of aquaculture differs with regard to the type of system used, the Maryland Sea Grant Extension Program estimated the cost of producing one pound of aquacultured fish at $1.75 (Lipton and Harrell, 2004). Market price varies, but imported market weight Atlantic salmon sells for about $2.19 per pound. Assuming these inputs, a $.44 per pound profit may be realized. Naturally-produced Atlantic salmon has sold for up to $8 per pound in farmers' markets, so the potential for greater gains is possible.

Compared to livestock enterprises in the state, trout and salmon farming are efficient ways of producing protein as it takes less than two pounds of feed to produce one pound of fish compared to three pounds of feed per one pound of gain in poultry (Hamre, 1991; National Fisheries Institute, 2004; Westers, 2001). Feed represents almost 60 percent of aquaculture costs, so feed efficiencies are important (Westers, 2001). Organic feed sources may increase production costs, but the possible returns for certified organic aquaculture fish may well offset this concern.

The U.S. aquaculture industry is just beginning to adopt new technologies and husbandry efforts that will launch it into the growing aquaculture movement throughout the world.

USDA forecasts a 6.58 percent per-capita seafood consumption increase by Americans from now until the

[1] When this research was conducted in 2006-2007, USDA and other state government certifying agencies had no rules for fish to be certified organic. In October 2008, the National Organic Standards Board, a USDA advisory panel, approved criteria for farmed fish to be labeled "organic." (Federal Register, Vol. 73, No. 207. October 24, 2008) As of June 2009, the proposed regulations had not been adopted by USDA.

year 2020 (Johnson, 2003). Pennsylvania's aquaculture industry could significantly contribute to this market and, through organic certification, tap into additional income streams, including the production of world-wide organic feed sources. This could provide significant revenue to farmers and agribusinesses within Pennsylvania.

Research Goals

The goal of this project was to develop feeds for rainbow trout using only organically certified plant or fish proteins and oils as the primary components. The second goal was to complete a feasibility study to determine the efficacy of marketing organically certified aquaculture products in central and southeastern Pennsylvania.

The Aquaculture Research and Education Center of Cheyney University (AREC) subcontracted with the Regional Economic Development District Initiatives of South-central Pennsylvania (REDDI), a 501(c)(4) organization, to obtain data for the agricultural development research portions of this project. REDDI was well suited for this project because of its existing initiatives supported by the Pennsylvania Department of Community and Economic Development linking agriculture and economic development to create value-added opportunities for farmers.

Methodology

The predominant species of food fish raised in Pennsylvania include rainbow trout, brook trout, brown trout, and Atlantic salmon. These species generally receive feeds that contain a significant amount of marine fish protein (herring, menhaden, anchovy, etc.). These sources of protein are often contaminated with pesticides or heavy metals due to the roles of these species in the food chain and, because they are from wild sources whose backgrounds cannot be identified, they cannot be certified organic.[1]

This research project circumvented these two problems by developing feeds that do not contain fishmeal or fish oils from wild-caught sources and by developing feeds using only organically certified proteins as the primary components. Though non-organic plant-based feeds have been developed for rainbow trout (Smith et al., 1988), this project looked to build on previous experimental data (Hughes, unpublished data), which indicated that an organically certifiable blended yeast protein may also serve as a primary protein source in this type of formulation.

Feeds

The feeds were formulated using linear programming computer software developed for this purpose (Mix-It 2+, Agricultural Associates). Nutrient specifications for the feeds were input into the program along with the nutrient composition of the ingredients to be used. The formulae generated were then visually evaluated for cost and other factors (pellet durability, palatability, nutrient profile, etc.) and the ones best meeting all criteria were selected for use in the feeding study.

Two experimental feeds were generated: one feed used the organic yeast protein blend (NuPro, Alltech Inc., Nicholasville, KY) as its primary protein source, while the other used soy protein as its primary protein source. The control diet for this study was a modification of a standard open-formula trout diet (Piper et al., 1982) (See Table 1).

All diets were mixed and pelleted using standard practices by the staff of AREC and sufficient quantities of each diet, to last for no more than two months, were pelleted prior to the start of the experiment and then as necessary for the duration of the 12-week feeding study. To create the finished feeds, all ingredients (including supplemental mineral and vitamin mixes) were mixed until a uniform consistency was achieved. The mix was fed into a laboratory scale pellet mill and was cold extruded through a die, which provided formed pellets of the correct size for the age of fish being fed. After extrusion, the pellets were placed into a forced air drying unit and the amount of moisture in the pellets was reduced to approximately 10 percent. All feed not currently being fed was stored under refrigeration in plastic containers. The control and experimental diets

Table 1. Percent Composition of Control and Experimental Feeds

Ingredient	Control	Soy	NuPro
Herring Meal (65% MP)	51.0	--	--
Soybean Meal	10.0	75.0	10.0
NuPro	--	--	66.0
Wheat Middlings	8.0	8.0	8.0
Brewers Yeast		5.0	--
Whey, low lactose	5.0	--	--
Wheat Germ Meal	5.0	6.0	--
Blood Meal	5.0	--	5.0
Soy Oil	10.0	10.0	10.0
Vitamin Mix #30[a]	0.4	0.4	0.4
Mineral Mix #1[a]	0.2	0.2	0.2
Choline Chloride (70%)	0.3	0.3	0.3
Ascorbic Acid	0.1	0.1	0.1

[a] See Piper et al. (1982; pp. 394 and 399) for the contents of these mixes.

were subjected to proximate and amino acid analyses using standard procedures (AOAC International).

Fish

This study used rainbow trout fry, which had an average weight of 5.3 grams per fish. The fish were initially held in a central receiving tank. They were then individually netted out and randomly assigned to one of 12, 6.5-liter hatching jars (20 fish/jar). Each jar was supplied with recirculated water at an average temperature of 15°C and a flow rate guaranteeing at least four water changes per hour. The fish were held under these conditions for a period of one week to allow them to acclimate to their new environment prior to the initiation of the study.

Each diet was randomly assigned to four of the 12 jars. This allowed for quadruple replication of each treatment to strengthen the project's statistical analyses.

The fish were fed five times daily over the 12-week period. During the experiment, the amount of food the fish were fed was based on a hatchery constant of 7.5, calculated according to the method of Buterbaugh and Willoughby (1967). The amounts of feed required were calculated weekly and the fish were observed daily for behaviour and morphologic changes. Total fish weight of each replicate was determined biweekly and weight gains and feed efficiency ratios (amount of weight gained/ amount of food fed) were determined from this data. All feeding and handling was done by the project director and a technician.

The weight gain, feed efficiency ratios, and cost of rearing data were analyzed to determine significant differences in the mean values for the treatments.

Results and Discussion

After 12 weeks, the fish fed all three diets performed well (See Table 2), and there were no mortalities or physical abnormalities observed in any of the fish. The fish on the control diet and those on the soy-based diet gained weight and converted food to body mass at rates that would be expected for this species when fed a good quality feed. The fish receiving the feed containing NuPro did not feed as aggressively as the other fish, however, and some of the food appeared to go uneaten, indicating there may be palatability problems with this formulation. Other studies in which large quantities of yeast were incorporated into the feed noted similar results. Though palatability appears to decrease the effectiveness of this feed for supporting growth under commercial situations, additional research on modifications to the formula may mitigate this problem.

No statistical difference in the actual weight gains and the cost of production values for the fish fed the control and soy-based rations indicate that the soy-based feed can be produced for the exact same cost as the control feed ($1.47 per kilogram) or less, depending on market conditions. A previous long-term study (Smith et al., 1988) has shown that diets, such as the soy-based ration used here, can support full life growth of rainbow trout and that these fish are readily accepted by consumers.

Table 2. Effect of Feeding Control and Organic Diets on 12-Week Weight Gains, Feed Efficiency Ratios, and Cost of Production

Treatment	Gain/fish (g)	Feed Efficiency Ratio	Cost of Production	
			$/lb	$/kg
Control Feed	46.69	0.87	$.67	$1.47
Soy-Based Feed	45.11	0.85	$.69	$1.52
NuPro/Soy Feed	43.15	0.63	$.92	$2.02

While this study has shown that a successful organic formula can be produced for rainbow trout, the researchers recommend the resolution of three additional issues. First, it is imperative that a commercial feed manufacturer be located for the feed. This will address safety issues related to the improper mixing of the feed if it were to be done by a farmer or other inexperienced individuals. Second, these formulas should only be seen as the first step in this process. Small changes in the formulas to adjust amino acid balance, mineral balance, or palatability may have a great effect on the production characteristics of both experimental feeds. With feed costs comprising as much as 60 percent of the total rearing costs of trout, a small positive change in performance could make a big difference in the bottom line of an aquafarm. Lastly, there were no quantitative tests done to assess shelf-life and/or pellet durability concerns. Considering the ingredients used, the researchers assumed that the experimental feeds would have a similar shelf-life to the feeds currently being produced today. Storage at room temperature should be sufficient for up to three months as long as dry conditions are maintained. Pellet durability was not a problem during this study, but more directed testing is needed to see how the pellets would hold up when packaged in large quantities (20 kg bags) and handled roughly.

The data presented here only apply to fingerling rainbow trout. These feeds may be useful with other species, such as largemouth bass and certain other carnivorous fish, but the researchers suggest that an experimental feeding trial be conducted before these formulas are fed at production levels with other species. The soy-based formula may also be used with tilapia, though it is a bit high in nitrogen and cost for this species, and would result in excessive ammonia excretion, which

may cause problems in certain recirculating systems. Quite often the use of feeds developed for one species to feed another species will cause problems because of unforeseen nutrient imbalances or interactions. As stated above this should always be done carefully until the species-feed combination has been proven safe.

Marketing Potential for Farm-Raised Fish in Pennsylvania

The researchers conducted a preliminary analysis of the marketing potential for farm-raised (aquacultured) fish in Pennsylvania, with respect to trout, Atlantic salmon, and, to a lesser degree, hybrid striped bass and tilapia. The researchers note that very little quantifiable data exist on fish marketing by small-scale producers in the state. This is mainly due to the proprietary nature of sales contracts and prices. The Northeast Aquaculture Center (NRAC) notes that more and updated marketing research is vital to the growing aquaculture potential in the northeast region. Lack of sufficient funding for such research and limited information from producers and buyers make this a challenging task.

The following information reflects a cross-section of anecdotal material and industry perspectives that provide an insight into the opportunities and challenges related to marketing Pennsylvania food fish.

Identifying intra- and interstate sources of organic ingredients

For the study, the researchers needed to identify and quantify the types of organic aquaculture feed components and feeds that were available. While many ingredients were readily available and many could be obtained from Pennsylvania sources, the researchers noted that fish products would be almost impossible to use because of the lack of a true "organic" designation by USDA for aquatic animal products. The researchers located two organic suppliers but the ability of their organic designations to stand nationwide was unlikely at the time of the research. Furthermore, impromptu inquiries placed to feed manufacturers attending the 2006 World Aquaculture Conference and the 2006 PennAqua Conference indicated a growing interest in the development and sale of organic aquaculture feeds.

Market research regarding aquaculture Atlantic salmon and other high market value species

Based on a report by the NOAA Fisheries Service (2007), Americans currently consume 16.3 pounds of fish and shellfish per person per year. This is a 7 percent increase from 2000. The report also notes that 84 percent of seafood consumed in this country is imported, and domestically aquafarmed fish are becoming a viable option for consumers. While environmental concerns are voiced about offshore aquaculture, several species of finfish can be raised successfully through inland contained (including recirculating) operations. Also, while the aquaculture industry is expanding in the U.S., with an estimated value in excess of $1 billion, it is still only supplying less than 10 percent of the seafood consumed in this country.

Pennsylvania has long been a primary producer of trout and other valuable fish species. It also was among the first five states to establish a fish commission prior to 1870 (Stickney, 2001). Over the years, numerous aquaculture ventures, with varying degrees of success, have been launched in the state. Pennsylvania remains the national leader in producing trout for sports fishing and environmental stocking purposes and is among the top five states for producing farm-raised food fish (USDA National Agricultural Statistics Service, 2008b).

Cottage-industry to medium-sized aquaculture ventures in Pennsylvania have wide-ranging marketing options and prices for products. Direct pond-side marketing businesses (fee-fishing operations) enjoy a standard fee that involves no transportation, and processing, wholesaling and other add-on charges. Further benefit is derived from selling food, beverages and souvenirs to round out the experience.

Food fish producers, selling to wholesalers and brokers, have faced tougher marketing situations, most often accepting prices paid at dockside or through wholesalers and hauler-brokers. This system compares to livestock producers selling animals through a local auction where they receive the price buyers are paying on that particular day. Market prices for trout have been reported at $3.70 to $3.99 per pound and the total value of food size trout sales in Pennsylvania was reported at more than $5 million in USDA's most recent survey (USDA National Agriculture Statistics Service, 2008b).

While these prices provided profit to some larger size operations over a sustained period, many farm-scale operations have not derived the same advantages. Pennsylvania aquafarmers must then identify which market segment will become most profitable for their individual operation: wholesalers, restaurants, seafood stores, supermarkets or direct sales. The Kearney/Centaur Study by the National Marine Fisheries Service (Lipton, 2004) established that retail stores mark up seafood by about 32 percent over their purchase price, while food service establishments averaged a 178 percent markup. While restaurants and seafood stores present options for marketing farm-raised fish, they also expect a steady supply and consistent quality. Offering a year-round steady supply of fish is a limiting factor in most cases for small-scale producers who do not have the equipment or

labor necessary to operate a continuous production system.

Local producers must also compete with imports that are supported, in many instances, by foreign-government subsidized promotions to chefs, wholesalers and processors. An effective strategy for the small and medium-sized growers (50,000 – 100,000 pounds per year) is to shorten the distribution chain and target those segments that provide the greatest return – the consumer or the restaurant specialty markets (NRAC, 2003).

Some larger farmers' markets have presented opportunities for alternative direct sales, but these have been limited in scope and longevity. Market rents, labor issues, storage and display equipment, and a year-round supply of fish have presented challenges to fish farmers selling through farmers' markets. Family operations often experience problems in supplying the necessary labor to be away from the farm several days a week that markets are open. Rising fuel and other transportation costs also narrow profit margins at farmers' markets.

Small-scale operations for the rural Pennsylvania producer were estimated to cost approximately $200,000, which includes constructing new facilities, filter systems and first-year costs. This cost would be lower in some cases as new construction would not always be necessary. Annual returns were estimated at $12,000 to $15,000. This compares to a new poultry production unit that costs $250,000 and generates an income of about $8,000 a year for Pennsylvania producers (Handwerker, 2003).

As consumers become increasingly concerned about food safety issues, aquafarmers may be able to capitalize on the ability to produce protein sources under controlled conditions while marketing the product as "natural" or in the future, "organic."

Consumers have already shown they are willing to pay more per pound, quite often double the price, for certified organic seafood by purchasing European organic fish (O'Dierno and Myers, 2006). If organic status is approved for aquacultured products in the U.S., an even more valuable market will open up. Large aquaculture companies that are anticipating this market development are establishing their presence in the U.S. and gearing up for increased specialty fish production and vertical integration of farm to market operations.

Pennsylvania is historically, geographically and strategically placed to take advantage of the coming fish and seafood protein market that many analysts predict for the future. New technologies, including recirculating systems, offer more environmentally sound and efficient ways to produce consistently good quality fish year-round. Farmers seeking additional revenue streams are excited about the possibility of aquafarming and aquaponics (raising fish and plants together), but marketing remains an elusive piece of the puzzle.

Market research, consumer preference studies, pilot farm-to-chef and farm-to-institution programs and local food promotional programs need to be in place to assist farmers to find the best and most consistent outlets for this product. The Pennsylvania Aquaculture Advisory Council's marketing subcommittee has discussed numerous marketing programs, including promoting Pennsylvania fish to chefs and developing recipe cards for consumers. Much the same as livestock groups have found beneficial over the years, funding for research and promotion are key factors in identifying and establishing marketing streams for aquaculture products. In 2003, the Northeast Regional Aquaculture Center identified the following areas of research necessary for a viable aquaculture industry in the region:

- Consumer preference – determining what to grow and why.
- Price elasticity of seafood purchases – will consumers really pay more for aquacultured products vs. imports?
- Expanding the market for Pennsylvania products and for exports.
- Packaging and product handling.
- Effective channels of distribution.

Ethnic Markets

The researchers also looked at marketing to Asian and other ethnic populations, who purchase live fish as a mainstay of their diet. While ethnic markets have been identified as good targets for specialty fish and seafood items, many of these markets operate independently and obtain product from specialty wholesalers and local fishermen. At a strategic planning session of the Pennsylvania Aquaculture Advisory Council in 2005, industry leaders noted the following regarding ethnic populations and aquacultured products:

- The Asian market prefers eel, carp, tilapia and striped bass over trout or salmon.
- This market prefers live fish. This presents certain problems in transportation and sales, especially in terms of not spreading fish diseases by live transport of fish across state lines.

There is increasing concern about invasive species of fish entering specific bodies of water through live food fish channels and many states have begun banning live fish sales in an attempt to curb the trafficking of invasive carp, soft-shell turtle, eels and other fish. It seems unlikely, however, that this market will entirely disappear.

Ethnic markets are often clustered in larger cities with many different nationalities, including Chinese, Korean, Vietnamese, Thai and Cambodian, purchasing from small community stores. Anecdotal information from Pennsylvania points to striped bass and tilapia as the favorite live fish species purchased by Asian populations at small stores and fish vendors. A New Jersey

Department of Agriculture study pinpointed tilapia as the most popular live fish purchased by ethnic populations in the Northeast (Myers et al., 2005). These populations regard trout and salmon as more expensive varieties and many consumers within the Asian population remain price conscious in purchasing fish for everyday meals. This holds with the New Jersey study showing that price was at the top (78 percent) of the important attributes in purchasing live fish.

The study also indicated the following:

- Asian consumers visited fish vendors an average of 6.5 times per month.
- Consumers spent an average $14.80 per visit.
- Quality and freshness were the top reasons consumers buy live product.
- Physical appearance of the fish at the store and year-round availability were critical factors in purchasing choices.

In the south-central Pennsylvania region, the percent change in the Asian population shows significant increases within the region's eight counties. This increase could influence fish consumption and marketing trends for aquacultured products. The Asian population in south-central Pennsylvania in 2004, and the percent change since 2000 is shown in Table 3.

Table 3: Asian Population in South Central Pennsylvania, 2000, and Percent Change from 2000 to 2004

County	Population 2004	% Change 2000 to 2004
Adams	788	31
Berks	5,434	18
Cumberland	5,233	25
Dauphin	6,685	18
Franklin	1,143	31
Lancaster	8,818	12
Lebanon	1,305	12
York	4,667	16

Data source: U.S. Census Bureau

Trends

Seafood industry reports reflect the concern that protein choices within the next 20 years will decrease from the more traditional sources of beef and poultry to alternative sources, such as aquacultured products. Health experts also predict that aging baby boomers will contribute to higher per capita seafood consumption. Ethnic populations that eat comparably more fish on a daily basis than other populations in the U.S. will also be purchasing more seafood. (USDA Economic Research Service, 2003)

As organic standards are applied to the aquaculture industry, there may be a substantial market for organic fish and demand will influence the pricing of this industry. Consumer confidence in "organically grown" seafood will lead to increased rates of product purchase and a willingness to prepare seafood meals for the family (O'Dierno and Myers, 2006).

Another interesting trend in seafood retailing is selling by portion control, where the product is sold by the piece, usually a six-ounce fillet for $1.99 (Atlantic salmon). This strategy gives the consumer the perception that the price is low when it is actually more than $5 per pound (NRAC, 2003).

These trends may well offer more opportunities for marketing Pennsylvania aquacultured products. On-farm producers, however, still face strong competition from imports and large vertically integrated processor/sellers. By identifying niche markets, investigating cultural and regional product branding, reducing "middleman distribution systems" and using direct sales, on-farm aquafarmers may well be able to tap into new markets for high-value fish sales.

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