Development of Value-Added Products in Aquaculture

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Abstract

Aquaculture is becoming increasingly important in satisfying consumer demands for good quality seafood. It has maintained a steady, positive growth over the years when compared to marine fisheries and is supplying the nutritional needs for both developed and developing countries. While aquaculture has supplied fresh fish and shellfish to global markets, there is an increasing opportunity for expanding value-added products. There are several advantages to value-added processing, including creating safer products, preserving high quality characteristics, extending shelf-life and enhancing economic return to the producer/processor. Value-added products can come in several forms including traditional processed products; market-driven products that have a steady or increasing demand; health-driven seafood, which is becoming an increasingly important niche, values-driven product that is focused more on environmental concerns and social issues, and technology-driven seafood products which often adds safety as well as quality characteristics to products. These different opportunities for aquaculture will be discussed in detail. Value-added processing will play an important role in the growing aquaculture sector to help meet demands of the consumer for safe, wholesome, high-quality seafood products.

Keywords: aquaculture, value-added seafood, technology

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Introduction

World fisheries have changed dramatically since 1990 and if one were in a room of fishery biologists, economists, social scientists and fishery managers there would be an active debate of what changes are the most important. This would include the limitation of production in open-water fisheries, the rise of aquaculture and its importance in world trade, globalization of the marketplace, the increased voice of environmental groups in fishery policy and management, and the rise of the consumer.

This paper will concentrate on the importance of aquaculture and globalization of the marketplace with a special focus on value-added products. World aquaculture production continues to increase at about 5% per year while wild capture has leveled off and slightly decreased (Figure 1). Carp production still dominates aquaculture production, but tilapia and other marine species are rapidly increasing (Figure 2). Whereas carp is primarily used for domestic consumption, aquaculture fish and shellfish are becoming increasing important in the global marketplace. While an overall growth of 5% is hopeful, there is still concern that this will not keep up with demand, and overall consumption will gradually decline as population grows.

The steady demand for fish as food has continued and, for the most part, this increased demand is being supplied through aquaculture (Delgado *et al*. 2003). The dramatic increase in aquaculture production is a two-edged sword as there is unease about environmental impacts in developing countries where most of the growth is occurring. The role of aquaculture in either supplying domestic food needs or being a mechanism for foreign investment and economic benefits through international markets is also a major concern for these countries (Rosegrant *et al*. 2004). In the U.S. we tend to think of aquaculture in terms of imported farmed shrimp, salmon and more recently tilapia and pangasius, along with some domestic production of species such as catfish as the principle components of aquaculture. It is worth noting that the production levels of these species are minor compared to the aquaculture of carp and shellfish which are used for domestic consumption in China and Southeast Asia (Fig. 2). Although

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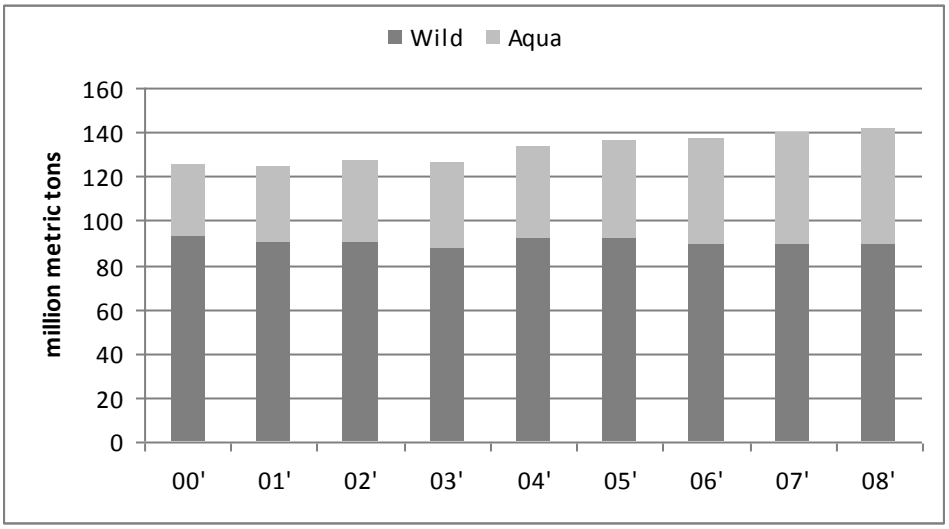
farmed salmon and shrimp are significantly less than carp in terms of production they are major commodities for international trade. Tilapia has also significantly increased in production recently and is having an impact on the sales of white fish in U.S. and European markets. The "catfish wars" have shown that the introduction of high quality aquaculture whitefish can make strong inroads in the U.S. within a relatively short period of time (WSJ 2009). This is even truer lately as the U.S. consumer looks for new species in the marketplace that can satisfy their demand for seafood.

This paper will begin with a discussion of the overall advantages of value-added processing for aquaculture. It will then focus on several major drivers in both the seafood and aquaculture industry which offer opportunities in specific areas in the marketplace. These include topics such as markets, environmental issues, health aspects, new technologies and resources.



Source: FAO, 2010

Figure 1. Total production: wild-caught and aquaculture

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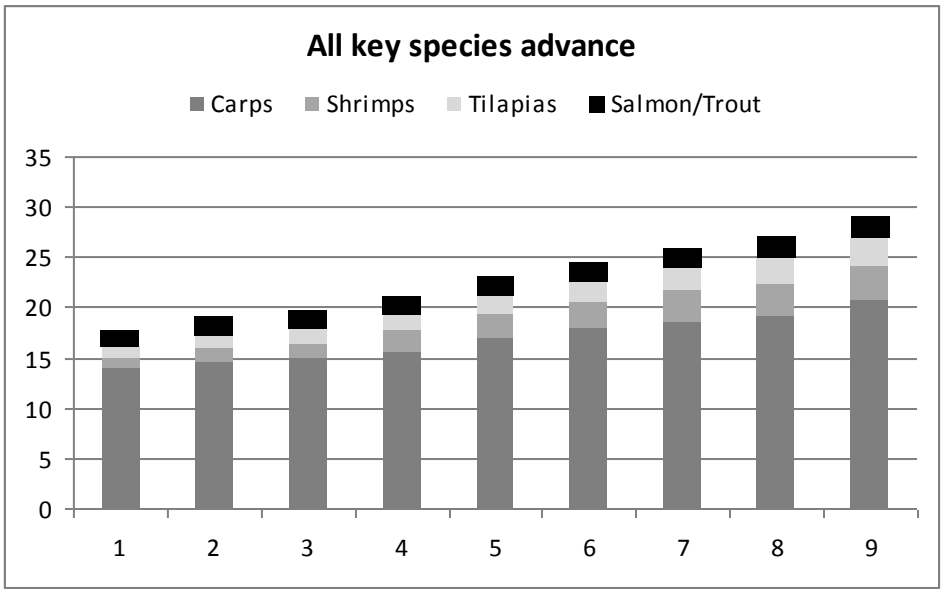

Source: FAO, 2010

Figure 2. World aquaculture production of key species

Value-Added Processing

There are several advantages of value-added processing in aquaculture for both large sector organizations as well as individual companies. Value-added products can:

- Provide another level of safety
- Increase shelf-life
- Help maintain a high level of quality
- Open new market opportunities
- Offer a solution for supply issues

Value-added fish and shellfish products usually undergo some level of processing that will inactivate and/or kill bacteria and pathogens. The inactivation or reduction of bacteria in a food generally results in shelf-life extension and can also provide new market opportunities. Deterioration of fish and shellfish quality is attributed to decomposition of key components of the raw material from endogenous enzymes or microbial action. Heat and cold are the two

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major food processing treatments used throughout the world and both have a significant effect on inactivating enzymes and destroying microorganisms. However, processing can be a two-edged sword, as food products can undergo alteration (e.g. protein denaturation) that will affect final product quality and acceptability. Freezing is a good example of a process that has been in existence for more than 100 years but only recently been used to maintain high quality and preserve the natural attributes of fresh fish and shellfish. Thirty years ago conventional wisdom was to freeze fish when it was nearing the end of its fresh shelf-life and to hope that consumers would accept this product at a discounted rate compared to the fresh product. Over the past decade, however, the seafood industry has been taking a closer look at freezing as a means of maintaining the high quality attributes of seafood. Freezing would also contribute to an increased shelf-life and, consequently, boost distribution and market opportunities. For example, harvest ponds have become analogous to preserving the intrinsic quality of fish/shellfish and provides the fishermen/harvesters with new opportunities to develop novel, high-end markets. Value-added processing also allows flexibility in supply issues. A producer/processor can harvest fish and shellfish at times of optimum quality even if there are seasonality effects. The extended shelf-life that value-added offers, allows the finished product to be released over an extended period of time rather than a short period. Conversely in times of harvest shortages, value-added products can help to alleviate high demand for the product and satisfy customer demand. This blending of disciplines, safety, quality and extended shelf-life has provided opportunities in value-added product development that will hopefully expand in the aquaculture industry over the next several years and provide companies with a growing source of new and profitable market options.

Market-driven

Fish and fishery value-added products have been traded on the global marketplace between the major fishing nations for decades. Approximately 38% of the total fishery production is currently traded through international markets (Barry 2010). Recent trends in globalization have lead to the expansion of sourcing fish from developing countries and increased inter-regional trade for both wild-caught and farmed fish. Japan and the U.S. are the largest

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importers of seafood while China, Norway and Thailand are the leading exporters of fish and fishery products in international markets. Less developed countries, such as Vietnam, have dramatically increased their seafood exports over the last decade and rank 5th in total exports. What has also changed in the last 10 years is the ability of smaller producers in developed and developing countries to enter the global marketplace as well. The use of the internet to facilitate trade has become a standard for sourcing fish and meeting demands. At a local level, the use of the internet for direct marketing, and establishing niche markets are valuable tools that enable the small producer to compete. However, there are trade-offs and one must be willing to take on the responsibilities of distributors, salesmen, quality assurance personnel, etc. while developing these markets.

When the needs of both the consumer and the industry converge, we see great opportunities for success in the arena of seafood value-added products. For example, this occurred in the mid-1990s in the farmed salmon industry. During this period, farmed salmon production was increasing by more than 10% per year in both Norway and Chile, while Alaska was experiencing record harvests of wild-caught salmon. The oversupply caused dramatic declines in the wholesale market price of both wild-caught and farmed salmon, and the industries were under considerable pressure to create changes in the traditional ways that they had marketed salmon to the public. A few decades ago, salmon was considered a high-end product more often known to consumers through white-tablecloth restaurants rather than home consumption. Consumers shied away from cooking the product at home, as it was not considered very convenient to cook, there were several bones that often had to be removed for meal preparation, it would smell up the kitchen, and of course the consumer had no idea how to prepare and cook salmon in their own kitchen. These sentiments changed dramatically when boneless, skinless salmon fillets from Chile were introduced into the U.S. marketplace. Seemingly overnight, salmon was easy to prepare and affordable. Furthermore, the fillets were of good quality and, more importantly, consistent. With the boneless salmon fillet, the consumer began to view seafood in a new light. The U.S. consumer also found that salmon matched up well with the favorite American pastime of backyard grilling right alongside steaks and burgers. The wholesale price of salmon fillet continued to drop from $4/lb in 1994 to less

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than $3/lb in 1997 so that the retail price to the consumer at larger grocery chains was often $4.99/lb or less (Johnson 2004). This was a considerable bargain to seafood lovers who five years previously would have been hard pressed to find salmon fillets (with the bones) at <$10/lb. The workmanship and consistency of the farmed salmon fillets was also far superior to what was usually experienced by the consumer. The mystery of cooking fish seemed to disappear with simple instructions of grilling fish on the barbecue. It was easy to do, kept odors outside, impressed the guests and, quite simply, was delicious. The public responded appropriately and the number of salmon consumers began to skyrocket in the U.S. Salmon consumption doubled from 0.7 lb/yr in 1990 to 1.4 lb/yr by 1997 and continued to rise to 2.2 lb/yr by 2002. Salmon products are now offered in practically all major grocery store outlets and in a range of white-clothed to red-checked table-clothed restaurants throughout the U.S. Although the wild-caught salmon industry initially experienced financial losses due to the reduced prices of farmed salmon, they too eventually benefited from this rise in salmon consumption and they also began to recognize the importance of responding to consumer needs. I would rate the boneless farmed-salmon fillet in the mid-1990s as one of the true stars of seafood value-added products. Although simple in concept, it demonstrates the power of understanding consumer needs at the right time and being able to fill that market niche.

Values-driven

Values-added agriculture and fisheries has become very important for marketing and sales over the past decade. "Values Added" markets refer to the social or environmental attributes purchasers take into consideration beyond product quality and price when making food purchases. These may include credence values such as low environmental impact, fair wages and treatment of workers, as well as humane treating of the animals themselves. Although there has always been a conservation voice with regard to the utilization of natural resources, the seminal moment for many was the dolphin-free tuna effort that occurred in the 1980s (Russell 2002). This demonstrated how a well-organized campaign focused on the end-user (the consumer) could impact harvest practices of a fishery. There have been a number of similar efforts since then and they continue to grow. One could argue the effectiveness of

various conservation-based initiatives but there is no question that their presence is felt in decision making at both the federal and local levels as well as in the marketplace. The development of the Marine Stewardship Council (MSC) which combined the policy arm of the World Wildlife Fund (WWF) and the economic power of Unilever Corporation (the largest wholesale/retail operation in Europe) was a watershed event where the fishing/seafood industry took notice of conservation-based management (Gulbrandsen, L. H. 2009). Once several key fisheries, e.g. Alaska salmon and pollock, came onboard, the importance of being identified as a sustainable fishery to distinguish oneself in the marketplace was recognized. The number of MSC certified fisheries has grown to 128 fisheries in 2010 and the number of fishery products rose to 2,366 representing a growth of 66% year-to-year (MSC 2011). Currently, 23% of consumers recognize the MSC label. More importantly large retail operations are requiring their fishery resources be sustainable and certified (Elton and others 2011). This remarkable transition to sustainable products is becoming more crucial for aquaculture as well. There is wide recognition that demand for fish and shellfish product will continue as health messages are reinforced and population increases. With wild-caught fisheries production being flat, increases will need to come from aquaculture. The Food and Agriculture Organization (FAO) has estimated that by 2030 and additional 37 MMT of fish from aquaculture will be needed to keep current consumption levels. In the rush to be certified, there have been a number of organizations that have been formed to fill this need. This has caused some confusion in the marketplace that is being slowly clarified. The WWF has joined forces with several NGOs and producer groups to create the Aquaculture Stewardship Council (ASC) to certify fish farming operations. While the main driving force for certification are large retail operations, there is an increasing voice from the consumer making demands that all fish and shellfish come from sustainable operations. Aquaculture Certification Council, Inc. is a relatively new NGO established to certify social, environmental and food safety standards at aquaculture facilities throughout the world. It is based in Missouri and builds on elements of the voluntary Global Aquaculture Alliance Responsible Aquaculture Program in a certification system that combines site inspections and effluent sampling with sanitary controls, therapeutic controls and traceability. It certifies the process and not the product. The FAO has its own Global GAP (Good Aquaculture Practices) as well as the Best Aquaculture Practices certification, a

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program supported by industry. The Global Aquaculture Alliance has developed the Best Aquaculture Practices (BAP) standards that is gaining acceptance from a number of large retail chains. The standards specifically deal with food safety, environmental integrity, social responsibility and animal welfare. This will get sorted out over time and the most efficient and trustworthy programs will rise to the top. Large retail operations such as Walmart, Unilever and other stores will dictate what programs are satisfying their customer needs. The main issues for certification will continue along the lines of environmental impacts and health issues (e.g. antibiotics and other additives).

Unlike the wild caught fisheries, the local food or locavore movement has had little impact on local aquaculture production as a marketing tool except for bivalves. In the U.S., this is because of the low volume of aquaculture production in fisheries such as shrimp and tilapia. The exception to this rule is in the shellfish industry. There are efforts underway to regionally identify shellfish such as clams and oysters from both a gustatory standpoint as well as being sustainable harvested. The Pacific Northwest oyster industry has promoted their oysters as the "canary in the coal mine" as a marker species that helps assures clean water in coastal communities and highlight issues with ocean acidification (Downey 2009). The sensory qualities of different water bodies, freshness of the product and the desire to support local shellfish operations have made a perfect combination to give "terroir" attributes to locally grown oysters (Synder 2009; Cacciola 2010). Whether this concept can expand to other aquaculture operations remains to be seen. There is interesting work in several sea bass operations in Europe that are focused on integrated and sustainable aquaculture operations that have the potential of developing strong local and regional markets (Abend and Mayor 2009).

Health-driven

Fish has been recognized as a health food since the 1980s. Early studies with the Greenland Inuits (Bang and Dyerberg, 1980) and Danish men (Kromhout and others 1985) suggested an association between fish consumption and reductions in death from coronary heart disease (CHD). Research over the next few decades supported the association between fish

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consumption and reductions in CHD incidence and mortality (König and others 2005), and identified two compounds that have a major role in these beneficial effects: the omega-3 polyunsaturated fatty acids (PUFA) common in fish oils, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Simopoulos, 1991; Mozaffarian and Rimm, 2008). These fatty acids cannot be synthesized in substantial amounts by the human body and must be obtained through the diet, with the main source being seafood (Williams and Burdge, 2006). In addition to reduced CHD risk, a number of other health benefits have been strongly associated with EPA/DHA intake. These include reduced risk of other cardiovascular disease outcomes such as sudden death (Mozaffarian, 2008) and stroke (He and others 2004), increased duration of gestation (IOM, 2005), and improved visual, cognitive development in infants (Brenna and Lapillonne, 2009; IOM, 2005), and reduced cognitive decline, dementia, and depression (van Gelder and others 2007). Seafood also contains a number of vitamins (for example, A, B-complex, and D) and minerals (such as selenium, iodine, iron, and zinc) that have been linked to various health benefits (WHO, 2002).

The recently published 2010 dietary guidelines from the USDA recommend that consumers eat at least 2 meals of seafood per week, and preferably more. Other organizations such as the Institute of Medicine, the FAO /World Health Organization (WHO) also recommend consumption of 2 servings per week of a variety of fish. These recommendations are based on EPA/DHA of about 250 mg per day (DGAC, 2010; FAO/WHO, 2008). Many developing countries rely on aquaculture fish and shellfish to satisfy their nutrient needs, such as protein as well as receive the benefits of omega-3 fatty acids. There are increasing numbers of consumers from developed countries that are also turning to increased fish and shellfish consumption due to the high nutrient value. In a recent survey of 500 consumers more than 50% were aware of the beneficial effects of omega-3 fatty acids and 44% said they would consider consuming products with fish oils added.

This is one area that aquaculture fish can improve upon. Except for farmed trout, many of the farmed fish tend to be lower in EPA/DHA content. Talapia and pangasius species which are currently in the top ten of consumed fish in the U.S. have relatively low amounts of these long-

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chain omega-3 fatty acids. There is an increase in the number of consumers that are eating fish and shellfish for health reasons and there are studies to show EPA/DHA levels can be increased through diet manipulation. Additional research is needed to maximize these levels in certain fresh water species to give maximum health benefits to consumers.

Technology-driven

Value-added product development can be driven by new technologies that allow for processing breakthroughs in product safety, quality or efficiency of production. Emerging technologies, such as pulse-light, ohmic heating, high pressure processing, etc., have spurred increased research activity and potential applications in improving the safety and quality of seafood products. Novel packaging technologies have allowed for innovative developments in value-added products and new market opportunities for many traditional products. One of the aquaculture sectors that has embraced some of these technologies has been the oyster industry, which is surprising as there have been few changes in the processing of oysters over the past century. The implementation of new technologies in oyster processing have focused on a unique combination of safety and quality parameters that have revolutionized the industry and created several new commercial products. The need for reducing illnesses brought on by the natural pathogens of *Vibrio vulnificus* (Vv) and *Vibrio parahaemolyticus* (Vp) caused a dramatic increase in sponsored research activities in this field. What was unexpected in this research was that researchers and their industry counterparts not only increased the safety of the product but also developed several new products unique to the consumer. The industry implemented these technologies in a relatively short period of time as they responded to the safety concerns of federal agencies and consumer groups. The first method out of the starting gate was the use of alternating heat and cold temperatures that appeared to "shock" Vv and kill off a number of the cells. This became know as the "Ameripure" process and uses a heating bath of 50°C followed by a cold water treatment to reduce Vibrios to a safe level. Another technology that was brought to a new level was rapid freezing of oysters. Research has shown that rapidly freezing oysters significantly reduced the Vp levels and also preserved many of the intrinsic characteristics of the oyster for the consumer (Liu 2009). The use of liquid N_2 in the

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freezing process preserved much of the flavor and texture characteristics as well as greatly improved the shelf-life of the product. Several companies are now freezing shellfish, thereby creating a portfolio of safe products for the consumer to choose from.

An example of an emerging technology that has been implemented by some oyster growing operations in the U.S. is high pressure processing (HPP). This technology was a response to Food and Drug Administration concerns over possible hazards associated with raw oysters. Originally implemented by Motivatit Co. in Louisiana, HPP was shown to by several researchers to inactivate Vibrio pathogens (Styles *et al*. 1991; Calik *et al*. 2002). The process relies on a conveyor system, which moves shell stock, 2 ½ bushels at a time immersed in water, into a tank. The intake end of the canon is then sealed shut and 45,000 psi of pressure are applied to the contents. This amount of pressure severs the adductor muscle from the shell, which results essentially in a perfectly shucked oyster (He *et al*., 2002). Pressure is brought down in the tank via the mechanized control panel and the oysters are released from the exit end of the tank onto another conveyor from which the meats and shell are separated. Research at the OSU Seafood laboratory determined the optimum pressures to use for the shucking process and has also shown a reduction of Vp due to HPP (Shiu, 1999; Calik *et al*. 2002). The industry has used HPP to develop a new, popular convenience product at the retail level as well. This is in the form of a whole oyster in a shrink-wrapped band that is internally shucked and ready for consumption. The consumer needs only to cut the band to have oysters on the half-shell. The HPP project represents a major opportunity to preserve and enhance the economic impacts of the oyster industry. For the first time in over 100 years, a new technology has been introduced to replace the traditional method of processing oysters.

Final Comments

One of the great advantages aquaculture has over wild-caught fisheries is the ability to expand its resources over the next twenty years. As has been stated earlier in this paper, wild-caught resources have reached a plateau and they are unlikely to increase. The only realistic potential for growth is through aquaculture. Price (production costs), taste and sustainability are the

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principle factors that need to be addressed for success in value-added products. Sales of farmed tilapia have risen dramatically over the past decade and it is presently ranked fourth in terms of seafood consumption in the U.S. The consumption change for tilapia in the U.S. has one from 0.35 lb/person/yr in 2001 to 1.45 lb/person/yr in 2010 which represents a 300% increase. Its firm flesh, moderate taste and appearance lends itself to value-added product development, especially as frozen fillets with a variety of sauces and presentations. This will continue over the next decade as long as production holds steady and price remains reasonable. One of the strongest appeals of tilapia has been its price point which was under $1/lb in 2009. Increased demand caused doubling of price in the second year which hasn't slowed its consumption as the price point is still attractive compared to other species in most markets. Both tilapia and pangasius lend themselves to value-added products and it will be interesting to see whether other species can be developed in enough volume to help meet the demands for high quality value-added products.

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