



Application of Biotechnology for the Sustainable Development of Aquaculture-a Review

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Abstract

Aquaculture, or the farming of aquatic animal and plants species, represents one of the fastest-growing food production sectors. Aquaculture also plays an important role in rural economies through the creation of new employments. In these cases, aquaculture outputs will need to be enhanced several folds in order to meet the rising demands for fish and other aquatic products in coming years. Aquaculture is not also left out in the application of biotechnological approaches. The aquaculture industry is currently faced with solving the simultaneous problems of developing economically viable production systems, reducing the impact on the environment and improving public perception. Aquaculture could help to meet increasing demand, and biotechnology can make a great contribution to improve aquaculture yields. Biotechnology is offering valuable applications and all of these applications could help improve the selective breeding, hybridization, productivity, health, growth, nutrition, cryopreservation and conservation of genetic resources in aqua cultural stocks for the benefit of human beings. However, there is need for the regulation of biotechnology activities in terms of the potential adverse impacts on the environment and human health. Therefore, based on published literature. this review discussed the importance of biotechnology in aquaculture, and the environmentally sound use and management of aqua cultural biotechnology in sustainable development of fisheries.

Keywords

Aquaculture, biotechnology, fisheries, transgenic forms, sustainable development

INTRODUCTION

Aquaculture is the fastest growing food sector in the world with its increasing role in the economic development and safe food strategy of countries. Recently aquaculture sector is faced with several challenges such as low productivity, low diversification of species, high competition in the market and environmental impacts that have resulted from the intensification and global development of aquaculture industry. Biotechnology is one tool that holds much promise towards

addressing these aqua cultural problems. The relatively new tools of biotechnology offer significant opportunities to improve aqua cultural productivity and environmental quality worldwide. Today biotechnology has developed creative new methods to detect the gene liable for specific characteristics, such as disease resistance, nutrient composition, and insert them into another fish or aquatic organism (Fletcher *et al.*, 2011). Genetic modification and biotechnology also hold tremendous potential to improve the quality and quantity of fish reared in

aquaculture. Successful development and application of biotechnology are possible only when a broad research and knowledge base in the biology, variation, breeding, agronomy, physiology, pathology, biochemistry and genetics of the manipulated organism exists. Benefits offered by the new technologies cannot be fulfilled without a continued commitment to basic research. Biotechnological programmes must be fully integrated into a research background and cannot be taken out of context if they are to succeed. The potential area of biotechnology in aquaculture include the use of synthetic hormones in induced breeding, transgenic fish, gene banking, uniparental and polyploidy population and health management.

Concept of sustainable development in aquaculture

The Rio declaration of 1992 clarified that governments have a global responsibility for resolving conflicts over the environment in ways that protect the interest of humanity and nature. One good example of international obligations that has included the concept is the Convention of Biodiversity (CBD). With regard to aquaculture, recommendations for employment of sustainability can be found in the Holmen kollen guidelines for sustainable aquaculture (1999), in the Norwegian ministry of fisheries and costal affairs strategy for an environmental sustainable seafood industry (2009), and in the EU communication; A strategy for the sustainable development of European aquaculture (2002). The main contested values and practices of sustainable development are what values are important within sustainable development and how to set priorities between them, and how to achieve maintenance and preservation of nature and biodiversity versus a just society and economic development (Kamara *et al.*, 2006). A conceptual framework for sustainable aquaculture has been presented from three perspectives: environmental, economic and sociological (Caffey *et al.*, 1998). This implies that introduction of modern biotechnology must be explored both with regard to the adequacy of present approaches and with regard to the problem-solving nature of the new technology. Hence, sustainable development requires a renewed focus on stakeholders and their needs; it demands clearer understanding of stakeholder's perspectives and public concerns as well as attention to issues of institutional structure and representation in decision-making processes (Anne Ingeborg Myhr *et al.*, 2011).

Genetically modified species (Transgenics)

The first transgenic fish was produced Zhu *et al.* (1985) in China, who claimed the transient

expression n putative transgenics, although they gave no molecular evidence for the integration of the transgene. The technique has now seen successfully applied to a number of fish species. Transgenics involves the selective transfer of one or more genes for desired traits from one variety to another. These traits may include improvement of growth rates, larger size, more efficient feed conversion into muscle and control of sexual maturation (Elzaeems, 2004). Growth hormone genes from human or animal sources was successfully introduced into several fish species such as salmon, trout and tilapia, resulted several times faster growth than their natural counterparts. This is a faster and more accurate method of breeding new varieties. If desired traits cannot be achieved by traditional breeding, the transfer of genes between species also is possible. For example, better tolerance to environmental stresses and increasing of resistance to extreme environments are important applications to establish unique characteristics and produce a valuable biological product such as antifreeze protein gene (AFP) transfer in fish for adaptation to a freezing environment (Hew *et al.*, 1992). Intensification and sustainable development of aquaculture will rely on disease prevention, and therefore, biotechnology is essential way for greater resistance to pathogens and improvement of farmed species health through selection for disease resistance (El-Zaeem and Aseem, 2004). Also, by using this technique disease transfer between cultured and wild populations can be reduced. The most promising tool for the future of transgenic fish production is undoubtedly in the development of the embryonic stem cell (ESC) technology. These cells are undifferentiated and remain totipotent so they can be manipulated *in vitro* and subsequently reintroduce into early embryos where they can contribute to the germ line of the host. This would facilitate the genes to be stably introduced or deleted (Melamed *et al.*, 2002).

Nucleocytoplasmic Hybrids

A variant of transgenic technique is the production of nucleocytoplasmic hybrids. Again, it has been possible to produce a hybrid fish by transferring the nucleus of the crucian carp, *Carassius auratus* into the egg cytoplasm of the carp, *Cyprinus carpio*; about 1% of the progeny survived and was found to grow faster than the parental species (Shaoji *et al.*, 1984).

Polyploidy in fishes

The polyploid state refers to individuals with extra sets of chromosomes. The normal and most common chromosome complement is two sets (diploid). Polyploidy is lethal in mammals and birds, but has led to the development of many useful, improved plant

varieties, including domestic wheat (Strickberger, 1985). Triploid fish are viable and are usually sterile, which is a result of lack of gonadal development (Chourrout *et al.*, 1986). Culture of triploid fish can be advantageous for several reasons. The potential of increased growth (Chourrout *et al.*, 1986), increased carcass yield, increased survival and increased flesh quality are the main culture advantages (Dunham, 1996). At the onset of sexual maturity, reduced or inhibited gonadal development may allow energy normally used in reproductive processes to be used for growth of somatic tissue (Wolters *et al.*, 1982). The sterility of triploids would be desirable for species such as tilapia, where excess reproduction may occur in production ponds (Shelton and Jensen, 1979). Use of sterile triploids can prevent the permanent establishment of exotic species in otherwise restricted geographical locations (Shelton and Jensen, 1979). Induction of triploid in interspecific hybrids can prevent the backcrossing of hybrids with parental species (Curtis *et al.*, 1987), and also allows viability in some unviable diploid hybrids (Allen and Stanley, 1981). Other potential uses include supplemental stocking of natural populations without compromising the genetic integrity of the resident population, disruption of reproduction in nuisance species and sterilization of transgenic fish, all mechanisms for reducing environmental risk and applying genetic conservation.

Biotechnology and Fish Breeding

Gonadotrophin releasing hormone (GnRH) is the key regulator and central initiator of reproductive cascade in all vertebrates (Bhattacharya *et al.*, 2002). It is a decapeptide and was first isolated from pig and sheep hypothalamus with the ability to induce pituitary release of luteinising hormone (LH) and follicle stimulating hormone (FSH). Since then only one form of GnRH has been identified in most placental mammals including human beings as the sole neuropeptide causing the release of LH and FSH. However, in non mammalian species (except guinea pig) twelve GnRH variants have now been structurally elucidated, among them seven or eight different forms have been isolated from fish species. The most recent GnRH purified and characterized was by Carolsfeld *et al.* (2000). Salmon GnRH analogue profusely used now in fish breeding and marketed commercially under the name of oovaprimo throughout the world. The induced breeding of fish is now successfully achieved by development of GnRH technology.

Disease control

Disease outbreaks are a serious constraint to the development of intensive aquaculture systems and

can have a major impact on production due to mortality and decreased growth. It has been recognized that disease is the most significant factor impacting the intensive production of shrimp, salmon, carp and tilapia, with losses of 10 – 90 percent of total production (Peinado Guevara and López-Meyer, 2006). Although many aquatic animal pathogens are well studied, unlike in terrestrial animals, the spread of pathogens is easy through water, and control is difficult due to high density culture in fluid environment. Disease occurs in all systems, from extensive to intensive, although heavy losses are always possible in intensive production systems (Bondad-Reantaso, *et al.*, 2005). Here biotechnological tools can be a valuable part of management approaches. Their scope of application is broad – they can be used as sensors in the production environment, for waste management (through controlled microbial technologies), and for disease detection and control (molecular methods). Traditionally, disease control is often carried out only after mortality has been observed. In the past, the diagnosis of fish diseases has been achieved primarily using histopathological methods, supported by parasitological, bacteriological and viral studies based on necropsy and in vitro cell culture. These are well-proven techniques; however, they require a high level of expertise and are often quite time-consuming, not being susceptible to automation. For these reasons, although expert training is required, polymerase chain reaction (PCR) technology has become an important tool for pathogen assessment in developing countries.

Biodiversity conservation and fisheries management

Good fisheries management requires effective conservation measures, which require better understanding of the population structure of the fishery. One of the most important population parameters for assessing the fate of a population is the effective population size (N_e). N_e determines the amount of genetic variation, genetic drift and linkage disequilibrium in populations and can be calculated as half the reciprocal of the rate of inbreeding (Tenesa *et al.*, 2007). Due to differences in the biological and environmental factors affecting the survival of individual families, many species show a relatively large variance in family size, further decreasing the N_e (Falconer and McKay, 1996). Fisheries resource managers have focused on the actual number of individuals in a population (census numbers) (Grant, 2007), which may be many times higher than the effective population size (Primmer, 2006). Therefore, it is difficult or even impossible in some cases to infer the effective population size

using the census number. Inadequate procedures for stock enhancement can yield a very small effective population size due to the high prolificacy of fish and shellfish species. Thus, a very small number of breeders could be used for restocking purposes, and bottlenecks can affect the fitness of the population in future generations. A range of biotechnology-based approaches are being used to conserve wild fish populations, such as the use of molecular markers: to estimate N_e in wild populations; to study gene flow between farmed and wild fish populations; and to monitor and understand changes in wild fish population sizes (Hansen, 2008).

Cryopreservation

Cryopreservation is a process where biological material is long-term preserved by cooling to low temperatures usually at -196°C in liquid nitrogen. As any physiological activities and biochemical reactions is tranquilized and effectively stopped at these low temperatures, therefore making it possible to keep them viable for long period. The development of cryopreservation technology provides short- and long-term storage of gametes, and thus the technology has been adapted to cryopreservation of fish spermatozoa. Application of the method to aquaculture increases the flexibility in breeding of species; specifically, if the sexes mature at different times (in hybridization) or spawning season is very short. Cryopreservation overcomes problems of low amount of semen from males in photoperiod treatment. The resulting benefits could include year-round production of gametes and creation of new markets (cryopreservation of genetically improved or phenotypic sperm). Gene banking of cultivated and wild aquatic organisms is also essential, and the technique may help to conserve genetic resources and biodiversity.

Vaccines

Vaccination is the action in which a host organism is exposed to organic (biological) molecules that allow the host to mount a specific immune reaction through which it has a better capability to fight subsequent infections of a specific pathogen compared with genetically similar non-vaccinated hosts. It has also been shown to be cost-effective and has led to the reduction in use of antibiotics. A wide range of commercial vaccines is available against bacterial and viral pathogens and many new vaccines are under development. Most target salmon and trout, and there are expanding opportunities for marine fish (Thompson and Adams, 2004). The most straightforward approach is to culture the pathogen after it has been inactivated and presented to the host. So far, vaccines containing more than ten bacterial pathogens and five viral pathogens have

been produced based on such inactivated antigens (Sommerset *et al.*, 2005). Alternatively, the pathogen is not inactivated but chemically or genetically weakened so as to survive only for a limited period in the host, where it induces a specific immune response without causing disease and mortality. Such vaccines are generally described as "live" vaccines, and there is concern that the attenuated strain may back-mutate and revert to the virulent wild type (Benmansour and de Kinkelin, 1997). The use of vaccines provides good immune prophylaxis for some of most important infectious diseases of finfish. In developed countries, their use has proved very effective at decreasing the unsustainable use of antibiotics. Commercial vaccines using inactivated bacterial pathogens are available for some species: channel catfish, European seabass and seabream, Japanese amberjack and yellowtail, tilapia, Atlantic cod, salmon and trout (Ingunn *et al.*, 2005).

CONCLUSION

The use of successful and effective biotechnologies in aquaculture is very much confined to genetic manipulations and improvements and to health management. Most biotechnological interventions have been developed for improved production and the better management of aquaculture. Most have been targeted towards high-value commercial aquaculture species generally produced for international markets. Although many small-scale farmers are producing for export markets, the significant uptake of many biotechnological interventions and innovations has generally been restricted to commercial or industrial aquaculture operations. To eliminate uncertainties and vulnerabilities in the risks, governmental support is the essential element in enhancing aquaculture development without any environmental impact. Moreover, biotechnology has raised important ethical and morality issues which need to be carefully addressed before its application to aquaculture. In conclusion biotechnology is an important key for aquaculture.

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