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Review

Biotechnology and species development in aquaculture

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The use of biotechnology in various aspects of human endeavour have obviously created a great impact but not without some risks. Not withstanding, there is still the need for its adoption as more of the already adopted biotechnologies are being improved upon with lesser demerits. 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. Whereas significant progress has been made in understanding production systems, improvement in cultured stocks has not kept pace with productivity demands. This paper considered aquaculture as the only way to increase fish production and also discusses technical environmental and management considerations regarding the use of genetically modified fish organism (e.g. fish) in aquaculture. This paper discusses advantage of biotechnological research application and commercialization.

Key words: Biotechnology, species, development, aquaculture.

INTRODUCTION

Fish supply from the capture fisheries in countries all over the worlds is believed to have reached or close to maximum sustainable yield and thus, aquaculture remains the last hope for providing enough fish for the world, being the cheapest source of animal protein. From a global perspective, the total supply of fish food (excluding china) has been growing at a rate of 2.4% since 1961 while the human population has been growing at 1.8% p.a (NEPAD, 2005). The per capital supply has increased to 8.3 kg/yr for low Income Food Deficit Countries (LIFDCS) to 14.8 kg/yr for developing countries in general. Overall, the average capita supply for countries with inland capture fisheries is <2.5 kg/person, but amongst it the top 20 countries for inland fisheries, there are 13 African countries including Chad, Uganda, Mali, Congo Republic, Gabon, Tanzania, Zambia, Kenya, Benin, Egypt, central African Republic, Malawi and Congo DR with per capital fish supply ranging from 4.5- 9 kg/capita (FAO, 2004). For Africa, therefore, inland fisheries make an important contribution to total food supply.

Aquaculture has grown strongly in most regions of the world where the potential exists, except in sub-Saharan Africa (FAO, 2004). In the entire region, only Egypt has achieved the scale of change observed else were (NEPAD, 2005). In spite of decades of investment and technical input, it has failed to thrive where expected, and in many cases remain precarious and marginal. However, aquaculture has grown in specific conditions and context, and inspite of the many current economic, demographic and social challenges in the region, a more positive perspective of market-led growth and more realistic understanding of technical potential, linked with the possibilities of broader economic regeneration, suggests that future opportunities may be much more definite (NEPAD, 2005).

The use of modern biotechnology to enhance production of aquatic species holds great potential not only to meet demand but also to improve aquaculture. Genetic modification and biotechnology also holds tremendous potential to improve the quality and quantity of fish reared in aquaculture, although, not without significant controversy and risk. Biotechnology has the potential to enhance reproduction and the early developmental success of culture organism. The technology is used in several different ways in aquaculture and its application benefits both producers and consumers of aquacultural products. Areas of biotechnology in aquaculture are transgenics, feed sources and improve composition of the feed. Other ways in which biotechnology is applied to

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aquaculture include: improvement of growth rates and control of reproductive cycles through hormone therapy, production of new vaccines, conserving genetic resources, enhancing unique biomedical models and development of diseases resistance in fish (FAO, 2000).

The development of genetically modified fish has undergone intensive research since the first production of genetically modified mammal (Daulin et al., 1995). Genetically modified fish are being developed for both academic and applied goals, allowing the production of useful model systems as well as new genetic strains with improved characteristics for aquaculture (Maclean and Penman, 1990; Chen and Powers, 1990; Houdebine and Chourrout, 1991; Fletcher and Davies, 1991; Maclean and Laight, 2000). A variety of genes have new been introduced into fish with the goals of influencing traits such as growth, maturation, freezing tolerance, flesh quality and disease resistance (Shears et al., 1991; Chatakondi et al., 1995; El-zaeem, 2001; Dunham et al., 2002; El-zaeem and Assem, 2004; El-zaeem, 2004).

Therefore, the aim of paper is to review the areas in which biotechnology is being used in aquaculture, and highlight prospects and advantages in its application and advancement.

TRANSGENIC FISH

Biotechnology can be used to introduce desirable genetic traits into the fish, thereby creating harder stock. Transgenics involves the transfer of genes from one species into another species, in this case, fish. By using different transgenic techniques, researchers are seeking to improve the genetic traits of the fish used in aquaculture. Researchers are trying to develop fish which are larger and grow faster, more efficient in converting their feed into muscle, resistance to disease, tolerant of low oxygen levels in the water and tolerant to freezing temperatures.

Growing fish that are longer and heavier is the goal of researchers who are experimenting with applying various types of growth hormone in fish. One method of doing this is to dip the fish in a solution which contains the hormone. However, there are some problems with this technique. First, it may be difficult to produce large quantities of purified growth hormone, the method is labour intensive, and it is difficult to determine if the fish are getting the right amount of growth hormone. Therefore, researchers have developed new strains of transgenic fish which naturally produce just the right amount of growth hormone to speed their growth. Such fish is more cost-effective since they would produce higher levels of growth hormone on their own, and they would pass this trait to their offspring. There are two main techniques which researchers use to transfer genetic material in fish. One is called micro-injection, in which the genetic material is injected into newly fertilized fish eggs. However, this method is time consuming, so researchers may prefer to use electroporation. This involves transferring the genetic material, or DNA, into fish embryos through the use of an electrical current.

A foreign gene can be transferred into fish *in vivo* by introducing DNA either into embryos or directly into somatic tissues of adults (Sudha et al., 2001). Direct delivery of DNA into fish tissues is a simple approach, providing fast results and eliminating the need for screening transgenic individuals and selecting germ line carriers. Gene transfer and expression following intramuscular direct injection of foreign DNA into skeletal muscles of fish has been achieved by several studies (Hansen et al., 1991; Rahman and Maclean, 1992; Anderson et al., 1996; Tan and Chan, 1997; Xu et al., 1999; El-zaeem, 2004; El-zaeem and Assem, 2004; and Hamelda et al., 2004).

Genetic engineering is a vague term that has come to be nearly synonymous with gene transfer, that is, the production of transgenic fish or genetically modified organism (GMOS). This technology is progressing rapidly and it is now possible to move genes between distantly related species. Since the development of the GE fish in the early 1990s (Aken, 2000), researchers and aquaculture companies have concentrated on genetically engineering fish that would grow faster and need less feed. As mentioned earlier, many research groups have successfully introduced growth hormone genes from human or animal sources into several fish species such as Salmon, Carp, trout and tilapia, causing them to grow several times faster than their natural counterparts.

FISH FEED PRODUCTION

Nutrition, defined as the process by which an organism obtains food from its environment needed for its survival and growth, is believed to serve as determining factors in the profit level and adequate economic returns in intensive fish farming (Nwanna, 1995). Biotechnology is also helping to answer some of the technical and environmental concerns of the fish farming. Many of these centers around what the fish eat. Right now the most common protein source for many fish diets is fish meal. Fish meal, a by product of fish processing, is used because of its high quality and high protein content. However, it has some disadvantages. One disadvantage for fish producers is that it is expansive. Another concern regarding fish meal is the stability of supply. Fish meal comes from the by products of wild fish, but world fish stocks are declining. At the same time, fish farming is on the rise, and demand for fish meal is increasing. Given these factors, it is unlikely there will be enough wild fish to meet the increasing demand for fish meal. The use of fish meal in aquaculture causes other environmental concerns, as well. It contains levels of phosphorus far beyond the requirement for optimal growth in fish. The excess phosphorus goes into the water, causing problems such as eutrophication or excess algae growth.

As a result of these concerns with fish meal, researchers are using biotechnology to produce alternative plant-based protein sources. Plant protein has the potential to address the problem of phosphorus pollution, since plants do not contain such high phosphorus levels. Also, the use of plant protein in aquaculture would help take the pressure off wild fish stocks. Biotechnology is often used in feed processing. Plant protein also requires processing because plants contain anti-nutritional compounds as a defence mechanism. These compounds must be destroyed during processing or they could harm the fish. Researchers are also dealing with these antinutritional factors by producing feed enzymes to counter-act them. Phytase is one example: this enzyme would help fish make the best use of the phosphorous available in a plant-protein based feed.

ENHANCING EARLY DEVELOPMENT AND REPRODUCTION

Biotechnology can be applied to enhance reproduction and early development of cultivated aquatic organism. The resulting benefits could include year-round production of gametes and fry of economically valuable species and creation of new markets for specialized, genetically improved brood stock. Similarly, biotechnology may provide techniques for improving the reproductive success and survival of endangered species, thereby helping to preserve the diversity of life on earth.

HYBRIDISATION

Hybridisation is a simple genetic technology that has become easier with the development of artificial breeding techniques, such as the use of pituitary gland extract and other hormones to initiate gamete gland extract and other hormones to initiate gamete development and induce spawning (the depositing of eggs) and an increased understanding of environmental cues that influence reproduction, such as day length, temperature or water current.

Many of the natural reproductive isolating mechanisms that species develop in the wild can now be overcome by fish farmers. These improvements in reproductive technologies have also assisted aquaculturists greatly in their effort to domesticate aquatic species. In addition, by making it possible to remove the natural constraints and timing of breeding, farmers are able to mate many more species at the times that are most beneficial and thus help to ensure a steady and consistent supply of fish to the market.

Hybridisation can also be used to produce single sex groups of fish when the sex-determining mechanisms in the parental lines are different; for example, hybridisation of *Nile tilapia, Oreochromis niloticus* and the blue *tilapia*, *O. aureus.*

CRYOPRESERVATION

The development of cryo-preservation or low temperature technology allows the short and long term storage of gametes. Currently, these low temperature techniques can only be used on male gametes eggs and embryos and generally not be stored in this way. Freezing gametes can increase the flexibility of a fish breeder, especially when breeding species where the sexes mature or migrate at different times, when the breeding season is very short, when the breeders are far apart or when one sex is exceptionally rare (Hagedorn et al., 1997; Hagedorn and Kleinhans, 1998).

HEALTH IMPROVEMENT OF SPECIES

Biotechnology offers substantial opportunities to improve the health and well being of cultivated aquatic organisms. More than 50 diseases for instance affect fish and shell fish cultured in the United States, causing losses to tens of millions of dollars annually (Shelton, 1996). Biotechnology not only improves the survival, growth vigor and well being of cultivated stocks, but also can reduce disease transfer between cultivated and wild stocks. New products and market opportunities can be developed related to aquatic animal health and well being. Genetic biotechnologies are being used to improve fish health through conventional selection for disease resistance and through the use of molecular investigation and diagnosis. Genetically engineered vaccines are also being developed to protect fish against pathogens.

CONCLUSION

The expansion and intensification of aquaculture will no doubt be further boosted by application of biotechnology. Biotechnology is also crucial in the management of wild fisheries which in turn has link with aquaculture. Aquatic ecosystems offer abundant resources for research and development. Yet, the potential of this domain as the basis for new biotechnologies remains largely unexplored. Indeed, for the vast majority of aquatic organisms (primarily microorganisms) identified, there is insufficient knowledge to permit their intelligent management and application. For example only an insignificant portion of funding has been devoted to biotechnology and aquaculture in Africa. Additional donor support for research in key areas of biotechnology and aquaculture is therefore, necessary. This will generate both new fundamental knowledge and advanced technologies for producing new adapted aquatic organism (especially fish) and other products while developing and improving bioremediation, enhancing cultivation of aquatic species and expanding understanding of biological processes in aquatic ecosystems and their role in global change.

REFERENCES

Aken J (2000). Genetically Engineered fish: Swimming Against the Tide of Reason, Green Peace Canada 250 Dundas St. W, suite 60s, Toronto, Ontario MST25 1-3pp.

Anderson ED, Mourich DV, Leongo JA (1996). Gene expression in rainbow trout *(Oncorhynchus mykiss)* following intramuscular injection of DNA. Mol. Mar. Biol. Biotechnol. 5(92): 105-113.

Chatakondi N, Lovell RJ, Duncan PL, Hayat M, Chen TT, Power DA, Weete DJ, Cummins K, Dunham RA (1995). Body composition of transgenic common carp (*Cyprinus Carpio)* containing rainbow trout growth hormone gene. Aquacult. 138: 99-109.

Chen T, Power DA (1990). Transgenic fish Trends Biotechnol. 8: 209-215.

El-zaeems SY (2004). Alteration of the productive performance characteristics of *Orechromis niloticus and Tilapia Zillii* under the effect of foreign DNA injection. Egypt J. Aquat. Boil. Fish. 8(1): 261-278.

El-zaeem SV (2001). Breeding studies in Tilapia PH.D Thesis, Fac. Of Agric (Saba-Bacha). Alex Univ. Alexandria, Egypt.

El-Zaeem SY, Aseem SS (2004). Application of biotechnology in fish breeding: 1 –production of highly immune genetically modified Nile, tilapia *Orechromis niloticus* with accelerated growth by direct injection of Shark DNA into skeletal muscles. Egypt. J. Aquat. Biol. Fish. 8(3): 67-92.

FAO (2004). The State of World Fisheries and Aquaculture. Report (http://www.fao.org).

FAO (2000). How appropriate are currently available biotechnologies for the fishery sector in developing countries? Conference on Biotechnology in Food and Agriculture. August 1- Oct 2000.

Fletcher G, Davies PL (1991). Trangenic fish for aquaculture. Genet. Eng. 13: 331-897.

Hagedorn M, Kleinhans FW (1998). Cryo preservation of fish embryos,: Is it with in the foreseable future for aquaculture? Cryo-presentation of Gametes and Embryos of Aquatic species. World Aquaculture Society. Tiersch T, Mazik P (eds). Seattle. WA.

Hagedorn ME, Hsu FW, Kleinhans, Wildt DE (1997). New approaches for studying the peameability of fish embryos: Toward Successful Cryoperserv. Cryobiol. 34(4): 335-347.

Hamelda AA, Riad SA, El-zaeem SY (2004). Genetic alternations following the production of genetically modified Nile Tilapia *(Orechromis niloticus)*. Egypt. J. Genet. Cytol. 33(2): 369-387.

Hansen E, Fermandes K, Goldspink G, Butter-Worth P, Umeda PK, Chang KC (1991). Strong expression of foreign genes following direct injection into fish muscle. FEBS Lett. 290: 73-76.

Houdebine LM, Chourrout D (1991). Trangenesis in fish. Experiential 47: 891-897.

Maclean N, Laight RJ (2000). Transgenic fish: an evaluation of benefits and risks. Fish Fish. 1: 146-172.

Maclean N, Penman D (1990). The application of gene manipulation to aquaculture. Aquaculture 85: 1-20.

Nwanna LC (1995). Utilization of Azolla Africana Diets in the production of Tilapia M.Sc Thesis, Department of Wildlife and Fisheries Management, University of Ibadan, Ibadan, Nigeria.

Rahman A, Maclean N (1992). Fish transgene expression by direct injection into fish muscle. Mol. Mar. Biol. Biotechnol. 1: 286-289.

Shears MA, Fletcher GL, Hew CL (1991). Transfer, expression and stable inheritance of antifreeze protein genes in Atlantic Salmon. (*salmo salar).* Mol. Mar. Biol. Biotechnol. 1(1): 58.

Shelton WL (1996). Reproductive manipulation of fishes: ecologically safe assessment of introductions. US-ARS. Biotechnology Risk Assessment Research Grants, Program Abstract of Funded Re-search. Mackie. Lewis Publishers, Bocakaton, p. 12.

Sudha PM, Low S, Kwang J, Gong Z (2001). Multiple tissue transformation in adults' zebr fish by gene gun Bombardment and muscular injection of naked DNA. Mar. Biotechnol. 3: 119-125.

The new Partnership for African's Development (NEPAD) (2005). Aquaculture Development in Africa: NEPAD fish for all, consultative workshop Cairo, Egypt 27th-28th June 2005.

The new partnership for African's Development (NEPAD) (2005). Inland Fisheries in Africa. Key issues and future Investment, opportunities for sustainable Development; Technical Review paper, NEPAD-Fish for all summits 22nd-25th August 2005. Abuja, Nigeria.

Tan JH, Chan WK (1997). Efficient gene transfer into Zebra fish skeletal muscle by intramuscular injection of plasmid DNA Mol. Mar. Biol. Biotechnol. 6(2): 98-109.

Xu Y, Tian HL, Chan CH, Liaoj YT, Lam TJ, Gong Z (1999). Fast skeletal muscle-specific expression of zebra fish myosin light chain 2 gene and characterization of its promoter by direct injection into skeletal muscle DNA Cell Biol. 18(1): 85-95.