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GENERAL ARTICLE

Biotechnological Innovations in Aquaculture

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Abstract

Aquaculture is gaining commendable importance to meet the required protein source for ever increasing human population. The aquaculture industry is currently facing problems on developing economically viable production systems by reducing the impact on environment. Sustainable and enhanced fish production from aquaculture may be better achieved through application of recent biotechnological innovations. Utilisation of transgenic technology has led to production of fishes with faster growth rate with disease resistance. The full advantage of this technology could not be achieved due to concern of acceptance for Genetically Modified Organisms (GMOs). The biotechnological intervention in developing plant based feed ingredient in place of fish meal which contain high phosphorus is of prime area of attention for fish feed industry. The replacement of fish meal will also reduce fish feed cost to a greater extent. Year round fish seed production of carps through various biotechnological interventions is also need of the hour. This paper discusses technical, environmental and managerial considerations regarding the use of these biotechnological tools in aquaculture along with the advantages of research application and its commercialization.

Introduction

Importance of aquaculture is increasing due to its demand in international and domestic markets. On the other hand, universally regarding the 'Capture fisheries', the world is

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believed to be near maximum sustainable yield. Hence, aquaculture proves to be better hope for providing enough fish supply to the world. People's preferences for fish as a cheap protein source and less cholesterol food are the other two main reasons for its ever increasing demand. 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% (Neiland *et al.*, 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. Fisheries is the sunshine sector of Indian economy which provide healthy livelihood to the economically backward population. It has been recognized as a powerful income and employment generator as it stimulates growth of a number of subsidiary industries (Goswami & Zade, 2015).

As per a report, the total fish production during 2013-14 is at 9.58 million metric tonnes with a contribution of 6.14 million metric tonnes from inland sector and 3.44 million metric tones from marine sector respectively. The overall growth in fish production in 2013-14 has been 5.9%, which has been mainly due to 7.3% growth in inland fish production. The growth in marine fish production has been 3.7% (Thakur, 2014).

The use of modern biotechnology to enhance production of aquatic species holds great potential not only to meet demand but also to improve the quality of aquaculture. Genetic modification and biotechnology also holds tremendous potential to improve the quality and quantity of fish. Biotechnology has the potential to enhance reproduction and the early developmental success of culture organism. Such biotechnological tools can be used for various purposes like production of sterile fish, including polyploidy and hybridization (Wong & Zohar, 2015), manipulation of reproductive season through photo-thermal manipulation, improvement of desirable traits through selective breeding programme in aquaculture (Zohar *et al.*, 2016) and its application benefits both for producers and consumers alike. Other areas of biotechnology of interest in aquaculture include transgenic, food sources, improvement in the composition of the feed, improvement of growth rates, 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; 2014).

The development of genetically modified fish has undergone intensive research since the first production of genetically modified mammal (Devlin *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 & Penman, 1990; Chen and Powers, 1990; Houdebine & Chourrout, 1991; Fletcher & Davies, 1991; Maclean & 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-zaeems, 2001; Dunham, 2002; El-zaeems & Assem, 2004; El-zaeems, 2004). The present article reviews the areas in which biotechnology is being used in

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aquaculture, highlight prospects, advantages in its application and advancement.

Transgenic Fish:

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) (Moav *et al.*, 1992; Aken, 2000). This technology is progressing rapidly and it is now possible to move genes between distantly related species. 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 (Sundström & Devlin, 2015).

Researchers are trying to develop fishes, 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. Hormones are extensively used for this purpose, but a major drawback lies in deciding the actual level of the hormone to be administered. The new strains of transgenic fishes developed naturally produce just the right amount of growth hormone to speed their growth. Such fishes are more cost-effective since they would produce higher levels of growth hormones, and they would pass this trait to their offspring (Carvan, 2000).

One of the techniques to transfer genetic material in fish is micro-injection, in which the genetic material is injected into newly fertilized fish eggs. However, this method is time consuming, so researchers prefer to use electroporation. This involves transferring the genetic material or DNA into fish embryos by using an electrical current (Dunham & Winn, 2014). 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; Conti, 2011). 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 & Maclean, 1992; Anderson *et al.,* 1996; Tan & Chan, 1997; Xu *et al.,* 1999; El-zaeems, 2004; El-zaeems & Assem, 2004; and Hamelda *et al.,* 2004).

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. At present, the most common protein source for many fish diets is fish meal which is a by-product of fish processing industries and is high in protein quality and content. However, it has some disadvantages like it is expensive and its continuous supply is uncertain. Fishmeal comes from the by-products of wild fish, but world fish stocks are declining year by year. 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 environmental concerns due to high phosphorus content. The excess phosphorus goes into the water, causing problems such as eutrophication or excess algae growth. Hence, researchers prefer 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 high phosphorus levels. Researchers are also working towards producing feed enzymes like, phytase which would help fish make the best use of the phosphorous available in a plant-protein based feed. The idea of introducing exogenous enzymes into fish feed is not new but their efficacy in fish feeds

is being reinvestigated. Addition of proteolytic enzymes to diets resulted in only small positive effects in common carp (Srivastava *et al.,* 1994). Anti-nutritional factors like phytase can help fish to make the best use of the phosphorus available in a plant protein based feed (Edun, 2011).

Enhancing Early Drvelopment & Reproduction :

Biotechnology can be applied to enhance reproduction and early development of cultivated aquatic organisms. 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 like cryopreservation of gametes, polyploidization, androgenesis, gynogenesis for improving the reproductive success and survival of endangered species, thereby helping to preserve the diversity of life (Assem & El-zaeems, 2005).

Chromosome manipulation research has a short history in fish compared to that of crops and animals. Since 1943, early attempts were initiated, and until recently various techniques have been developed to interfere with normal functioning of the metaphase spindle apparatus during nuclear cycles of cell division in fish eggs using large scale production of genetically sterile fish (triploids) population lies with several causal agents, both physical and chemical (Dunham, 2002). The production of putative tetraploids might have tremendous impact, because of promising future of the mating of normal diploid and tetraploid individuals (Bhosale *et al.,* 2015).

Cryopreservation & Health Improvement of Species:

Cryopreservation helps to store gametes for future use. Freezing gametes can increase the flexibility of a fish breeder, especially when breeding species where the sexes mature or migrate at different times, then the breeding season is very short, when the breeders are far apart or when one sex is exceptionally rare (Hagedorn *et al.,* 1997; Hagedorn & Kleinhans, 2000).

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 vigour 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 (add examples and references) are also being developed to protect fish against pathogens (Fjalested *et al.*, 1993).

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. Indeed, for the vast majority of aquatic organisms (primarily microorganisms) identified, there is insufficient knowledge to permit their intelligent management and application. Additional donor support for research in key areas of biotechnology and aquaculture is therefore, necessary. Most of the genetically improved strains reaching the aquaculture industry were developed through traditional selective breeding (selection, crossbreeding and hybridization). Emerging, more modern technologies for genetic manipulation seem to take 1020 years from being established experimentally. Till date chromosome-set and sex manipulations were intensively investigated in several species but are still need to refine for others. Molecular techniques (DNA markers and gene manipulations), are intensively

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investigated. This is also true for transgenic fish, which could have affected the industry already had it not been restricted by public concern. 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.

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