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Importance of Transgenic Fish to Global Aquaculture: A Review

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Abstract

Many faster growing transgenic fish including both cold water (salmon, trout) and warm water (tilapia, carp) species have been produced. The development of transgenic fish can serve as excellent experimental models for basic scientific investigations, environmental toxicology and in biotechnological applications. The fast growth characteristic of GH gene transgenic fish will be of great importance to support aquaculture production and economic efficiency. The transgenic fish are efficient feed converter, thus more economical for the fish farmer as the feed accounts for 60-70% of total cost in aquaculture.

Keywords: Aquaculture; Fish; Transgenic

Introduction

Transgenic are organisms into which transgene has been artificially introduced and the transgene stably integrated into their genomes [1]. Transfer of transgene into the nucleus of a target cell where integration into the host genome takes place. The first transgenic fish were produced in [2] and as of 2003, more than 35 species had been genetically engineered in research laboratories worldwide [3]. A number of fish species are in focus for gene transfer experiments and can be divided into two main groups: animals used in aquaculture [4] and model fish used in basic research [5]. Among the major food fish species are carp (*Cyprinus* sp.), tilapia (*Oreochromis* sp.), salmon (*Salmo* sp., *Oncorhynchus* sp.) and channel catfish (*Ictalurus punctatus*) while zebrafish (*Danio rerio*), medaka (*Oryzias latipes*) and goldfish (*Carassius auratus*) are used in basic research. Transgenic fish show better gross food conversion, the increase in fish weight per unit of food fed than their unmodified relatives [6].

Methods in the production of transgenic fish

Microinjection method: Microinjection method has been used successfully in the production of transgenic fish and is a commonly used technique due to its simplicity and reliability [7]. The use of the microinjection method results in higher survival rates for manipulated fish embryos than the electroporation method [8]. The most established method for gene transfer in fish is microinjection. Microinjection that allows delivery of the transgene directly into the nucleus, Transgene is directly microinjected into the male pronuclei of fertilized eggs [1]. Transgenic technology through DNA microinjection into zebra fish embryos has made great gain in the last decade. It is shown that the DNA injected into the cytoplasm of fertilized zebra fish eggs could integrate into the fish genome and be inherited in the germ line [9]. The frequency of germline transmission of a microinjected DNA could be as a high as 20% in zebra fish [10].

Disadvantage

This method is not only time-consuming procedure for animals such as fish that produce a large number of eggs [11] and labour intensive but is also limited by the physiology of fish eggs. The nuclei of fish eggs are small and difficult to visualize, the chorion, hardens soon after fertilization [12] and in many fish species the pronuclei of fertilized eggs is not visible and transgenes are usually injected into the egg cytoplasm. This technology, however, still has as the major constrains the low efficiency generation of transgenics. To improve the efficiency of selection of transgenics, genetic markers are co-injected with the transgene to monitor for transformed zygotes. The Green Fluorescent Protein (GFP) from Jellyfish (*Aequorea victoria*) has been used for this purpose in zebrafish [13].

Electroporation method: Electroporation has been shown to be the most effective means of gene transfer in fish since a large number of fertilized eggs can be treated in a short time by this method [14]. Electroporation utilizes a series of short electric pulses to permeate the cell membrane that make possible the formation of temporary pores on the surface of the target cells through which the transgene is introduced into the cytoplasm where it is then delivered to the nucleus by the cellular machinery [1]. Electroporation has been preferred in many laboratories for gene transfer in fish systems because of its efficiency, speed and simplicity.

Disadvantage

The presence of a tough chorion layer around the fish eggs reduces efficiency, removal of the chorion is a tedious procedure and introduces additional stress on newly fertilized eggs. In traditional electroporation methods, either levels of transfer have been low with few studies showing germ-line transmission and expression [15] or the device used is no longer commercially available [16].

Sperm mediated gene transfer method: Spermatozoa are capable

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of binding DNA and carrying it into an egg. Fish spermatozoa can be stored in seminal plasma with little loss of viability for long periods. Therefore, this technique appears very promising for gene transfer in fish [11].

Retroviral infection method: The successful use of Retroviruses for gene delivery in fish has been reported [17].

Disadvantage: The preparation of retroviral particles including the transgene of interest is a very laborious process, increases costs and requires technology.

Advantages of transgenic fish

The growth rate of Transgenic fish can be increased by 400% to 600% [18] while simultaneously reducing feed input by up to 25% per unit of output, thereby improving food conversion ratios [19]. Transgenic fish have been developed for applications such as the production of human therapeutics, experimental models for biological research, environmental monitoring, ornamental fish and aqua cultural production. Growth enhanced transgenic fish have improved feed-conversion efficiency [20], resulting in economic and potential environmental benefits such as reduced feed waste and effluent from fish farms. Transgenic strains provide useful model systems for studying the consequences of growth enhancement from genetic, physiological and ecological standpoints [21]. The trait of growth rate has received the greatest attention because of its importance in aquatic animal production systems. Two to threefold increase relative to non-transgenic fish have been reported for tilapia and Atlantic salmon and up to twofold increases in common carp. Commercial production of transgenic fish able to transmit desirable characteristics, such as enhanced growth or disease resistance to their progeny. Growth acceleration in fish has been one of the targets of gene transfer experiments [22]. Zebra fish are a good model for the rapid study of GH-transgenes, before selecting the construct to use in economically important species. AquAdvantage salmon, a modified Atlantic salmon reach commercial size in one-third of the time required for non-transgenic salmon [23]. The faster growth of each generation can lead to increased production per unit time along with savings on total food per pound of meat produced [24]. Use of transgenic fish as bioreactors for the large-scale production of rare human therapeutic proteins or novel foods for specific dietary requirements. Transgenic lines of tilapia engineered to produce human clotting factor VII, which is used in liver transplants and in treating injuries. Zebra fish genetically modified to manifest a defective aortic valve development has made it possible to identify the role of an enzyme, UDP-glucose dehydrogenase, in the process of the embryonic development of this valve [25]. Transgenesis is proposed as a mean for removing allergenic substances in seafood. Fish are recognized as test organisms with distinct and superior benefits in providing insights to disease processes [26]. The development of transgenic animal models represents a revolutionary advance in the study of a variety of disease processes [27]. Fish as cost-effective and important animal models in genetics, developmental biology and toxicology [28]. Development of transgenic fish as a model in reducing or replacing selected mammals used in toxicity testing. Medaka fish has several characteristics that are especially well suited for environmental toxicology, including well-characterized histopathology. They have been used extensively in chemical hazard testing, carcinogenesis bioassays [29] and germ cell mutagenesis studies [30]. Tilapia expressing extra copies of trout growth hormone gene grow much faster than their non transgenic counterparts which do not possess extra copies of the growth hormone gene [31]. Transgenic fish have been used to study developmental regulation of genes, improve cold tolerance, increase growth rate, and improve feed utilization [32]. Fast-growing transgenic coho salmon [18], medaka [33], rainbow trout [34] and tilapia [35] containing novel growth hormone genes reached sexual maturity sooner than unmodified counterparts. The efficiency of growth and feed conversion can also be increased in finfish by creating transgenic fish that incorporate a gene construct encoding growth hormone [36]. Genetically modified fish have also been developed as experimental models for biomedical research, especially in studies involving embryogenesis and organogenesis [37] as well as in the study of human diseases [38], Xenotransplantation [39] and recombinant protein production for producing important therapeutic agents [40].

Disadvantages of transgenic fish

Inducing transgenesis is a relatively transgene. Mosaicism, the condition in which not all cells in embryos have the targeted transgene, can occur. The primary ecological concerns regarding utilization of transgenic fish are the loss of genetic diversity and loss of biodiversity, and reduction in species richness [41]. Transgenic fish are those related to their involuntary escape into environment. Concerns range from interbreeding with native fish populations [33] to ecosystem and effects resulting from heightened competition for food and prey species. The sterilization of transgenic fish will help in reducing the interbreeding risks associated with the escape of transgenic fish. Introduction of transgenic fish into natural communities is a major ecological concern [41]. Reduced sperm production in the GH transgenic Nile tilapia, *Oreochromis niloticus* [42]. Extremely fast-growing transgenic salmon and loach have low fitness and die inefficient process. Only about one out of every 100 eggs microinjected will stably incorporate the recombinant DNA sequence into its genome and subsequently transmit the transgene to its progeny. Transgenesis is unnatural in the sense that the insertion of DNA material in transgenic animals would not take place without human intervention. Transgenic fish could produce new or modified proteins that could be toxic to humans, they generally show reduced swimming ability and lower reproductive performance than non-transgenic fish. The transgenic fish are also more active and aggressive when feeding, and more willing to risk exposure to predation. Changes in cognitive abilities or brain function and structure have occurred in transgenic fish. The transgenic salmon pose serious ecological threats to wild populations and are not engineered for natural environments. Transgenesis can result in an unpredictable number of copies and site of integration of the early [43].

Conclusion

There are many applications of transgenic fish technology in aquaculture and biomedical research and several major problems that need to be solved in order to utilize this technology efficiently and safely. Further research should work with the DNA sequences of fish rather than mammalian origin to increase public acceptance and avoid sequences of bacterial or viral origin. Transgenic technology is developing rapidly. However, consumers and environmentalists remain cautious of its safety for use. Research is needed to ensure the safe use of transgenic technology and thus increase public assurance.

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