

Transgenic fish and their pros and cons in aquaculture

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[DOI:10.5281/FishWorld.16646412](https://doi.org/10.5281/FishWorld.16646412)

Abstract

Fish transgenesis is the artificial phenomenon of integration of a transgene into the fish genome to produce transgenic fish. This integration of the transgene into the fish host can be achieved through various methods, including microinjection, electroporation, sperm-mediated gene transfer, and retroviral infection. For instance, the microinjection method for producing transgenic fish involves injecting a DNA containing the transgene directly into the male pronucleus of fertilized eggs, allowing for integration into the fish genome, followed by incubation and screening for successful germline transmission in the offspring. Transgenic fish have various pros features, such as improved growth rate, disease resistance, enhanced color in aquaculture, and many more; however, ecological issues, including the loss of genetic variety, loss of biodiversity, decline in species richness, and behavioral changes of transgenic fish, are some of the cons in aquaculture.

Keywords: Transgenic fish, methods, advantages, ecological issues, aquaculture

1. Introduction

The artificial introduction of the transgene into host genomes is transgenic, which is securely integrated into their genomes. The transgene integration into the host genome occurs during transgene transfer to a target cell's nucleus. The first transgenic fish was produced in 2003, and it was described that over 35 species had been genetically changed at research facilities worldwide. Fish used in aquaculture and model fish utilized in fundamental research are two categories of fish that are the target of gene transfer investigations. Among the principal food fish species are Carp (*Cyprinus* sp.), Tilapia (*Oreochromis* sp.), Salmon (*Salmo* sp., *Oncorhynchus* sp.), and Channel catfish (*Ictalurus punctatus*), whereas Zebrafish (*Danio rerio*), Medaka (*Oryzias latipes*) and Goldfish (*Carassius auratus*) are employed in fundamental research. Comparing transgenic fish to their non-modified relatives, they exhibit superior gross food conversion or a rise in fish weight per unit of food fed.

2. Methods to employ the production of transgenic fish

2.1. Microinjection method

Due to its ease of usage and dependability, the microinjection method is a frequently employed approach for producing transgenic fish. The microinjection technique yields more excellent survival rates for modified fish embryos than electroporation. Microinjection is the most well-known technique for gene transfer in fish. Transgene is immediately microinjected into the male pronuclei of fertilized eggs, allowing direct transgene delivery to the nucleus.

For instance, using DNA microinjection into zebrafish embryos, transgenic technology has advanced significantly during the past ten years. The DNA inserted into the cytoplasm of fertilized zebra fish eggs has been demonstrated to integrate into the fish genome and pass down via the germ line, as shown in Figure 1. In zebrafish, up to 20% of germline transfer of microinjected DNA has been reported.

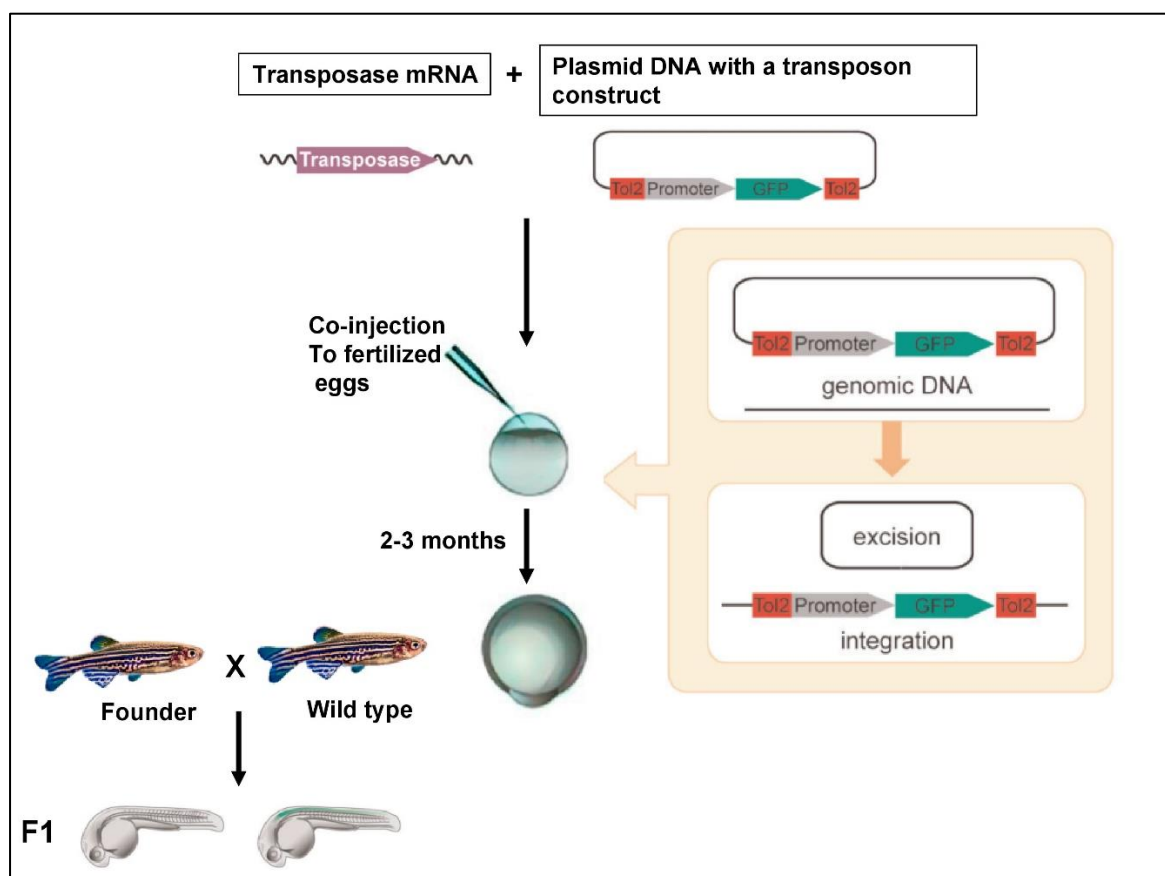


Figure 1. A Schematic of transgenesis in the zebrafish model. Into the fertilized eggs of zebrafish, the synthetic transposase mRNA and a donor transposon plasmid containing a Tol2 construct with a promoter and the gene-producing green fluorescent protein (GFP) are co-injected. Extracted from the donor plasmid and incorporated into the genome is the Tol2 construct. The F1 generation receives Tol2 insertions that were produced in germ cells. By

breeding the injected fish (founder) with wild-type fish, nontransgenic and transgenic fish heterozygous for the Tol2 insertion are produced since the injected fish's germ cells are mosaic. The embryo's spinal cord is shown in green in this picture, and the promoter is ostensibly characterized as a spinal cord-specific enhancer/promoter (Kawakami, 2007).

2.2. Electroporation method

Since it is possible to electroporate several fertilised eggs at once, it has been demonstrated to be the most efficient gene transfer technique in fish. Electroporation creates transient pores on the surface of target cells by using a series of brief electric pulses to smash the cell membrane, allowing the transgene to enter the cytoplasm and be transported by cellular machinery to the nucleus. Electroporation has been the method of choice for gene transfer in fish systems in many labs due to its effectiveness, rapidity, and simplicity.

2.3. Sperm-mediated gene transfer method

DNA can be carried into an egg by spermatozoa by being bound to it. Fish spermatozoa may be preserved in seminal plasma for extended periods with little loss of viability. Consequently, this method seems highly promising for fish gene transfer.

2.4. Retroviral infection method

In this method, retroviruses have been successfully used to transmit genes to fish, according to reports (Koo *et al.*, 2014).

3. Advantages of transgenic fish

Transgenic fish can have growth rates of 400% to 600% while requiring up to 25% less feed per production unit, leading to improved food conversion ratios. Transgenic fish have been created for various uses, including human treatments, experimental models for biological study, environmental monitoring, the production of ornamental fish, and aquaculture. Growth-enhanced transgenic fish have increased feed-conversion efficiency, which has positive economic and ecological effects, including reducing wasteful feed and effluent from fish farms. For understanding the impact of growth augmentation from a genetic, physiological, and environmental perspective, transgenic strains offer helpful model systems. The growth rate characteristic has drawn the most attention since aquatic animal production systems depend heavily on it. There have been reports of tilapia and Atlantic salmon having two to threefold increases compared to nontransgenic fish and up to twofold increases in common carp. Commercial production of transgenic fish that can pass on advantageous traits to their offspring, such as improved growth or disease resistance. Gene transfer experiments have one of their aims as fish growth acceleration. Before choosing the construct to utilize in

commercially significant species, zebrafish make a valuable model for quickly examining GH-transgenes. A modified Atlantic fish called AquAdvantage grows to market size in a third less time than nontransgenic salmon. Each generation's rapid growth can result in higher output per unit of time and cost savings per pound of generated meat. Using transgenic fish as bioreactors to mass produce innovative meals or rare therapeutic proteins for people with special dietary needs. Human clotting factor VII utilised in liver transplants and the treatment of wounds, is produced by transgenic tilapia lines. It has been feasible to pinpoint the function of an enzyme, UDP-glucose dehydrogenase, in the embryonic development of this valve using zebra fish that have had their aortic valves genetically altered to display a dysfunctional development. It is suggested that transgenesis be used to eliminate allergens in seafood. It is recommended that transgenesis be used to eliminate allergens in seafood.

Fish are acknowledged as test organisms that offer specific and superior advantages in revealing illness processes. A fundamental advancement in the understanding of several disease processes is the establishment of transgenic animal models. Fish are a cheap and valuable genetic, developmental biology, and toxicity animal model. Transgenic fish are being developed as a substitute or reduction in the usage of certain animals in toxicity testing. The well-characterized histopathology of medaka fish is one of several traits that make it exceptionally well-suited for environmental toxicity. They have been widely employed in investigations on germ cell mutagenesis, carcinogenesis bioassays, and chemical hazard testing. Compared to their nontransgenic counterparts that do not have extra copies of the growth hormone gene, tilapia that express additional copies of the trout growth hormone gene develop significantly more quickly. Transgenic fish have been used to examine how genes are regulated throughout development, boost cold tolerance, accelerate growth, and enhance feed utilization. With new growth hormone genes, fast-growing transgenic rainbow trout, coho salmon, medaka, and tilapia attained sexual maturity before their unaltered counterparts. Making transgenic fish with a gene construct expressing growth hormone can also improve the efficiency of growth and feed conversion in fish. Additionally, genetically altered fish have been created to serve as experimental models for biomedical research, particularly in studies of organogenesis and embryogenesis, as well as the investigation of human diseases, Xenotransplantation, and the production of recombinant proteins to develop significant therapeutic agents.

4. Disadvantages of transgenic fish

Transgenesis is the process of inducing it. It is possible for mosaicism when not all

embryonic cells have the desired transgene. The main ecological issues with using transgenic fish are the loss of genetic variety, loss of biodiversity, and decline in species richness. Fish that are considered to be transgenic have accidentally escaped into the environment. Concerns vary from the consequences on the ecology and interbreeding with local fish populations to increased competition for food and prey species. The hazards of interbreeding brought on by transgenic fish escaping will be decreased with sterilization. A significant ecological problem is the introduction of transgenic fish into natural populations. *Oreochromis niloticus* is a Nile tilapia that has been genetically altered to produce less sperm. Transgenic salmon and loaches that develop extremely quickly are less fit and have inefficient deaths. Only one of every 100 eggs that get a microinjection will successfully integrate the recombinant DNA sequence into its genome and pass the transgene on to its offspring. Since inserting DNA material into transgenic animals would not occur naturally, transgenesis is unnatural. In addition to usually having less swimming ability and less successful reproduction than nontransgenic fish, transgenic fish may create new or altered proteins that may be hazardous to humans.

Additionally, transgenic fish are more likely to take a chance on being eaten and are more aggressive and energetic when feeding. The brain's structure and function have changed in transgenic fish and their cognitive ability. The wild populations of salmon that have been genetically modified face significant ecological risks since these fish were not developed for natural habitats. The number of copies and location where the early gene is integrated during transgenesis might vary.

5. Conclusion

Transgenic fish technology has numerous uses in aquaculture and biomedical research. Still, a number of significant issues also need to be resolved before this technology can be used effectively and securely. To boost public acceptability and stay away from bacterial or viral origin sequences, future studies should focus on fish DNA sequences rather than mammals. Technology related to transgenics is evolving quickly. Consumers and environmentalists are still unsure about its safety for usage, though. Research is required to ensure the safe application of transgenic technology and therefore boost public confidence.

Reference

- Barman, H.K., Rasal, K.D. and Mondal, S., 2019. Status and prospects of gene editing and transgenic in fishes. *INDIAN JOURNAL OF GENETICS AND PLANT BREEDING*, 79(Sup-01), pp.292-299.
- Chen, T.T., Lin, C.M. and Kight, K., 1991. Application of transgenic fish technology in aquaculture. *Bull. Inst. Zool., Academia Sinica, Monograph*, 16, pp.375-386.
- Collin, J. and Martin, P., 2017. Zebrafish as a research organism: *Danio rerio* in biomedical

- research. In *Basic Science Methods for Clinical Researchers* (pp. 235-261). Academic Press.
- Grabher, C., Joly, J.S. and Wittbrodt, J., 2004. Highly efficient zebrafish transgenesis mediated by the meganuclease I-SceI. In *Methods in cell biology* (Vol. 77, pp. 381-401). Academic Press.
- Kawakami, K., 2007. Tol2: a versatile gene transfer vector in vertebrates. *Genome biology*, 8(1), pp.1-10.
- Koo, B.C., Kwon, M.S. and Kim, T., 2014. Retrovirus-mediated gene transfer. In *Transgenic Animal Technology* (pp. 167-194). Elsevier.
- Kumari, J., Flaten, G.E., Škalko-Basnet, N. and Tveiten, H., 2017. Molecular transfer to Atlantic salmon ovulated eggs using liposomes. *Aquaculture*, 479, pp.404-411.
- Liu, Z.J., 2006, May. Fish genomics and analytical genetic technologies, with examples of their potential applications in the management of fish genetic resources. In *Workshop on Status and Trends in Aquatic Genetic Resources* (Vol. 8, p. 145).
- Maclean, N., Rahman, M.A., Sohm, F., Hwang, G., Iyengar, A., Ayad, H., Smith, A. and Farahmand, H., 2002. Transgenic tilapia and the tilapia genome. *Gene*, 295(2), pp.265-277.
- Rasal, K.D., Chakrapani, V., Patra, S.K., Ninawe, A.S., Sundaray, J.K., Jayasankar, P. and Barman, H.K., 2016. Status of transgenic fish production with emphasis on the development of food fishes and novel color varieties of ornamental fish: implication and future perspectives. *Journal of Fisheries Sciences. com*, 10(3), p.52.
- Tonelli, F.M., Lacerda, S.M., Tonelli, F.C., Costa, G.M., de Franca, L.R. and Resende, R.R., 2017. Progress and biotechnological prospects in fish transgenesis. *Biotechnology Advances*, 35(6), pp.832-844.
- Wakchaure, R., Ganguly, S., Qadri, K., Praveen, P.K. and Mahajan, T., 2015. Importance of transgenic fish to global aquaculture: a review. *Fisheries and Aquaculture Journal*, 6(04), pp.8-11.