Prospects and Challenges of using Fish Species for Biomedical Research in Nigeria: A Review

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KEYWORDS

Biomedical studies,
One Health Concept,
Piscine Model,
Public health,
Research

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ABSTRACT

This review investigates the prospects and challenges of using fishes for biomedical research in Nigeria, highlighting the potential benefits and research application of various fish species in biomedical studies. Fish species have been utilized in biomedical research in different parts of the world due to their unique anatomical, physiological and genetic characteristics.Many fish species have been used in biomedical research, including zebra fish (Danio rerio), Mexican tetra fish (Astyanax mexicanus), killifish (Nothobranchius furzeri), goldfish (Carassius auratus), Medaka (Oryzias latipes), Clarias gariepinus (African Catfish), Tilapia species (e.g., Oreochromis niloticus), Common carp (Cyprinus carpio). Zebra fish (Danio rerio) is one of the most commonly used species due to its genetic similarity to humans and it's ability to serve as models for various human diseases. The various aquatic habitats in Nigeria provide a rich source of fish species that can be used for different biomedical studies. The potentials of biomedical research is also driven by the fast growth of aquaculture and the study of fish as bio indicators for environmental health. There is also a growing interest in utilizing fish species for biomedical research,in the areas of cancer research, drug development, and toxicological studies in Nigeria. Despite the potential benefits of using fish species in biomedical research, there are several challenges that need to be addressed. Limited infrastructure, funding, and professionalism in fish research may hinder the progress of utilizing fish models in biomedical research in Nigeria. To fully realize these potentials of utilization of fishes for biomedical research, investments in infrastructure, funding and capacity building in fish biology and biomedical studies are necessary.

INTRODUCTION

Biomedical Research focuses on the use of animal models to understand human health conditions, as it can replicate disease pathogenesis, diagnosis, and treatment in a way that resembles humans (Mukherjee *et al*., 2022). Animal studies are utilized in research that seeks to understand complex questions of disease progression, genetics, lifetime risk or other biological mechanisms of a whole living system that would be unethical, morally unacceptable or technically unfeasible or too difficult to perform in human subjects (National Association for Biomedical Research, 2020). Animal models are vital for several biomedical research fields such as cancer biology and therapeutics, neuroscience, pharmacology and toxicology, neurophysiology of diseases, endocrinology and environmental biology (Bale *et al*, 2019). They also enable the development and testing of drugs, vaccines, and surgical techniques applicable to human and Veterinary Medicine (Andersen and Winter, 2019). The models may involve complete animals or only particular cells, tissues, organs, genes, or other agents that reproduce pathological processes (Swearengen, 2018). Most of

the species utilized in biomedical research are rodents as they are deemed ideal models for studying pathologies that affect human populations due to their physiological homology (Makowska and Weary, 2020).

However, aquatic models, such as the zebra fish (*Danio rerio*), have long been used in biomedical research replacing the use of rats in many cases due to their genetic similarity to humans and its ease of maintenance in laboratory settings (Choi *et al*., 2021; Adhish and Manjubala, 2023). Additionally, the rapid development and transparent embryos of zebra fish allow researchers to easily visualize and directly observe developmental processes (Patel and Srinivasan, 2024). Fish species have been increasingly used to investigate human diseases in the last two decades due to the high degree of genetic, anatomical, and physiological similarities to humans as over 80% of disease-causing human proteins have an orthologue in fish (Zang *et al*., 2022). Fish species have been widely used in biomedical research for studying various diseases, drug development, and toxicology testing because of their genetic similarities to humans, ease of maintenance, and rapid reproduction rates (Thakuria, 2021). For example, zebra fish (*Danio rerio*) have been extensively used in cancer research, neurobiology, and drug screening due to their rapid development, transparent embryos, and high fecundity (Zang *et al*., 2022). Similarly, the Medaka fish (*Oryzias latipes*) has been utilized in developmental biology research, while the killifish (*Nothobranchius furzer)* has been studied for its aging and regenerative capabilities (Kodera and Matsui, 2022). In recent years, researchers in Nigeria have begun to explore the potential of using fish species for biomedical research, with a focus on understanding the genetic basis of diseases, testing new drugs and therapies, and studying the effects of environmental toxins on human health.

Tilapia (*Oreochromis niloticus*) and *Clarias gariepinus* have been utilized as model organisms for studying the effects of pollution and climate change on human and environmental health. Nigeria's diverse aquatic ecosystems support a diverse range of fish species especially *T. zillii* and *C. gariepinus* (Anifowoshe *et al.*, 2022) that are increasingly recognized for their potential in biomedical research. The potential of biomedical research is also driven by the fast growth of aquaculture and the study of fish as bio indicators for environmental health (Okwuosa *et al*., 2019). The advantages of using fish in biomedical research are well known and include cost-effectiveness, high fecundity, short generation time, external development, transparency of embryonic stages, simple maintenance from embryo to adult, and ease of genome manipulation (Zang *et al*., 2022; Kodera and Matsui, 2022). Despite the numerous advantages of using fish species for biomedical research, there are also several challenges that researchers in Nigeria encounter. One of the main challenges is the lack of infrastructure and resources for conducting research on fish species (Jacobs *et al*., 2018). Additionally, there is a lack of trained personnel with expertise in working with fish species for biomedical studies. Training Programs and workshops on fish husbandry and experimental techniques are essential to build capacity in this area. Collaboration with international research institutions and organizations can also help to bridge the gap in expertise and resources. Thus, this study was aimed to provide an overview of the prospects and challenges of using fish species for biomedical research in Nigeria.

Advantages of using fish in biomedical research.

In recent years, small fishes such as Zebra fish and Medaka have been widely recognized as model animals. They have high homology in genetics and tissue structure with humans and unique features that mammalian model animals do not have, such as transparency of embryos and larvae, a small body size and ease of experiments, including genetic manipulation (Kodera and Matsui, 2022). Many fish species share a high degree of genetic homology with humans, making them valuable models for studying human diseases and physiological processes. For example, zebra fish (*Danio rerio*) share approximately 70% of their genes with humans (Choi *et al*., 2021, Adhish and Manjubala, 2023), allowing researchers to study the effects of specific genes on disease development and progression, providing valuable insights into potential therapies and control measures. Fish species are relatively easy to maintain in laboratory settings, making them cost-effective, requiring minimal space and resources compared to larger animal models. Fish species also have a relatively short generation time and high reproductive capacity, allowing for rapid breeding and large-scale genetic studies. (Thakuria, 2021). Fish have a relatively short life cycle and reproduce quickly, allowing researchers to study disease progression and treatment effects over a relatively short period of time. This is particularly important in a resource-constrained country like Nigeria, where funding for research is limited.

Furthermore, fish have rapid reproduction rates and high fecundity, allowing researchers to generate large numbers of offspring for experimental studies. These factors make fish models cost-effective and efficient for conducting a wide range of biomedical experiments (Zang *et al*., 2022). Additionally, the transparent embryos of zebra fish allow researchers to easily visualize and study the development of organs and internal

structures without the need for dissection (Patel and Srinivasan, 2024). This is useful for studying early development, organogenesis, and cellular behavior. Furthermore, fish species have a well-developed immune system that can be used to study immune responses and infectious diseases. For example, the African catfish (*Clarias gariepinus*) has been used to study the immune response to bacterial infections, providing valuable insights into the mechanisms of host-pathogen interactions. Additionally, fish species have a unique ability to regenerate tissues and organs, making them valuable models for studying tissue regeneration and wound healing (Choi *et al*., 2021). Fish models are small in size that can be easily modified genetically to suit the study of the therapeutic motive or to make transgenic fish models with specific genetic modifications (Thakuria, 2021; Adhish and Manjubala, 2023).

The most Commonly used fish species for biomedical research

Many fish species have been used in biomedical research, including zebra fish (*Danio rerio*), Mexican tetra fish (*Astyanax mexicanus*), killifish (*Nothobranchius furzeri*), goldfish (*Carassius auratus*), Medaka (*Oryzias latipes*), *Clarias gariepinus* (African Catfish), Tilapia species (e.g., *Oreochromis niloticus*), Common carp (*Cyprinus carpio*) etc. These species not only contribute to food security but also hold significant potentials for advancing biomedical research in areas such as pharmacology, toxicology, embryology, oral biology and environmental health monitoring.

1. **Zebra fish** (*Danio rerio)*: The zebra fish is an excellent choice for a model organism due to its well-characterized genome and high levels of genetic, anatomical, and physiological similarity to humans up to a certain extent (Patel and Srinivasan, 2024). The freshwater teleost is a popular piscine model choice because of its high embryo yield, rapid reproduction rate, transparent embryos, economical maintenance, and fewer space requirements for setting up these zebra fish husbandry systems. Zebrafish embryos develop outside of the uterus, so they are easily accessed post-fertilization for various studies (Adhish and Manjubala, 2023). Zebra fish have been extensively used in cancer research, neurobiology, and developmental research due to their rapid development, transparent embryos, and high fecundity (Zang *et al*., 2022).

2. **Killifish** (*Nothobranchius furzeri*): The turquoise killifish has emerged as a new and unique fish model, especially for ageing research due to its unique life cycle, and this fish also seems to be useful for age-related neurological diseases (Kodera and Matsui, 2022).

3. **Mexican tetra fish** (*Astyanax mexicanus*): The Mexican tetra fish, *Astyanax mexicanus*, has emerged as a valuable model organism in biomedical research due to its unique characteristics and adaptability to laboratory settings. This small freshwater fish species, native to Mexico, has been extensively studied for its regenerative abilities, genetic diversity, and evolutionary adaptations. In recent years, researchers have increasingly turned to the Mexican tetra fish as a model organism to investigate a wide range of biological processes and diseases.

4. **African Catfish** (*Clarias gariepinus*): This species is widely farmed and recognized for its resilience and adaptability to various environmental conditions, and large size which allows for easy handling and experimentation. It serves as a model organism in various research areas, including toxicology and disease resistance due to its rapid growth and ability to thrive in different environments. African catfish is also known for its tolerance to environmental stressors, (Nguinkal *et al*., 2023) making it an ideal model organism for studying the effects of pollution and climate change on human and environmental health.

5. **Tilapia species** (e.g., *Oreochromis niloticus*): Tilapia species, such as *Oreochromis niloticus*, are also commonly used in biomedical research in Nigeria for their fast growth rate, ease of breeding, affordability and availability in local markets. The role of Tilapia in nutritional studies and potential for genetic research makes it valuable for biomedical applications, particularly in understanding metabolic processes and disease patterns.

6. **Common carp** (*Cyprinus carpio*) is another commonly used fish species in Nigeria for biomedical research, particularly in studies related to immunology, toxicology, and disease modeling.

7. **Goldfish** (*Carassius auratus*) is another commonly used fish species in Nigeria for biomedical research, particularly in studies related to toxicology and environmental pollution.

8. **Medaka** (*Oryzias latipes*): Medaka is a complementary model to zebra fish. Like zebra fish, Medaka has short generation time, are easy to breed in large numbers in the laboratory, and produce transparent eggs, making it a valuable model organism for various research fields including embryology, genetics, and toxicology (Kodera and Matsui, 2022).

Application of fish species in Biomedical Research

Fish offer a versatile and powerful platform for a range of biomedical research. Their application in biomedical research continues to extend beyond developmental biology and disease modeling, uncovering knowledge of biological processes and encouraging exploration of new scientific frontiers which include;

Developmental Biology: Fish species, particularly zebra fish and medaka are used to study developmental biology due to their transparent embryos and external fertilization, which allow real-time observation of organ formation, cell differentiation, and embryonic development (Patel and Srinivasan, 2024). Zebra fish embryos develop externally, allowing for easy observation of developmental processes such as organogenesis and tissue differentiation. Researchers investigate mechanisms of organogenesis, morphogenesis, and the impact of genetic mutations on developmental pathways.

Genetics and Genomics: Fish models have been used to study gene function, gene expression patterns, and genetic variation, providing valuable insights into the genetic basis of human diseases. This can be employed to identify genes involved in development, disease, and behavior (Adhish and Manjubala, 2023).

Disease Modeling: Fish are employed to model human diseases, including cancer, cardiovascular diseases, and neurological disorders, which permits the study of disease mechanisms, progression, and the testing of potential therapeutic interventions. For example, zebra fish have been used to study a wide range of human diseases, including cancer, cardiovascular diseases, and neurological disorders (Choi *et al*., 2021).

Drug Discovery and Toxicology: Fish species have been increasingly used in drug discovery and toxicology studies due to their physiological and pharmacological similarities to humans. Researchers use fish to evaluate the efficacy and safety of new drugs, identify potential side effects, and screen for bioactive compounds (Andersen and Winter, 2019; Zang *et al*., 2022). Fish models have also been used to study the toxic effects of environmental pollutants and industrial chemicals, providing valuable information on the mechanisms of toxicity and potential health risks to humans and the environment under the One health concept.

Regenerative Medicine: Fish species have a remarkable ability to regenerate tissues, which can be useful for studying tissue repair and regeneration in humans. Zebra fish and Medaka have the ability to regenerate a variety of damaged tissues and organs, including fins, heart, and spinal cord, following injury. Zebra fish can regenerate damaged heart tissue, providing valuable insights into potential treatments for heart disease in humans. Due to its high regenerative potential, zebra fish are being considered the future of personalized regenerative treatments (Adhish and Manjubala, 2023).

Neurobiology: Fish species have also been used to study various aspects of neurobiology, including neural development, behavior, and neurodegenerative disorders. Zebra fish and turquoise killifish have been used to study the development of the nervous system and the genetic basis of neurological disorders such as epilepsy and autism (Kodera and Matsui, 2022).

Immunology: Fish species have been used as models for studying the immune system and host-pathogen relationships. Fish possess a diverse immune system that shares many similarities with the mammalian immune system, making them valuable models for studying immune responses to pathogens and vaccines.

Pharmacology: Fish species have been used in pharmacology research to study drug metabolism, drug interactions, and drug toxicity. Fish models have been used to study the pharmacokinetics and pharmacodynamics of drugs, providing valuable information on drug absorption, distribution, metabolism, and excretion.

Prospects of Fish Species for Biomedical Research in Nigeria.

1. **Biodiversity**: Many freshwater fish species inhabit aquatic environments in Nigeria, including lakes, rivers, and coastal areas (Anifowoshe *et al.*, 2022). This biodiversity provides a valuable resource for biomedical studies, particularly in exploring adaptations to the environment and resistance to diseases. The availability of a wide range of fish species in Nigeria provides researchers

with a diverse species of fish to study, allowing for a more comprehensive understanding of biological processes.

2. **Aquaculture Development**: The growing aquaculture sector, which currently produces around 310,000 tonnes of fish annually (FAO, 2022), presents opportunities to cultivate species that can be utilized for research purposes. Species such as *Clarias gariepinus* and *Tilapia* spp are already prominent in aquaculture and could serve as models for various biomedical applications.

3. **Research Opportunities**: Fish are excellent bio indicators due to their sensitivity to environmental changes (Okwuosa *et al*., 2019). Fish species are sensitive to environmental pollutants and toxins, making them valuable models for studying the effects of these substances on human and environmental health.

Challenges of Fish Species for Biomedical Research in Nigeria

Despite the prospects of using fish species for biomedical research in Nigeria, there are also several challenges that need to be addressed. One of the main challenges is the lack of infrastructure and resources for conducting research on fish species (Jacobs *et al*., 2018). Many research institutions in Nigeria lack the necessary equipment and facilities for studying fish species, making it difficult to conduct high-quality research in this area, therefore limiting the potential for biomedical studies using fish species. Another challenge is the lack of expertise in fish biology and biomedical research. Many researchers in Nigeria have limited knowledge of fish biology and may not be familiar with the techniques and methods used in biomedical research such as fish handling, restraint and bleeding. This can hinder the progress of research on fish species and limit the potential benefits of using these animals for biomedical research. There is also limited availability of specific fish species for research purposes. While Nigeria is home to a wide variety of fish species, many of these species are not well characterized or readily available for research purposes like the zebra fish. This can make it difficult for researchers to obtain the necessary fish species for their studies, hindering the progress of biomedical research with fish species in Nigeria.

There is inadequate funding for biomedical research using fish species in Nigeria. Research funding is limited in Nigeria to support the use of fish species as model organisms in biomedical research. Another challenge is the lack of standardized protocols and guidelines for using fish species in biomedical research. This lack of standardized protocols can lead to inconsistencies in research practices and ethical concerns regarding the treatment of fish species in laboratory settings (Sloman *et al*., 2019). Fish lack certain mammalian organs, such as lungs, mammary glands, and a placenta, limiting their use for specific tissue and organ studies. Overfishing, pollution, climate change and habitat destruction also led to declining fish populations and biodiversity (Jacobs *et al*., 2018). These factors threaten the availability of species that could be valuable for research. Inadequate government policies regarding fisheries management hinder the sustainable exploitation of fish resources. While the high cost of production inputs and unstable economic conditions limit the growth of aquaculture, which is essential for providing a steady supply of fish for both consumption and research.

CONCLUSION AND RECOMMENDATIONS

Fish species hold great promise for biomedical research in Nigeria due to their genetic similarity to humans, unique physiological characteristics, and potential for studying a wide range of pathologies and disorders. The use of fish in biomedical research offers numerous advantages, including their genetic similarity to humans, rapid development and reproduction, transparent embryos, and cost-effectiveness. These advantages make fish valuable models for studying a wide range of human diseases, malformations and malfunctions providing valuable insights into disease mechanisms and potential treatment and control options. However, there are also significant challenges that need to be addressed, including the lack of infrastructure and professionalism in fish husbandry, as well as the limited availability of specific fish species for research purposes. There is need for capacity building and training of researchers in fish biology, genetics, and experimental techniques to fully harness the potentials of these organisms in biomedical research. Collaborative efforts and investments in research infrastructure are essential to advance the field of fish-based biomedical research in Nigeria. There is also a need for regulatory framework to govern the use of fish species in research, ensuring that researchers adhere to animal ethical research and welfare guidelines.

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