An Overview Of Diagnostic And Therapeutic Advances In Aquaculture Disease Control

***Adeneye A Obanjo**
Department of Fisheries, University of Port Harcourt, Nigeria.

***Correspondence:** aa.obanjo@gmail.com

Received: Aug 22, 2023; Revised: Oct 20, 2023; Accepted: Oct 23, 2023; Published: Oct 25, 2023

CITATION: Obanjo AA. An Overview Of Diagnostic And Therapeutic Advances In Aquaculture Disease Control. *Recent Adv. Biol. Med.* 2023; 9(4): 9800036. https://doi.org/10.18639/RABM.2023.9800036

ABSTRACT
With the growth of the global economy, aquaculture has become increasingly important. Aquaculture faces the greatest challenge from infectious diseases, as they cause billions of dollars in economic losses every year. Using scientifically proven technologies is the key to reducing these impacts. By applying this knowledge to develop novel diagnostic techniques (molecular diagnostics, biosensors, spectroscopy and nanoparticles) and therapeutic agents (vaccines, gene silencing methods, etc.), advances in science are leading to an improved understanding of infectious diseases. Here, we are going to discuss some current diagnostic methods, preventive measures, and therapeutics used to control infectious diseases in aquaculture.

KEYWORDS: Diagnosis; Technologies; Biosensor; Vaccines; Therapeutics Aquaculture.

ABBREVIATIONS
FAO: Food and Agriculture Organization, PCR: Polymerase Chain Reaction, RT-PCR: Real-Time Polymerase Chain Reaction, DPO-mPCR: Dual-Priming Oligonucleotide-based multiplex PCR, LAMP: Loop-mediated Isothermal Amplification, VHSV: Viral Hemorrhagic Septicemia Virus, ELIS: Electrochemical Impedance Spectroscopy, QCM: Quartz Crystal Microbalance, ELISA: Enzyme-Linked Immunosorbent Assay, MALDI: Matrix-Assisted Laser Desorption/Ionization, TOF: Time-Of-Flight, WSSV: White Spot Syndrome Virus, ISAV: Infectious Salmon Anaemia Virus, SAV: Salmonid Alphavirus, RNAi: RNA interference, CRISPR: Clustered Regularly Interspaced Short Palindromic Repeat, LED: Light Emitting Diode, GCRV: Grass Carp Reo Virus, gcJAM-A: Grass Carp Junctional Adhesion Molecule-A, GM: Genetically Modified.

1.0 INTRODUCTION
A controlled aquatic environment, such as an ocean, river, lake, or pond, is used to breed various aquatic organisms. Humans consume fish and crustaceans for protein, which increases the demand for fish and crustaceans [1]. Apart from that, it can produce products for feed, fuel, cosmetics, pharmaceuticals, food processing, and to restore threatened and endangered aquatic species [2]. Approximately USD 263.6 billion was spent in 2018 on aquaculture production, according to the latest FAO report on The State of World Fisheries and Aquaculture. It is estimated that approximately 82.1 million tonnes of aquatic animals were produced (USD 250.1 billion), while 32.4 million tonnes of aquatic algae were produced (USD 13.3 billion), and 26000 tonnes of ornamental shellfish and pearls were produced (USD 179,000) [3]. Aquaculture faces several challenges that impact seafood production, such as climate change, disease, water and soil pollution, and harmful algal blooms [4]. Aquaculture diseases pose a serious threat to aquatic life, so they must be addressed to prevent further danger. Thus, this review focuses on recent technological advancements in diagnostics and possible treatments for aquaculture diseases.

2.0 DIAGNOSTIC AND THERAPEUTIC MEASURES IN AQUACULTURE

2.1 MOLECULAR DIAGNOSTIC APPROACH (MULTIPLEX PCR AND LAMP)
It is widely accepted that PCRs and RT-PCRs are the gold standard techniques for detecting pathogens in aquaculture [5,6]. As a result of the non-specific primer extension products produced by multiplex PCR, mismatch amplicons are amplified, resulting in false positive results [7]. Using DPO-mPCR as a solution these drawbacks of conventional multiplex PCR are reduced [8]. Vibrio species [9] and shrimp viruses [10] have been detected using DPO-mPCR recently. In addition to having a high level of sensitivity and specificity, the thermocycler is an expensive piece of equipment that requires a high level of technical expertise to operate.

Researchers in Japan developed LAMP to overcome the limitations of PCR. A heat block or a water bath were used to amplify the target sequence in 2000 [11]. Observable changes in color or turbidity are the outcome of LAMP [12], making it an ideal in-field diagnostic assay for detecting viruses [13,14] and bacteria [15]. In comparison with conventional PCR, the LAMP assay is reported to be at least 10-fold more sensitive.

2.2 BIOSENSOR DIAGNOSTIC APPROACH

The use of biosensors in aquaculture is becoming increasingly popular for the diagnosis of pathogens. The main components of a biosensor are the bio receptor, the transducer, and the signal processor [15]. Bioreceptors immobilize biorecognition layers to bind analytes (DNA, proteins, enzymes, antigens, antibodies, etc.). Electrical signals are obtained from the stimulus interaction by a transducer. Predetermined algorithms quantify the data obtained and present them in a user-friendly analog-digital format. Based on the conversion mechanism of the sensor, biosensors can be categorized as optical, electrochemical, electrical or piezoelectric [14].

VHSV was detected and monitored on fish using an electrochemical genosensor without fluorescence [15]. Using chemical reactions (redox reactions) or electrochemical parameters, an electrochemical biosensor detects current. The hybridization of the target sequence with the probe was measured using cyclic voltammetry, differential pulse voltammetry, and ELIS. For field analysis, the electrochemical cell is coated with different inks (carbon, gold, platinum). It has been used for screening *V. parahaemolyticus* [15] and determining Arowana fish's sex [11]. Malachite green (antibacterial agent), a dye toxic to mammals, has also been traced by electrochemical methods [12].

QCM is a piezoelectric sensor that detects pathogens through nanoscale biomolecule (receptor-ligand) interactions. *Aeromonas hydrophila* and VHSV, which are found in fish species, have been detected with this QCM immunosensor. Compared to indirect ELISA, QCM immunosensor offers sensitivity, a rapid label-free response, and real-time monitoring (frequency shift) over indirect ELISA. Mass changes in binding interactions are associated with frequency shifts.

2.3 SPECTROSCOPY-BASED DIAGNOSTIC APPROACH

An Italian team used MALDI-TOF analyses to identify 47 vibrio species using a MALDI and mass analyzer [11]. In order to identify vibrio species, the 16S rRNA gene sequence [12] is the gold standard, but because of the genome's high similarity, its discriminatory power is insufficient. The virulence of *V. tapetis* isolates was evaluated with MALDI-TOF mass spectrometry in another study [13].

2.4 NANOTECHNOLOGY DIAGNOSTIC APPROACH

Magnetic nanoparticles have been used in aquaculture wastewater treatment to remove nitrates, phosphates, biological oxygen demand, and heavy metals. To circumvent the problem of bacterial resistance, Portuguese researchers also used this technique to remove antibiotics from aquaculture wastewater. Additionally, Bio-Plex assays using magnetic microsphere beads have also been used to detect salmon anemia virus using Luminex bead array technology. In order to detect WSSV, an electrochemical electrode containing graphene quantum dots and gold nanoparticles was developed. Cyanobacterial toxins can be detected by quantum dots coupled with biosensors such as aptamer DNA.

2.5 GENOME SEQUENCING APPROACH

ISAV and SAV were analyzed using third-generation nanopore sequencing using the MinION platform in combination with PCR. The purpose of this analysis is to uncover the origin and spread of disease outbreaks by analyzing the genomes of fish viruses. In addition to inferring historical trends, pathogenicity, drug interactions with aquatic pathogens, and transmission patterns, second-generation and third-generation genomic studies also provide epidemiological information.

3.0 PREVENTION, THERAPEUTIC AND FUTURE ASPECTS OF AQUACULTURE

As synthetic biology emerged from genetic engineering, molecular biology and microbiology, it designs, redesigns, manufactures or modifies living organisms, genetic materials (DNA and RNA) and proteins for use in medicine. Several technologies are currently being applied in aquaculture to control and treat diseases. Below are more details on immunostimulants, vaccines, antimicrobial and antiviral biomolecules, as well as gene silencing techniques (RNAi and CRISPR).

3.1 IMMUNOSTIMULANTS

Aquaculture health can be maintained through a combination of preventive strategies rather than relying solely on diagnostic measures. By implementing biosecurity measures, aquaculture farmers can minimize the risk of disease outbreaks by restricting the use of facilities maintaining high water quality through Biofloc technology, and other measures [10]. Water-nutrient cycling using Biofloc technology detoxifies excess ammonia-nitrogen waste through the use of abundant microbiota.

3.2 VACCINES

By recognizing and fighting pathogens, vaccines trigger the immune system, resulting in antibody production that provides protection. The most common vaccines used in aquaculture are inactivated vaccines, live attenuated vaccines, nucleic acid-based vaccines, peptide subunits and recombinant vectors. It is possible to produce an inactivated vaccine by completely killing the pathogens by heating, irradiating, or using chemicals [5].

In the field of vaccine development, a new approach known as codon deoptimization is being explored. As a result of this method, silent mutations occur in viral sequences without altering amino acids, and codons within the viral genome that are less preferred by the host are recoded. To attenuate the virulence of poliovirus, this method was first used to reduce protein synthesis.

3.3 POTENTIAL THERAPEUTICS

Antimicrobial products approved for use in aquaculture have recently been used as therapeutics for farmed fish, but overuse may lead to drug resistance in aquaculture. Therefore, a detailed understanding of pathogen life cycles that are closely associated with host cell pathways or molecular pathways is essential and contributes to the development of effective treatments against infectious diseases. It is possible to treat aquaculture pathogens without the use of antimicrobial drugs using LED technology, an alternative therapy that is more environmentally friendly and effective. Seven major bacterial pathogens that could infect fish and shellfish have been successfully inactivated using blue LEDs in recent studies [8,9].

The CRISPR-associated nuclease 9 (Cas9) system is another novel gene-silencing approach that can be used to modify, repair, or knock out specific genes in hosts. With this system, a single guided RNA binds complementarity to the target DNA sequence, followed by the Cas9 enzyme acting as “molecular scissors” for cutting and disrupting the target genome sequence and editing it by adding external donor templates. There have been a limited number of studies on disease resistance using this technique, and it is primarily used in aquaculture for editing genes related to immunity, breeding, nutritional regulation, sex determination, pigmentation, and fertility of aquatic animals. In order to reduce infection with GCRV, the CRISPR-Cas9 technique was first used to knock out the gcJAM-A gene.

4.0 DISCUSSION

The demand for aquaculture is increasing globally, which makes it increasingly important for the global economy. There are many threats to aquaculture, but infectious diseases are among the most serious because they will result in billions of dollars in economic losses every year. Increasing scientific understanding of infectious diseases is bringing about a new perspective. When it comes to aquaculture, disease is a serious concern that must be taken care of if aquatic species are to be protected. The treatment of aquaculture effluent with magnetic nanoparticles has been successfully applied. In combination with biosensors such as aptamer DNA, quantum dots are fluorophores that can detect cyanobacterial toxins. In addition to magnetic microsphere beads, Luminex beads array technology has also been utilized in this study. The concept of synthetic biology is derived from genetic engineering, molecular biology, and microbiology in order to create, construct, produce, or change biological systems. A wide range of aquaculture technologies is now using synthetic biology as a means to manage diseases and treat patients, including the feeding of fish and the equipment used to feed fish. In order to protect the host from pathogen invasion, vaccines trigger the immune system to recognize and combat the invasion. The aquaculture industry has used a diverse range of vaccines for its animals, including inactivated vaccines, live attenuated vaccines, nucleic acid-based vaccines, peptide components, and recombinant vectors.

5.0 CONCLUSION

In conclusion, many diagnostic tools have been developed, and prevention measures have been implemented to stop infectious disease outbreaks in the aquaculture industry, but very few diagnostic tools are available to farmers in the field to diagnose multiple diseases. As well as these issues, research and debate on reliable prevention and treatment methods have continued to be intense, including their efficacy, toxicity, consumer perceptions of GM products, commercialization, and sustainability. As a result, further studies need to be conducted to determine whether these treatments and therapeutic agents affect the immune system and how they work. A risk assessment, as well as public perception surveys, are also important to take into consideration the ethical and biosafety aspects.

CONFLICT OF INTEREST

None.

ORCID
Not available.

REFERENCES

1. Stevens JR, Newton RW, Tlusty M, Little DC. The rise of aquaculture by-products: Increasing food production, value, and sustainability through strategic utilisation. Mar Policy. 2018;90:115-24. https://doi.org/10.1016/j.marpol.2017.12.027
2. Naylor RL, Hardy RW, Buschmann AH, Bush SR, Cao L, Klinger DH, *et al*. A 20-year retrospective review of global aquaculture. Nature. 2021;591:551-63. https://doi.org/10.1038/s41586-021-03308-6
3. Cowley JA, Rao M, Mohr P, Moody NJ, Sellars MJ, Crane MS. TaqMan real-time and conventional nested PCR tests specific to yellow head virus genotype 7 (YHV7) identified in giant tiger shrimp in Australia. J Virol Methods. 2019;273:113689. https://doi.org/10.1016/j.jviromet.2019.113689
4. Chun JY, Kim KJ, Hwang IT, Kim YJ, Lee DH, Lee IK, *et al*. Dual priming oligonucleotide system for the multiplex detection of respiratory viruses and SNP genotyping of CYP2C19 gene. Nucleic Acids Res. 2007;35(6):e40. https://doi.org/10.1093/nar/gkm051
5. Xu YG, Sun LM, Wang YS, Chen PP, Liu ZM, Li YJ, *et al*. Simultaneous detection of Vibrio cholerae, Vibrio alginolyticus, Vibrio parahaemolyticus and Vibrio vulnificus in seafood using Dual Priming Oligonucleotide (DPO) system-based multiplex PCR assay. Food Control. 2017;71:64-70. https://doi.org/10.1016/J.FOODCONT.2016.06.024
6. See SA, Goh ZH, Chan YY, Chong KE, Tan GY, Bhassu S, *et al*. Biosafety evaluation and detection of shrimp viruses on field samples using Dual Priming Oligonucleotide (DPO) system based multiplex PCR assay. Gene Rep. 2021;23:101158. https://doi.org/10.1016/j.genrep.2021.101158
7. Notomi T, Okayama H, Masubuchi H, Yonekawa T, Watanabe K, Amino N, *et al*. Loop-mediated isothermal amplification of DNA. Nucleic Acids Res. 2000;28(12):e63. https://doi.org/10.1093/nar/28.12.e63
8. Yu Y, Yang Z, Wang L, Sun F, Lee M, Wen Y, *et al*. LAMP for the rapid diagnosis of iridovirus in aquaculture. Aquac Fish. 2021;7(2):158-165. https://doi.org/10.1016/j.aaf.2021.08.002
9. Zhu Q, Wang Y, Feng J. Rapid diagnosis of largemouth bass ranavirus in fish samples using the loop-mediated isothermal amplification method. Mol Cell Probes. 2020;52:101569. https://doi.org/10.1016/j.mcp.2020.101569
10. Luo X, Davis JJ. Electrical biosensors and the label free detection of protein disease biomarkers. Chem Soc Rev. 2013;42(13):5944-62. https://doi.org/10.1039/C3CS60077G
11. Wu Q, Zhang Y, Yang Q, Yuan N, Zhang W. Review of electrochemical DNA biosensors for detecting food borne pathogens. Sensors. 2019;19(22):4916. https://doi.org/10.3390/s19224916
12. Pires NM, Dong T, Hanke U, Hoivik N. Recent developments in optical detection technologies in lab-on-a-chip devices for biosensing applications. Sensors. 2014;14(8):15458-79. https://doi.org/10.3390%2Fs140815458
13. Cavalcanti A, Shirinzadeh B, Zhang M, Kretly LC. Nanorobot hardware architecture for medical defense. Sensors. 2008;8(5):2932-58. https://doi.org/10.3390/s8052932
14. Rafique B, Iqbal M, Mehmood T, Shaheen MA. Electrochemical DNA biosensors: A review. Sensor Rev. 2019;39(1):34-50. https://doi.org/10.1108/SR-08-2017-0156
15. Pohanka M. Overview of piezoelectric biosensors, immunosensors and DNA sensors and their applications. Materials. 2018;11(3):448. https://doi.org/10.3390%2Fma11030448