Review Paper on Recent Advances of Biotechnology Application to Aquaculture Development

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Abstract:- Recent advances in biotechnology have significantly impacted aquaculture production, revolutionizing the industry. which explores key developments in applying biotechnological tools to enhance various aspects of aquaculture. Molecular techniques, such as genetic manipulation, have enabled the selective breeding of fish for desirable traits, improving growth rates, disease resistance, and overall productivity. Furthermore, the application of advanced genomics and bioinformatics has facilitated the identification of specific genes associated with important traits, paving the way for precision breeding. Biotechnological interventions also extend to disease management in aquaculture. Novel diagnostic methods based on molecular biology enable early detection of pathogens, contributing to effective disease prevention and control. Vaccines developed through biotechnological approaches have shown promise in protecting aquatic species against various infections, reducing reliance on traditional antibiotics. Nutrition is another critical aspect benefiting from biotechnological advancements. Genetically engineered feed formulations, enriched with essential nutrients, enhance the overall health and growth of aquaculture species. Furthermore, by enhancing feed conversion efficiency and waste management, probiotics and prebiotics obtained from biotechnological processes aid in the development of sustainable and ecologically friendly practices. Aquaculture and biotechnology are integrated in environmental conservation and monitoring projects. Aquatic organisms are guaranteed ideal conditions through real-time water quality monitoring made possible by biosensors and molecular tools. Utilizing genetically engineered organisms, bioremediation techniques help to lessen the negative environmental effects of aquaculture operations. In conclusion, recent advances in biotechnology have propelled aquaculture towards a more sustainable, efficient, and environmentally conscious industry. The integration of molecular techniques, genetic manipulation, diagnostics, and environmental monitoring has opened new avenues for addressing challenges and optimizing production in aquaculture. The continued exploration and application of biotechnological tools hold great promise for the future of this crucial food production sector.

***Keyword:-** Biotechnology, Recent Advances, Aquaculture and Development.*

I. INTRODUCTION

Due to overfishing, the productivity of numerous major fish stocks is fleetly declining, and given the current state of the world and terrain, farther earnings aren’t imaged (Dunham, 2004, another recent reference). Being the least precious source of beast protein, monoculture is still the world's stylish chance of producing enough fish to feed everyone (Aerni, 2004). still, the monoculture sector moment has to address the issues of creating commercially doable product systems, lessening environmental effect, and enhancing public perception all at the same time while using lower land (Dunham, 2004). As the demand for aquacultured foods has grown, there has been a need for further effective product styles than the conventional bone, which have sustainability issues similar fish growth that's too sluggish and poor feed conversion. One of the most important ways to meet the expanding global population’s unborn food demands is the creation of enhanced fish seed stocks that can lead to advanced fish product (FAO, 2007). A new avenue for the development of inheritable coffers in monoculture has been made possible by biotechnology. Monoculture can profit from the operation of inheritable technologies for a number of reasons, including increased productivity, marketability, culturability, and resource conservation (Moses etal., 2005). Fish husbandry is the most popular type of monoculture. It entails the marketable civilization of fish, generally for food, in fences, fish ponds, or ocean enclosures (FAO, 2010). The objects of monoculture can be added up as follows- Producing abundant, nutrient- thick, protein-rich, and fluently digestible mortal food that will profit society as a total at low or reasonable costs;- Producing sportfish to support recreational fishing;- Producing baitfish for marketable and sport fisheries;- Producing cosmetic fish for aesthetic purposes;- Recycling organic waste; and- Producing artificial fish(Yemi, etal., 2008). The objectives of this study are to itemized the most and yet to be given utmost consideration aspects of recent biotechnology in to aquaculture practice in Nigeria, some of which will be *Transgenesis, Nanotechnology, Bioremediation, Gene manipulation and Hybridization.*

II. RAPID AQUACULTURE DEVELOPMENT

From 1991 to 2001, there was a noticeable increase in the knowledge of aquaculture among government agencies, institutions, and private investors as a reliable way to produce cheaper protein and a source of jobs. The situation at the beginning of this decade amply demonstrated the utter failures of government farms, particularly those under the Agricultural Development Programs (ADP) in the majority of the states. Even with the substantial funding provided by the World Bank as part of its intervention program to increase fish output, the goals were obviously not met because the development that was made could only be characterized as minimal. Although there was an increase in personnel, the level of skill remained questionable. There were some notable growth levels, improvements in the investor profile and investment scale, and a little increase in the number of small and medium-sized business owners (between 31,500 and 100,000 kg/ha/year) with fish farms producing an average of 10 tons annually. Even if the significant level of success of these fish farms was attributed to foreign assistance from their foreign technical or financial partners, it demonstrated the productivity level that can be reached with the correct combination of financial and technical help (FAO, 2010).

- *Biotechnology and Food Production:*

Biotechnology is one of the newest and most contentious areas in science today. Following the advancement of genetic engineering, which allowed researchers to alter the genetic code of live cells, biotechnology emerged in the 1970s (Island Harvest, 2007). The modification of DNA molecules to create altered animals or other organisms is known as genetic engineering. DNA, a double-stranded molecule found in every cell of an organism, is the component of a cell that regulates an animal or plant's genetic information (Island Harvest, 2007). Over the past few decades, biotechnology has advanced to the point that it is now possible to artificially manipulate genes and chromosomes in live organisms. Aquaculture research is very interested in the generation of transgenic fish and shellfish because of the possible production increases that this technology might provide (Dunham, 2004).

- *Biotechnology in Fish Production:*

The use of growth hormones (GHs) to boost growth and feed conversion efficiency, the use of antimicrobial peptides to boost disease resistance, the use of metabolic genes to support low-cost, land-based diets, and genetic techniques for sterility induction are some of the main areas of transgenic research in fish (FAO, 2007). Research on transgenic fish is widely established, but because of the difficulties in introducing and expressing foreign genes, transgenic marine invertebrates are still in their infancy. Successful gene transfer techniques have been developed as a result of early research on marine invertebrates, with studies aimed at enhancing disease resistance. Apart from transgenic studies, developments in chromosome manipulation, or polyploidy, have the potential to enhance aquaculture production, especially with regard to shellfish (FAO, 2007).

III. ANCIENT APPLICATION OF BIOTECHNOLOGY TO AQUACULTURE PRODUCTION

Mating relatives results in inbreeding. One of the three conventional breeding methods, inbreeding has been used to create new breeds and can be used with cross-breeding to create homogenous, exceptional individuals (Chapter 4). Intentional and uncontrolled inbreeding will lead to issues, even though directed and planned inbreeding might be advantageous. In terms of genetics, inbreeding reduces heterozygosity (i.e., genetic variety) and increases homozygosity (i.e., genetic similarity) in the progeny. Additionally, homozygosity is created when non-relatives mate, and the two types of homozygosity are genetically identical. Despite the fact that the two types of homozygosity are equivalent, there is a distinction because of how homozygosity is generated and what happens as a result (FAO 2008).

- *Genetic Drift*

Random variations in gene frequency that are not brought about by selection, migration, or mutation are known as genetic drift. The causes of the random changes can be man-made, as happens when fish farmers catch or spawn their fish, or they can be natural, like a landslide that splits a population or a storm that kills a significant section of a population or damages parts of its environment (FAO, 2008). Normal circumstances result in much fewer fish reproducing and producing viable progeny than adults; this is particularly true in aquaculture. It is possible that the frequencies of one or more genes will differ in the progeny compared to the parental generation when this subsample spawns; the fewer spawned, the greater the likelihood of these differences. Allele loss is the ultimate result of genetic drift, and the likelihood that an allele will be lost due to genetic drift increases with decreasing gene frequency (FAO 2008). When aqua-culturists select which fish to purchase for their foundation population, they also contribute to genetic drift (FAO 2008).

- *Domestication*

Domestication is a process of selection that modifies the gene pool of a population by weeding out alleles less suitable for the hatchery and favoring alleles that can take advantage of the conditions of culture. This increases an organism's adaptation to the culture environment and to all facets of the management that is used to raise it (Bilio, 2000). Intentional and accidental selection come together to form domestication. Domestication modifies the gene pool, and since these modifications are passed down to succeeding generations, the population gradually transforms. Aquaculturists, on the other hand, raise undomesticated plants and animals. All significant plants and animals raised for food in agriculture have become domesticated Since there is no clear distinction between the wild and the domesticated, domestication is a process that is difficult to measure. Continuous controlled reproduction for more than three generations is known as domestication (Bilio, 2000). Domestication may or may not include basic behavioral change. Fish, for instance, respond to the sound of a feed truck or the noise the feeder generates, and they can sense when they will be fed (Bilio, 2000). Enhancing hatchery survival rates, a common aquaculture strategy, is a type of domestication selection that has been demonstrated to indirectly select for smaller egg sizes, hence reducing wild viability. Domestication selection will take place if the survival and reproductive success of the stocked fish differs from that of their wild counterparts, even if the only method of fish culture is gathering wild eggs, culturing the fry/fingerlings for a short time, and then stocking them (Bryden, 2003).

IV. ADVANCE APPLICATION OF BIOTECHNOLOGY IN AQUACULTURE

Our understanding of genetics and molecular biology—including genomics, proteomics, and the structural biology of aquatic organisms—has greatly advanced. The genome of the puffer fish (Fugurubriges) has been sequenced (Aparicio et al., 2002), while the Japanese Medaka and zebra fish are next on the genomic sequence list. Africa's developing nations have produced and are developing global molecular profiling technologies (Ude et al., 2006). These include the development of protein and lipid chips, as well as micro assays utilizing DNA or oligonucleotide chips. With these developments, biotechnological applications in aquaculture are unavoidable (Hulata, 2001; Hew and Fletcher, 2001; Melamed et al., 2002; Ude et al., 2006). When it comes to improving aquaculture stocks, the use of biotechnological advancements is unavoidable. Numerous molecular markers, including RFLPs, AFLDs, and RAPD, are now accessible for genetic linkage mapping, genome analysis, and finger printing. Many fish species have benefited from transgenic technology, and efforts are being made to create transgenic fish with genes encoding antimicrobial peptides like lysozyme, which would confer disease resistance on the fish (Zbikowska, 2003).

➢ *Recent Biotechnology Application in Fish Breeding*

Currently, the most effective biotechnological technique for fish induction breeding is gonadotropin-releasing hormone (GnRH). In every vertebrate, GnRH is the primary regulator and core initiator of the reproductive cascade (Bhattacharya et al., 2002). It is a decapeptide that was originally discovered in the hypothalami of pigs and lambs. It has the capacity to stimulate the pituitary gland to release follicle stimulating hormone (FSH) and luteinizing hormone (LH) (Schally et al., 2003). Since then, it has been determined that the only neuropeptide responsible for releasing LH and FSH in the majority of placental mammals, including humans, is a single type of GnRH. Twelve GnRH variations, including seven or eight distinct forms that have been isolated from fish species, have now been structurally characterized in non-mammalian animals (apart from guinea pigs). Robinson et al. (2000) and Carolsfeld et al. (2000) produced the most current purified and described GnRH (2000). Numerous chemical equivalents have been developed based on structural variants and biological activities. One such analogue is the salmon GnRH analogue, which is widely utilized in fish breeding today and is sold commercially under the name "Ovaprim" worldwide. In actuality, unless the hormone urges them to do so, the majority of the commercially significant culturable fish in landlocked water do not breed. With the advancement of GnRH technology, fish can now be successfully bred using induction.

➢ *Improved Seed Production (Selective Breeding)*

Production of improved quality seed in terms of growth performance, disease resistance, and environmental adaptability is present and future of hatchery technology. Selective breeding is acting as a vital tool in the hatchery. Many successful examples of such species are GIFT, Jayanti rohu, common carp, salmon, sea bass etc. (Zbikowska, 2003). Selective breeding is at present only viable methodology to produce specific pathogen resistant seed. Efforts are going on around the globe to produce SPR shrimp and fish for disease free aquaculture (Sujit Kumar, 2020).

➢ *Metagenomics*

Microbial studies in **aquaculture** are intended to understand the benefits as well as the harmful effect of microbes on culture animals either it is fish or any other culture group such as crustacean and molluscs. In this perspective, metagenomics can present a better understanding of microbial association with the animal in different circumstances such as healthy or diseased, stunted or fast-growing, etc. by utilizing the genetic component of the sample from an organism or ecosystem. This section is intended to showcase some important potential applications of metagenomics in aquaculture (Sujit Kumar, 2020).

➢ *Induced Breeding and Biotechnology*

Induced breeding based on hypophysation (Chaudhuri, and Alikunhi, 1957) was developed long ago during the 1950s but it is the production of synthetic hormones which has helped in disseminating the technology of induced breeding to the ground level. Synthetic super-active analogues were developed using **biotechnological** tools such as recombinant DNA technology and protein engineering with better inducing efficacy at a lower dose. Such analogue possesses modified amino acid in position 6, which leads to higher resistance to peptidase. It has also altered the polarity and tertiary structure of the GnRHa, which outcomes in an enhanced receptor binding affinity (Pandia and Sheela, 2005).

➢ *Chromosome Manipulation in Aquaculture*

The application of chromosome sex manipulation techniques, including inducing polyploidy (triploidy and tetraploidy) and uniparental chromosome inheritance (gynogenesis and androgenesis), has been extensively utilized in cultured fish species (Pandian and Koteeswaran, 1998). These techniques play a crucial role in enhancing fish breeding practices by offering swift approaches for gonadal sterilization, sex control, enhancement of hybrid viability, and clonation.

➢ *Androgenesis*

Androgenesis, characterized by the generation of progeny solely from the male parent without any genetic contribution from the female, is a significant process in aquaculture. Induction of androgenesis holds the potential to yield all-male populations in fish, thus carrying commercial implications in aquaculture. Furthermore, it facilitates the development of homozygous lines of fish and aids in the recovery of lost genotypes from cryopreserved sperm. Notably, androgenetic individuals have been successfully produced in various species of cyprinids, cichlids, and salmonids (Bongers et al., 2014). Moreover, reports indicate the feasibility of androgenesis via heterospecific insemination in several fish species, such as *Cyprinus carpio, C. auratus, C. idella, Puntius conchonius, and Pangasius schwanenfeldii*. It is noteworthy that artificial androgenesis has primarily been limited to commercially significant food and ornamental fishes, with C. carpio serving as the universal sperm donor and O. mykiss as the universal recipient. A significant advantage of this technique lies in its ability to trace the density and distribution of parental genomes from an early embryonic stage, along with confirming the parental origin of haploid androgenotes that disintegrate during the embryonic stage (Pandian and Kirankumar, 2003).

➢ *Sex Control*

The utilization of sex control techniques to influence the characteristics of economically desirable teleost species is emerging as a vital management tool to enhance aquaculture production. Techniques enabling the production of mono-sex populations through sex manipulation hold potential utility in species where one sex is more economically valuable than the other. Two primary methods of sex manipulation include hormonal and genetic approaches. Hormonal or endocrine control involves administering sex steroids to fish during the early phases before sex differentiation commences. Given the protracted and labile nature of sex differentiation in teleosts, hormonal induction of sex reversal is feasible in both gonochoristic and hermaphroditic species. This induction entails administering an optimal dosage of sex steroids during the labile period, leading to the phenotypic transformation of genetic females into males, while genetic males retain their male identity. Presently, protocols for hormonal sex reversal have been documented for 44 species of gonochoristic and hermaphroditic fish, utilizing one of the 31 steroids (Pandian and Koteeswaran, 1998).

➢ *Transgenesis*

Transgenesis, or the introduction of exogenous genes/DNA into the host genome resulting in its stable maintenance, transmission, and expression, presents an excellent opportunity for modifying or enhancing the genetic traits of commercially important fishes, mollusks, and crustaceans for aquaculture. The concept gained traction when Palmiter et al. (1982) produced the first transgenic mouse by introducing a fusion gene of metallothionein and human growth hormone (mT-hGH) into a mouse egg, resulting in a significant increase in growth. Subsequent attempts at gene transfer in economically significant animals, including fish, followed suit. The transfer of foreign genes into fish can be accomplished in vivo by introducing DNA into embryos or directly into somatic tissues of adults (Hew, 1995). Direct delivery of DNA into fish tissues offers a simple approach, yielding rapid results and obviating the need for screening transgenic individuals and selecting germ line carriers. Successful gene transfer and expression have been achieved through intramuscular direct injection of foreign DNA into skeletal muscles of fish (El-Zaeem, 2004). However, despite considerable progress in various laboratories worldwide, several challenges must be addressed before the successful commercialization of transgenic broodstock for aquaculture becomes feasible.

➢ *Biotechnological Advancements in Fish Nutrition*

The aquaculture sector in numerous developing nations has experienced notable expansion in recent years, contributing significantly to both food security and poverty mitigation. Projected further growth in global aquaculture production accentuates the critical role of nutrition and feeding practices in fostering sustainable aquaculture. Consequently, there persists a concerted emphasis on the utilization of nutritionally balanced and meticulously formulated feeds in the production of finfish and shellfish. Concurrently, endeavors are underway to explore alternative and biotechnologically enhanced feed ingredients, concomitant with enhancements in pond management techniques and the manipulation of pond productivity. While the integration of exogenous enzymes into fish feed is not novel, ongoing assessments are aimed at elucidating their efficacy. Notably, the supplementation of diets with proteolytic enzymes has demonstrated modest positive effects in common carp (Dabrowska et al., 1979).

➢ *Nutrigenomics*

Feed constitutes a substantial expense in aquaculture, and the escalating cost of feed outpaces the growth rate of aquaculture, primarily attributed to diminished availability of fish for fish meal production. In response, fish meal substitution with alternative sources such as plant protein and poultry feather meal has been proposed. However, the metabolic ramifications of these substitutions necessitate thorough investigation (Sujit Kumar, 2020). Nutrigenomics presents an optimal approach for studying these effects, offering deeper insights into the biochemical and metabolic pathways implicated in the utilization of dietary macro- and micronutrients and energy derived from feeds. Such insights are invaluable for assessing organismal responses to nutrients from diverse sources, optimizing dietary nutrient utilization, and informing diet formulation. Given that biochemical pathways or nutrient metabolism are governed by one or more enzymes, which are gene products, a molecular approach to nutritional study becomes imperative (Sujit Kumar, 2020).

➢ *Biotechnology in Fish Health Management*

Disease challenges represent a significant impediment to aquaculture development. Biotechnological interventions, encompassing molecular diagnostic methods, vaccine utilization, and immune stimulants, have garnered attention for bolstering disease resistance in fish and shellfish species globally. Notably, for viral diseases, pathogen avoidance assumes paramount importance, underscoring the necessity for rapid pathogen detection methods. In this context, biotechnological tools such as gene probes and polymerase chain reaction (PCR) have emerged as potent assets. Gene probes and PCR-based diagnostic methods have been devised for various pathogens affecting fish and shrimp (Dabrowska et al., 1979). In the realm of finfish aquaculture, a myriad of vaccines targeting bacterial and viral pathogens have been developed. While some of these vaccines conform to conventional formulations comprising killed microorganisms, a new generation of vaccines incorporating protein subunits, genetically engineered organisms, and DNA constructs are currently in development. Immunization against disease represents a commonplace strategy in vertebrate systems (FAO, 2010).

- *Cryopreservation of Gametes or Gene Banking*

Cryopreservation, involving the long-term preservation and storage of biological material at ultra-low temperatures, offers a means of safeguarding genetic resources. The technology has been adapted from animal husbandry, with seminal success achieved in preserving fish spermatozoa (milt). Notably, spermatozoa from nearly all cultivable fish species have been successfully cryopreserved. Cryopreservation alleviates challenges associated with asynchronous maturation of male and female gametes, facilitates selective breeding and stock improvement, and enables genomic conservation (Harvey, 2006).

- *Nanotechnology*

Nanotechnology, hailed as a highly promising technology, has unveiled new avenues for applications in aquaculture and allied sectors (Guttmacher & Collins, 2002; Romero et al., 2006; Rather et al., 2011). Leveraging nanotechnology promises transformative applications in rapid disease detection, enhancing the bioavailability of pharmaceuticals such as hormones, vaccines, and nutrients in fish, and shellfish. The technology's immense potential for biomolecule analysis, development of non-viral vectors for gene therapy, targeted drug delivery, clinical diagnosis, and therapeutics underscores its significance. Notably, DNA nano-vaccines employing nanoparticle carriers hold promise for conferring robust protection against bacterial and viral diseases in fishes and shellfishes (Jayanta and Praveen, 2017).

- *Environmental Management and Bioremediation*

Aquaculture, akin to other intensive livestock production systems, generates nutrient-rich effluents fraught with pollution and/or toxicity potential. To address such challenges, biotechnological interventions such as bioremediation, probiotics, and vaccination offer considerable promise. Bioremediation entails the degradation of hazardous wastes into environmentally benign products using microorganisms or biofilter-capable macroorganisms such as bivalves. Probiotics, administered as live microbial feed supplements, serve to optimize intestinal microbial balance, thereby fortifying the host organism against pathogenic invasions. Notably, probiotics have demonstrated efficacy in reducing antibiotic dependency in shrimp aquaculture by suppressing the proliferation of pathogenic bacteria (Jayanta and Praveen, 2017**).**

- *Challenges*

Transgenic technologies present a promising avenue for effecting substantial and immediate enhancements in performance, such as growth rate, surpassing those achievable through alternative methods. However, the utilization of transgenic technology is impeded by valid apprehensions regarding potential environmental repercussions arising from the escape of transgenic fish into the wild (Beardmore et al., 2001). Alleviating this concern necessitates the development of transgenic fish rendered sterile through genetic modifications. Notably, the induced sterility should be reversible, allowing for fish fertility to be restored via straightforward treatments such as hormonal injections. This capability could facilitate the reproduction of brood stock and the production of sterile fry (Mair, 2001).

Another valid concern pertains to the desirability of employing transgenic fish species. Public apprehension regarding the use of transgenic organisms, fueled by concerns over unpredictable and adverse consequences, is justified given that the genetic alterations in transgenic individuals are often poorly characterized. The development of vaccines demands extensive research into the target pathogen and any resulting diseases (Subasinghe, 2009), entailing meticulous planning, field trials, and cost assessments. Presently, the deployment of vaccines may pose logistical challenges or prove economically prohibitive in developing nations, constituting a significant obstacle hindering the adoption of biotechnology in aquaculture. The ongoing debate surrounding the application of biotechnology in aquaculture remains unsettled, underscoring the imperative to address public perceptions regarding ethical and safety issues. Additionally, factors such as intellectual property rights and accessibility may further constrain its implementation.

V. CONCLUSION

In conclusion. The recent advances in biotechnology applications to aquaculture development are driving significant improvements in productivity, sustainability, and resilience. From genetic engineering and disease management to nutritional enhancements and environmental sustainability, biotechnology offers innovative solutions to the challenges faced by the aquaculture industry. As these technologies continue to evolve and mature, they will play a crucial role in ensuring the sustainable growth of aquaculture, contributing to global food security and the health of aquatic ecosystems. Aquaculture, the cultivation of aquatic organisms such as fish, shellfish, and seaweeds, has seen remarkable growth in recent decades, driven by increasing demand for seafood and the depletion of wild fish stocks. The integration of biotechnology into aquaculture is revolutionizing the industry, offering solutions to enhance productivity, sustainability, and resilience against various challenges.

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