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Seafood Preservation and Biotechnological Application in Seafood Safety and Quality

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Abstract

Seafood has become an essential source of protein, vitamins, minerals, and omega-3 fatty acids that benefit the human diet in this century. Considering consumer health and quality preferences, the growing seafood business is constantly adapting to meet new technologies for food safety and quality. Recent biotechnology techniques for development are used through numerous technologies to improve food safety measures and ensure that seafood items reaching consumers fulfill quality criteria. Biotechnology methods like DNA barcoding and high-throughput sequencing, the PCR-DGGE technique, DNA-based certification, and genetic markers like microsatellites and SNPs (single nucleotide polymorphisms) can be employed to authenticate seafood products, ensuring accurate labeling, helping track the origin of seafood products throughout the supply chain, promoting transparency and traceability, and preventing fraud. For the seafood quality assessment, acoustic biotechnological sensors combine omics technologies, proteomics, computer vision, and image analysis techniques. It also plays a vital role in nutritional quality enrichment and preservation by high-pressure processing, bio preservation, the microbiome, marine bioprospecting, and marine enzymes such as ficin, papain, pepsin, and subtilisin to improve seafood nutritional quality, reduce spoilage, and increase shelf life. Safety advancements have led to the development of rapid and sensitive methods for detecting pathogens, toxins, heavy metals, and foodborne contaminants in seafood, including molecular detection methods, enzyme-linked immunosorbent assays (ELISAs), biosensors, biomagnetism, loop-mediated isothermal amplification (LAMP), microfluidic-based assays, and bioremediation. This general article will teach us about the various biotechnological techniques and their uses in seafood safety and quality management.

INTRODUCTION

Over the past two decades, seafood consumption and popularity have gradually increased. However, creating high-quality items necessitates paying close attention to

the product's quality and safety and creating new products employing modern technologies. Through a variety of modern biotechnology advancements such as biomagnetism, biosensors, biomarkers, and bioassay methods are used to analyse and assess the quality of various seafood by finding concentrations of compounds including allergens, nutritional and non-nutritional components, antioxidants, and the presence of microbial contaminants, biotoxins, and other contaminants significantly effective in food safety evaluation. For the seafood safe to reach consumers, there are some techniques like PCR-DGGE technique, DNA barcoding, genetic markers to provide detailed information about that product, and traceability systems to trace the origin of seafood products, ensuring transparency and authenticity in the seafood supply chain. The use of biotechnology in the seafood sector results in safer, better-quality goods, environmentally friendly practices, and increased consumer pleasure. Biotechnological techniques, such as selective breeding and genetic engineering, can improve the quality of farmed seafood by enhancing desirable traits like growth rate, disease resistance, and nutritional content. As technology develops, biotechnological developments in the seafood sector continue to drive innovative things such as automatic grading machines, automatic packaging machines, metal detectors, modified packaging methods, and bio preservation (low-temperature storage, Bacteriocins, Fermentation, and bacteriocins). These methods help inhibit the growth of spoilage microorganisms and pathogens, reducing the risk of foodborne illnesses and preserving the freshness of the seafood. They are also essential for addressing problems and satisfying customer demands for safe, nutrient-rich, and high-quality seafood products. Here are some significant applications of biotechnology.

QUALITY ASSESSMENT

Biotechnological technologies are used in sensory evaluation and research with consumers to understand better customer preferences, perceptions, and acceptance of seafood items. The creation of items that meet customer expectations and desires is made easier with the use of this information. It uses computer vision and image analysis techniques to evaluate seafood's color, size, form, and other quality parameters, offering a quick and accurate quality judgment (Martínez and Sun, 2020 & Varela et al., 2010). Proteomics for Quality Assessment techniques, such as proteomics, are used to analyze the protein composition of seafood products. This enables the identification of potential quality indicators and allows for monitoring changes in protein profiles during storage and processing (Toldrá et al., 2012). Gomez-Pastora et al. (2020) research that acoustic biotechnological sensors, which measure acoustic qualities related to textural changes, are utilized for non-destructive and quick monitoring of seafood freshness. According to Power et al. (2022), combining omics technologies such as metagenomics, proteomics, and metabolomics with traditional quality indicators like color, texture, and flavor provides a new tool for unique processing optimization to assure seafood quality. To assure seafood quality, this technique combines microbiological identification and metabolite detection with assessing the allergenic potential of fish and shellfish and optimizing postharvest processing.

BIOSENSORS

The biosensors are sensors widely used to analyse and assess the quality of various seafood by finding concentrations of compounds such as allergens, nutritional and non-nutritional components, antioxidants, and the presence of microbial contaminants, biotoxins, and other contaminants (Kandeel et al.,2020). MBNs-based (bio) sensors for accurate and practical food safety evaluation. These sensors make it possible to create quick and accurate devices for the seafood industry that can assess freshness and identify allergens, nutritional and non-nutritional components, antioxidants, adulterants, toxins (Ciguatoxins and Tetrodotoxins), biotoxins, pathogenic contaminants of mycotoxins, and foodborne microbial contaminants, including fungal toxins, viruses, and foodborne bacteria (Mustafa and Andreescu, 2020; Wang et al., 2022; Reverté et al., 2023). Goulas et al. (2005) state that Real-time seafood spoilage detection uses biotechnological sensors, such as electronic noses and gas sensors. These methods aid in preserving the quality and freshness of seafood items. Wang et al. (2019) reported that Hypoxanthine and xanthine, which are produced during the ATP breakdown process, may be assessed using electrochemical biosensors to determine the freshness of cold seafood.

BIOMARKERS AND BIOASSAY

A biomarker is a measurable and quantifiable biological trait or substance that indicates a biological process, disease condition, or treatment response. Biomarkers may be detected in various biological samples, including blood, tissue, and genetic material. A bioassay, also known as a biological test, is an analytical method for determining a chemical's concentration, potency, or biological activity (for example, a medication, hormone, or toxin) by assessing its effect on living organisms or biological systems. They are used extensively in research and laboratories and are essential tools in pharmacology, drug development, clinical practice, and environmental monitoring. The technique used to detect hazardous chemical pollutants in marine species, such as chlorinated dioxins, dibenzofurans, biphenyls, and halogenated aromatic hydrocarbons (HAHs), in other marine toxins for determining and maintaining the safety of seafood and the health of the marine environment, it is crucial to monitor the levels of these pollutants as well as their spatial and temporal variability (Hahn, 2002 & Campàs et al., 2007).

DNA-BASED CERTIFICATION AND TRACEABILITY

For the seafood to be safe to reach consumers, information about the product and product recall management system and traceability techniques played an important role. Biotechnology enables the use of DNA-based certification, the PCR-DGGE technique, genetic markers like microsatellites and SNPs (single nucleotide polymorphisms) to provide detailed information about that product, and traceability systems to trace the origin of seafood products, ensuring transparency and authenticity in the seafood supply chain. As a result, there is a lower chance of supply-chain fraud, illicit fishing, and

mislabelling. (Ardura et al., 2010; Naaum et al., 2016; Sheikha et al., 2017). Ward et al. (2009) reported that other biotechnological techniques, including DNA barcoding and high-throughput sequencing, help precisely identify seafood species, avoid mislabelling, and maintain traceability.

BIOTECHNOLOGY IN SEAFOOD PROCESSING PLANT

In seafood processing plants, various biotechnological advancements are used for all units of pre-processing, processing, packaging, storing, and transportation. The major advantages are reduced the more employer power, reduced cost of making products, reduced time loss, and making large products with less time. Biotechnology uses machine vision and robotics to automate grading, sorting, and packing processes, ensuring precise and efficient classification of seafood based on size, color, quality, and quantity parameters. It is also used to identify metal contaminants in raw and processed seafood by using metal detectors (Babin et al., 2011). Biotechnology is involved in the development of biodegradable and edible packaging materials for seafood products. These innovative packaging solutions help reduce plastic waste and extend the shelf life of seafood while maintaining quality and safety (Rhim, 2014). According to Benjakul and Karnjanapratum (2018), biotechnology plays an important role in converting marine by-products such as fish skins, bones, and shells into value-added goods such as collagen, gelatin, and chitosan. These substances are used in the food, pharmaceutical, and cosmetic sectors.

Rapid Pathogen Detection:

Biotechnology allows for the rapid and precise detection of pathogens, disease-causing agents, and foodborne contaminants in seafood. Early detection helps prevent the spread of diseases and ensures that only safe products reach consumers. Biotechnological techniques like loop-mediated isothermal amplification (LAMP) and microfluidic-based assays enable quick and on-site testing, reducing the time to identify potential hazards. (Nogva et al., 2000). Enzyme-linked immunosorbent assays (ELISAs) and biosensors have been developed to assess the quality and freshness of seafood. These methods provide quick and reliable results, enabling better quality control throughout the seafood supply chain. (Kantamreddi and Seetapan, 2018). Molecular Detection methods, such as polymerase chain reaction (PCR) and DNA sequencing, are employed to detect pathogens and harmful contaminants in seafood. These methods allow for rapid and accurate identification of bacteria, viruses, and parasites, ensuring early detection and prevention of potential foodborne illnesses. (Huh et al., 2019; Raghunath et al., 2008)

Conclusion

In conclusion, biotechnology is pivotal in enhancing seafood safety and quality through various applications and advancements. As biotechnological research continues to advance, it holds great promise for further improving seafood quality, making the industry more sustainable, and meeting consumer demands for safe and nutritious products. As the field evolves, it will be important to balance technological progress, environmental sustainability, and consumer welfare to support a thriving and responsible seafood industry. Responsible application of biotechnology, adherence to regulations, and transparent communication are vital to ensuring that seafood quality

benefits from these technological advancements.

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