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Biosensor- Advances, Applications and its Role in Quality Assessment

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SUMMARY

Fish is an essential source of protein with many health benefits, which make it as a vital component of a balanced diet. In comparison with other protein sources like red meat, fish generally contains lower levels of saturated fats. Hence the consumption of fish and shellfish has become prevalent among worldwide. However, consumption of seafood products is threatened by fraudulent practices like mislabeling and species distribution. These can be minimized by the use of biosensors, which helps in evaluating fish quality at consumer level.

INTRODUCTION

Fish and shellfish, play an important role in reducing hunger, promoting health and minimizing poverty. Seafood products are highly nutritious which is a major source of protein, polyunsaturated fatty acids, and other essential nutrients, such as minerals and vitamins, which promote health of the world's population and economic. The demand for fish and seafood is growing worldwide. Fish production is a growth growing industry, with more than 196 million tons of fish predicted to be processed in 2025 (Sonia & Maria, 2019). Seafood fraud involves the intentionally inaccurate misrepresentation of fish or shellfish for economic gain which includes activities such as species substitution, illegal transshipment, short weighting, and mislabelling country of origin or production method. Distributors, retailers and other final seafood customers often buy fish of a lesser price and illegally sell these fish as their higher value relatives for the sake of increased profits (Jacquet and Pauly 2008).Fish is currently one of the most mislabelled foods in the world; in fact, it was recently shown that in 55 nations, about 20% of fish in the restaurant and commercial sectors was mislabelled. Since the supply chain for fisheries products is one of the most complex and globalized today, it is complicated to trace fish and seafood and detection of intentional and unintentional fraud. As problems related to the integrity and safety of the fishery sector are expanding, leading legislators, producers, and consumers have been searching for practical solutions to effectively protect themselves from fraud and health hazards related to fish consumption. Numerous biological and chemical methods have been developed over the years to determine the authentic nature of a wide range of foodstuffs, but these methods are not suitable for use at the consumer level. Nowadays, biosensors emerged as crucial tools in assessing fish quality, particularly in the context of aquaculture and food safety. These analytical devices combine biological components with electronic systems to detect specific substances, providing rapid and accurate measurements of various quality parameters in fish products.

Recent advances in sensor technology:

Biosensors utilized in food can be basically classified into two groups: immunosensors that detect pesticides and harmful bacteria, and enzyme sensors that detect food ingredients. Proximate analysis, nutritional labelling, detecting pesticide residues, naturally occurring toxins and anti-nutrients, processing modifications, microbial contamination, enzymatic inactivation, and BOD of wastes are some of the uses in the food sector (O'Connell et al., 2000). Biosensor determining the quality of a food is the glutamate sensor, where glutamate detection is often based on the enzyme glutamate oxidase that specifically converts glutamate to alpha-ketoglutarate. Similar to a glucometer, the glutamate oxidase catalysed reaction is detected within the biosensor by a change in current which directly reports on the presence of the flavour enhancer glutamate. The commercially available biosensor measures BOD with a combination of microbes consuming oxygen in the presence of organic compounds and a Clark electrode that determines oxygen concentration. A biosensor for the detection of pesticides and nerve agents was developed by immobilizing AChE and ChOD onto Au-Pt bimetallic NPs. Biosensors based on aptamers have been widely used in marine toxins detection by virtue of the merits including high sensitivity, stability and specificity. Significant advances in biosensors for fish quality measurement started in the 1980s, as recently outlined by Venugopal et al. (2000). Pesticides such as polychlorinated biphenyls can be discovered in fish and clams, as well as other food chains. There have been reports of pesticide detection using biosensors (Dankwardt and Hock, 1997; Ivanov et al., 2000).

An electrochemical immunosensor was developed by Bender and Sadik (1998) to detect pesticides. Pseudomonas sp., Bacillus sp., and some thermophilic bacteria are among the microbial cells that have been used in the development of several biosensors for BOD readings. In a maximum of 30 minutes, these devices may measure BOD concentrations as low as 1 mg per liter. Recently, an algal biosensor for monitoring water toxicity in estuarine environments has been recommended. Biosensors for evaluation of the quality of refrigerated and frozen aqua cultured seabass reared in aerated and hyperoxic conditions have been reported (Poli et al., 2000). Nanto et al. (1993) reported an aluminium-dopex zinc oxide thin film gas sensor capable of detecting freshness of seafoods. Cho et al. (1995) developed a new device for the rapid measurement of quality of wet fish using a microcomputer attached to a sensor. The device's portability and ability to quickly evaluate quality changes in several fish kept at different temperatures using criteria like TVBN and K-value indicate its possible application as a quality indicator kit for fish markets, which are not yet commercialized. Coupled enzyme systems, known as the 'KV-101 Freshness meter' and 'Microfresh' are available for industrial use (FAO, 1995).

Application of sensors in seafood:

Edible sensors for seafood freshness: A consumer-useable edible sensor that is very sensitive to gaseous amines has been designed for real-time freshness monitoring of food. The sensor produced is a pectin matrix film carrying a colorimetric indication, which is red cabbage extract. Anthocyanins in the form of red cabbage extract are used as the amine sensing element of the film. A small amount of 1 ppm of the amines under test causes a significant colour shift in the film, exhibiting the sensor's highly sensitive nature to gaseous amines. An highly efficient trimethylamine gas sensor has been developed by ultrasonic treatment loading of Au nanoparticles on tungsten oxide (WO_3) nanosheets made using solvothermal self-assembly method. This Au/WO3 sensor offers immense application potential for quick and non-destructive seafood freshness detection on the spot. Trimethylamine (TMA) is an important indicator of seafood freshness and quality. TMA levels rise as seafood decomposes due to action of bacteria on amino acids such as choline. TMA is the major component responsible for the distinctive "fishy" odour of perished seafood. TMA sensors are powerful tool for ensuring seafood quality and safety, giving producers and customers an accurate way to monitor freshness.

Surface plasmon resonance biosensor: Domoic acid (DA) is a natural toxin generated by tiny algae, particularly the diatom Pseudo-nitzschia. Surface plasmon resonance (SPR) biosensors are increasingly being used to detect DA. Molecularly imprinted polymer (MIP) films paired with SPR transducers enable a very sensitive and selective method of detecting domoic acid, a deadly neurotoxin that can accumulate in shellfish. This technique takes advantage of MIPs' particular features, which are constructed to have precise binding sites for target molecules, as well as SPR's sensitivity, which detects changes in refractive index upon binding.SPR technology is based on protocols that evaluate changes in refractive index (RI) on thin gold surfaces in real time to detect intermolecular interactions. SPR is widely recognized for its multiple advantages in the detection of cancer biomarkers such as non-destructive analysis, rapid and real-time monitoring of the target biomolecules, excellent selectivity, reliability, and cost-efficacy (Qu et al., 2020). The advantages of SPR biosensors over conventional methods of cancer diagnosis include their ability to detect cancer *in situ*, in real-time, and label-free with enhanced sensitivity (Patil et al., 2019).

Sensors in quality assessment:

Traditional methods of assessing fish quality rely on sensory evaluation by trained professionals, which is time-consuming, subjective, and may lead to inconsistencies in results. An electronic nose (e-nose) is an analytical instrument that mimics the human olfactory system and can be used to rapidly and objectively assess the quality of fish. The design and development of an electronic nose for fish quality assessment involves the use of various sensors to detect and analyse the volatile organic compounds (VOCs) emitted by fish. These VOCs are responsible for the characteristic odour of fish and can be used as a marker for freshness and quality. It is a rapid and powerful technique, which requires no special sample preparation to determine the aroma of a product. It is faster, more objective, and can be used to assess a large number of samples simultaneously. The multisensory concept was developed by selecting and adapting complementary rapid physical techniques to measure the quality of fish. This involved miniaturising the available instruments to make them portable so that they could be brought together to a single location. The outputs of the multisensor can be calibrated with the corresponding Quality Index Method sensory scores where, QIM was selected as the reference method.

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