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APPLICATION OF BIOSENSORS IN FISHERIES: A REVIEW ON REAL-TIME QUALITY ASSESSMENT AND MONITORING FOR SUSTAINABLE AQUACULTURE PRODUCTION

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Abstract

This manuscript provides a comprehensive review of the potential and utilization of cassava peel as a fish feeding redient. Agro-industrial activities in Indonesia generate substantial waste, including cassavapeel, which can serve as avaluable carbohydrate source in fish feed. Cassava is the third most important food crop commodity in Indonesia, and its productivity has been increasing over the years. Cassava possesses a good nutritional profile, with high starch content and energy value. Fermentation of cassava peel can enhance its nutritional value by increasing crude protein content and reducing anti-nutrients such as cyanide acid. Fermented cassava peel products have been shown to reduce reliance on imported feed ingredients and lower production costs without compromising fish growth. The utilization of fermented cassava peel waste presents a sustainable solution for converting agro-industrial waste into a suitable fish feed ingredient.

INTRODUCTION

Indonesia is the biggest archipelago country in the world. Based on United Nations Convention on the Law of the Sea (UNCLOS) 1982, national area 5.0 million km2; consists of 3.1 million km2 of national waters and a land area of 1.9 million km2, and an Exclusive Economic Zone (EEZ) of 3.0 million km2. Within this area there are the length of the coastline is approximately 81,000 km and the number of islands is approx. 17,000. In other words, 62% is national waters while 38% is land. The fisheries sector plays a strategic role in development a country's independent economy by providing basic materials for the people and raw materials for industrialization. Fisheries are a field that very diverse, but continue to develop with technological growth fast. Fish and seafood are an important part of a healthy diet and a good source of protein around the world. Fish consists of fat, amino acids and water so it is susceptible to spoilage due to micro organisms after post-mortem. Fish and seafood are highly perishable and can only be stored fresh ice for 8–14 days, depending on the species (Hicks, 2016). Production level Aquaculture has increased over time, making it important to develop efficient storage and processing methods and technology increase the shelf life of fish and seafood in order to reduce post-harvest losses. Pollution of water bodies by heavy metals, the role of biosensors is considered highly important.This waste from various companies is released into nearby water bodies because there are heavy metals such as zinc, lead and cadmiumin the water.

Water Toxic metals and other pollutants enter the body of aquatic flora andfauna. In this way these poisons enter the food chain and also inside human body. Before feeding aquatic food, its quality is necessary checked.The quality inspection process occurs at different levels, but the main checkpoint is where the consumer buys it. By Therefore, quality assessment technology must be fast, objective, accurate and sensitive to ultimately provide satisfaction to consumer’s orendusers. Biosensors that have been developed for such applications can also used for aquaculture. In recent research, fish biosensors Transgenic zebras have been developed as a first level screening toolfor toxicity air (Pawar, Gireesh-Babu, Siva Subbu, & Chaudhari, 2016).

In most cases, due to a lack of cold chain supplies and to earn easy profits, retailers and wholesalers try to deceive consumers by including false quality indicators on seafood. There have been several studies conducted to reveal this expansion and the severity of malpractices that occur in this agricultural sector. Many cases of seafood poisoning and deaths are reported every year as a result of post-mortem decay (Hicks, 2016). There are many artificial preservatives prohibited (such as formaldehyde) and cooking ingredients (such as calcium carbide) which are illegally used in excessive amounts by vendors for cutting cold storage costs at the risk of deadly effects on consumer health. The presence of these chemicals can only be checked in the laboratory by an expert technical team. Instead, the product must be tested in real-time and directly on the spot to find out health concerns for consumers. This is where biosensors come in to solve this problem quickly. Because biosensors work based on the principle of using biomolecules to convert small changes in mass, light, heat, pH, etc. into signals of electricity, they are very suitable for use on live and non-live seafood networks. Biosensors are now widely used for various sector problems in the fishery and aquaculture, which includes raising aquatic animals such as fish and cultivating water plants. In the production and maintenance of aquatic animals, monitoring and real-time process control is traditionally carried out by fishermen. Practices like these are very time-consuming, tiring, and demanding of skilled people. Only certain communities consist of people who have been involved in these activities for decades and manage the work. In the future, any type of work is possible to be handled by anyone without skills, just a little guidance. His contribution was made to new and intelligent technologies to make work easier and faster. Technical intervention is required in the basic principles of processing food, quality assurance, disaster risk identification, diagnosis, and prevention to achieve regional and global food security goals. Therefore, to improve consumer welfare and the efficient use of resources optimally, fast, real-time, portable, and extremely cost-effective technology is needed in the fisheries sector. Recent advances in biosensing technology and materials science have played an important role in understanding process dynamics in fisheries through molecular recognition materials, antigen-antibody interactions, and sequence transduction mechanisms.

BENEFIT

Digital technology brings significant operational benefits to the global food chain, increasing efficiency and productivity while reducing waste, contamination, and food fraud. The focus on digital technology is recently evolving into Industry 5.0, where AI and robotics are combined with the human mind to advance human-centered solutions. This view describes the role of the Quadruple Helix Hub (academic-industry-government, and society) in providing a convergent holistic approach to meet the diverse needs of the fishing industry by connecting and placing fisheries centrally in the stakeholder ecosystem. Digitization of data on food products from fisheries involves the use of technology to collect, store, analyze, and share information related to these food products.

Tracking and monitoring technology can be used to trace fishery products from the place of capture to the hands of consumers. This involves the use of QR codes or RFID to provide information about origins, capture methods, as well as time and location.

a. Safety and quality: Sensors and monitoring technologies can be used to check the quality of fishery products in real-time, such as temperature, product storage, cleanliness, and safety. This helps ensure products remain fresh and meet food safety standards.

b. Data analysis: The use of data analysis can help in understanding market trends, consumer preferences, as well as assisting in making strategic decisions related to production, distribution, and marketing.

Digitalization of data on food products from fisheries can improve operational efficiency, enhance food safety, strengthen the supply chain, and provide better information to consumers regarding the products they buy. The benefit of biosensors in the fisheries sector includes the detection of toxic substances, fish density, water quality, gas concentration, and the frequency of water exchange, which affects fish production and health. Transduction-based biosensors can also determine these factors. Because seafood is easily damaged and susceptible to microbial growth, it must be stored and transported only under specific temperature and humidity conditions.

PROBLEMS

Fish is a high-protein product that is important to meet the demands of an ever-increasing global population. However, stocks continue to run low in the wild, causing increased pressure on the deep-water aquaculture sector in terms of maintaining the supply of fish and seafood to global markets. Regardless of the fact that aquaculture is more diversified than the agricultural sector; there is significant pressure on the industry to continue to innovate in order to realize sustainability. This includes increasing fish production, better species selection, disease mitigation, reducing wastage, preventing environmental pollution, and creating more jobs globally.

Fishery product technology must be handled quickly and precisely because fish are experiencing a fairly rapid decline in quality in many sectors. Aquaculture experiences losses due to crop yields that suffer quality reduction before being marketed to consumers. Therefore, it is necessary to explore how digital transformation can help support and fulfill the need for expansion of the fishing industry, which includes the exploitation and utilization of ICT, IoT, cloud-based computing, AI, machine learning, immersive technologies, and blockchain. Biosensors to monitor the quality of the catch in real-time, from the cultivation process through harvesting until ready for consumption, are essential.

DIGITAL DATA DEVELOPMENT SOLUTIONS AND CHALLENGES

Among the new trends emerging in the field of agriculture, biosensors are now increasingly popular in all sectors, starting from agriculture. Biosensors are self-integrated tools for sensing and material characterization. Progress in biosensors has gone through different stages. Biocatalysts and transducers were initially separated in the previous generation, and then in the second, the components are integrated in such a way that eliminates the risk of one component affecting the function of other components. In modern biosensors, there is no need for any mediator. In this type of biosensor, enzymes are reduced directly on the electrode surface (Zein et al., 2018).

In general, the development of biosensor devices involves a series of steps including synthesis of sensing materials, selection of bioreceptor materials, complex media containing target analytes, signal processing units, analyzers, software development, and final sensing units. Fisheries biosensors can be classified based on the type of bio-recognition system used. Commonly used biorecognition systems involve a network of antibody-antigen, enzyme-coenzyme-substrate, and nucleic acid-complementary.

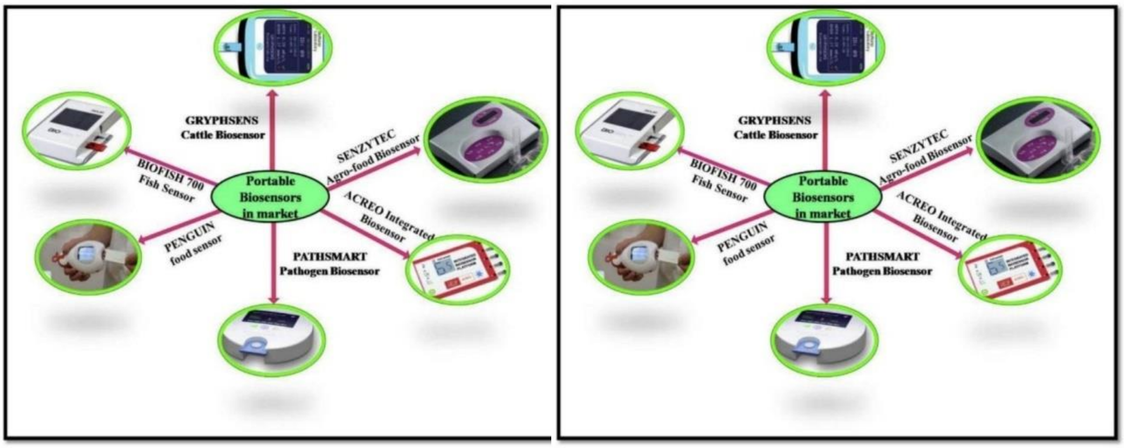

Figure 1

Microorganisms, plant cells, animal cells, and tissues can also be used as elements of bio-recognition. In recent research, electrochemical biosensors have been developed to determine the formaldehyde content in fish and developed a device suitable for commercialization in the consumer market. Formalin biosensor detection was found to be comparable to existing methods such as HPLC, digital image analysis, and spectroscopy (Noor Ain et al., 2016). There are various other attributes relating to the quality of seafood. Biosensors have been developed for determining freshness based on measuring changes in several quality indicators. Histamine is one of the indicators that appears in fresh fish with the onset of post-mortem spoilage due to improper storage and handling conditions. Biosensors have been developed using graphene-based amperometry, which has high stability, precision, and correlation with standard methods (Apetrei & Apetrei, 2016).

Xanthine, another indicator of fish and meat spoilage, has been determined quantitatively using electrochemical biosensing techniques using bionanocomposites and proved to be a reliable parameter for determining freshness (Dervisevic et al., 2017). Nowadays, even gender and animal species can be determined using biosensor techniques. In recent research, a highly sensitive DNA biosensor based on electrochemical transduction techniques has been developed to determine the sex of fish, making it possible to automate aquaculture for gender-based screening. The biosensor developed has a wide range of uses for controlling and monitoring various life processes specific to gender in research (Esmaeili et al., 2017).

Due to food consumption, stale seafood can cause various allergies, illnesses, and even death. Fish allergies, even in small amounts, have been found to be the most common food allergy in the world. Populations sensitive to fish allergies increased drastically along with mass fish consumption throughout the world. The major fish allergen, parvalbumin, has been detected by a fluorescence-based biosensor in mast cells with good reproducibility and rapid response. A specially developed biosensor measures parvalbumin and predicts fish allergy in human populations (Jiang et al., 2014).

For farmers cultivating fish in ponds and other bodies of water, continuous monitoring and control of fish health are needed to obtain good productivity. To reduce fish mortality and increase productivity, physiological conditions such as stress levels in farmed fish must be monitored. Stressful conditions in fish can cause changes and the release of several biochemical indicators such as glucose concentration. Although stress arising in fish can be detected through behavioral interactions, qualitative measurements and quantifying the causative agent accurately and precisely can only be done with the assistance of appropriate biosensors.

A study conducted using glucose oxidase to determine the increase in glucose concentration in fish blood due to stress revealed that biosensing technology is fast, sensitive, and suitable for on-site applications even in harsh climatic conditions (Wu et al., 2015). Therefore, the aquaculture sector has rapidly developed after the Blue Revolution and will move to a higher level after merging implications of current technologies such as microelectronics, nanoscience, and biosensors. Apart from that, there are several physical factors such as climate, soil, and topography that significantly affect agricultural productivity. With the increasing trend in genetic engineering, transgenic plants are now used in agriculture.

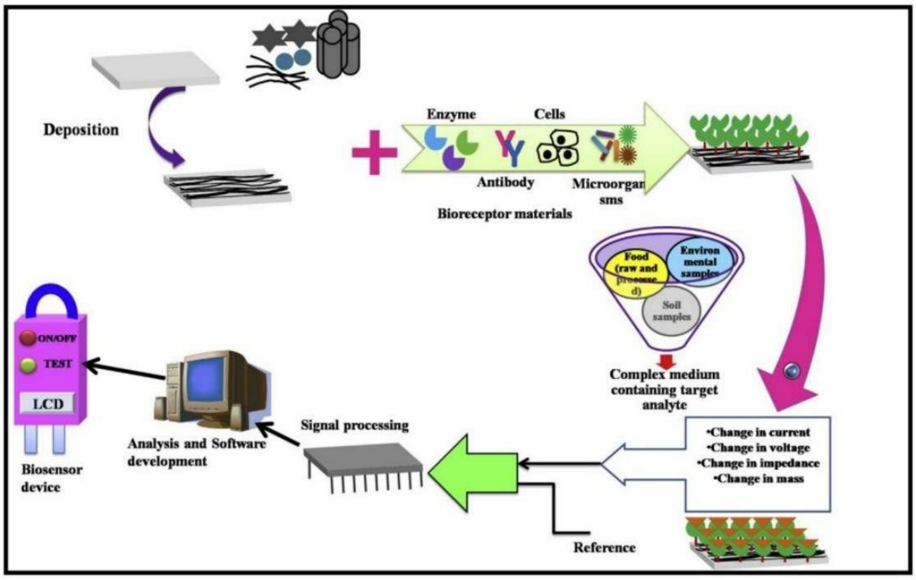

Figure 2

Although genetically modified (GM) crops have socio-economic benefits, economically, this plant poses a threat to the environment. Therefore, labeling of GM-derived foods is an important regulatory requirement in trade. The focus of biosensor development has been directed towards the in homogeneity arising in agriculture. A research team has developed an optical biosensor using an artificial thin-film chip to identify seven GM canola lines (Bai et al., 2012). Nowadays, biosensors have advanced to a high level and can help select climate-resistant plant and animal species through rapid assessment of the influence of environmental factors and animal genotype on various life stages (Neethirajan, Tuteja, Huang, & Kelton, 2017).

Climate change and global warming that occur every day are worrying progress of pathogen activity and result in challenging conditions for animal survival. Biosensors can help us choose animal breeds that are climate resistant and will survive even in varying conditions, mitigating the pressure generated afterwards. The digital challenge for fisheries is to optimize the role of government regions, agencies, or institutions responsible for handling the process of digitalization of the maritime sector, such as communications and information services. Third, for optimizing digital-based fisheries production, training and education are also very important. Digital technology can increase the efficiency of fisheries production, thereby reducing production costs, which might improve community economy. Obstacles and difficulties in the adoption and dissemination of technology need to be addressed sincerely through research institutions and organizations and development.

In the future, in agriculture, there will be no single sector untouched by the role of biosensors. The biosensor will appear as the most influential technology in modern precision fishing to help decision support systems in predicting disasters and assessing losses smartly and quickly, ensuring sustainable fisheries with improved productivity.

CONCLUSION

Digital technology in the fishing industry can play an important role in improving the quality of fishery products, preserving the environment, and supporting the economy of coastal communities. This review highlights significant developments in the adaptation of biosensors in various agricultural fields. It provides insight into the problem areas that exist in the field of agriculture, the role of biosensors and their potential implications, limitations, and scope for further improvements. Biosensors have a large market because of their potential wider coverage of crops, raw and processed foods, and monitoring environmental and quality control systems.

Advances in microfabrication technology, material science, and nanoengineering have a significant influence and beneficial impact on the fisheries biosensor market. Biosensors can detect multiple toxins simultaneously in processed foods to standardize quantitative measurements of health and industry. Food in agriculture basically has to be cheap and easy to bring to the field. The use of modified nanostructures as matrix materials and techniques for appropriate immobilization of biomolecules will improve the characteristic features of biosensors significantly.

Additionally, efforts have also been made to review the latest developments in the field of application of biosensors for livestock and livestock management in agriculture. Like humans, the livestock sector is also vulnerable to disease, infection, contamination, interference, and malnutrition. Despite various problems in aquaculture, poultry, and dairy animals, biosensor interventions in this field, including enzymatic and non-enzymatic biosensors, whole-cell-based biosensors, DNA, and aptamer-based biosensors, will certainly be very helpful in unlocking opportunities and overcoming further challenges for wider scale acceptance.

The popularity of implantable biosensors for point devices maintenance and adaptation of integrated circuit (IC) technology in transduction can play an important role in further progress and commercialization of this technology. Barriers to technology acceptance in the market need to be investigated in relation to risks and regulations that impact society.

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