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Biosensors for ocean acidification detection

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Abstract. Ocean acidification is a global environmental problem that significantly impacts Marine ecosystems and biodiversity. The traditional chemical analysis method has the problems of complex equipment and high cost in ocean acidification monitoring. In recent years, fluorescent protein biosensor technology, as an innovative monitoring method, has provided a new solution for the real-time detection of ocean acidification. Compared with traditional chemical analysis methods, fluorescent protein biosensors have the advantages of simple operation, high sensitivity and low cost. Current studies have demonstrated the potential of fluorescent protein biosensors for ocean acidification monitoring. The researchers designed a variety of fluorescent protein biosensors and conducted indoor and outdoor experimental validation. These results show that fluorescent protein biosensors can detect ocean acidification quickly and accurately and maintain stable performance under different environmental conditions. Further studies are needed to verify the consistency and reliability of fluorescent protein biosensors and traditional chemical analysis methods for ocean acidification monitoring. Future research directions include further improving the performance of the fluorescent protein biosensor, increasing its sensitivity and stability, and verifying its application in real Marine environments. This will help establish a better monitoring network for ocean acidification and provide a reliable scientific basis for Marine environmental protection and management decisions. The development and application of fluorescent protein biosensor technology will provide important support and guidance for us to better understand the impact of ocean acidification.

Keywords: ocean acidification, biosensors, fluorescent proteins.

1. Introduction

Ocean acidification is one of the global environmental problems that has attracted much attention in recent years. With the continuous increase of carbon dioxide emissions from human activities, a large amount of carbon dioxide is dissolved in seawater to form carbonic acid, resulting in a continuous decline in the pH of the ocean [1]. This acidification phenomenon has a broad and profound impact on Marine ecosystems and biodiversity.

To monitor and assess the extent of ocean acidification, traditional chemical analysis methods are widely used, but these methods often require complex experimental equipment and expensive costs, and there are uncertainties in the sampling and analysis process [2]. Therefore, finding new, fast, accurate and cost-effective monitoring methods is very important [3].

In recent years, fluorescent protein biosensor technology has become a popular method [4]. This technique uses fluorescent proteins as markers to detect the pH of the environment in real time by monitoring changes in fluorescence properties. Using the unique properties of fluorescent proteins, biosensors can provide immediate and quantitative measurements, opening up new possibilities for ocean acidification monitoring and research [5].

This paper reviews the application potential and related research progress of fluorescent protein biosensors in ocean acidification monitoring. First, the impact of ocean acidification on ecosystems and biodiversity will be briefly described. Then, the principle and design method of fluorescent protein biosensor are discussed. Finally, the existing research results of ocean acidification biosensors will be reviewed, and the future development direction and challenges will be discussed.

Through in-depth understanding and research of fluorescent protein biosensor technology, we are expected to develop a new, simple and efficient monitoring method for ocean acidification, and provide more accurate and reliable data support for protecting the Marine ecological environment and formulating corresponding protection strategies.

2. Algae sensors

Certain algae are very sensitive to ocean acidification, and their physiological responses are closely related to environmental pH. By monitoring changes in fluorescence or other metabolic substances inside the cells or on the surface of the leaves of these algae, changes in pH in the ocean can be measured indirectly [6]. This algae-based sensor has high sensitivity and real-time monitoring capability.

2.1. Working principle

Algae sensors reflect the pH of the surrounding environment based on changes in fluorescence or other metabolic substances inside the algae cells or on the surface of the leaves. Ocean acidification can lead to changes in the acid-base balance within cells, affecting the algae's physiological state and metabolic processes. Sensors can infer pH changes in the ocean by monitoring changes in these physiological parameters.

2.2. Technical possibilities

2.2.1. Using bioluminescence. a common algal sensor uses algae's fluorescent properties to measure environmental pH. these algal sensors work by introducing specific fluorescent markers or fluorescent proteins into the algal cells, and the intensity of the fluorescent signal changes when the cells are subjected to a specific pH level. By measuring the intensity of the fluorescent signal, the pH change of the environment can be measured indirectly. Algae biosensors have the ability to monitor environmental parameters in real time, and can quickly respond to target molecules or environmental changes in a short time to achieve real-time data acquisition. This capability makes it important in environmental monitoring and pollution warning applications [3].

2.2.2. Versatility and customizability. Algae biosensors can be optimally designed and engineered for specific target molecules to meet specific detection and monitoring needs. By analyzing the influence mechanism of specific target molecules on algae organisms, the selection of biological elements and parameter regulation can be optimized to improve the sensitivity and specificity of the sensor. Algae can sense and respond physiologically to environmental changes such as pH and carbon dioxide concentration, so that environmental parameters can be measured by monitoring their physiological parameters or metabolites

2.2.3. Selection of sensitive algal species. Algal biosensors enable accurate detection of specific molecular and environmental parameters based on the selectivity and sensitivity of algal organisms to target substances. Algae can sense and respond physiologically to environmental changes such as pH and carbon dioxide concentration, so environmental parameters can be measured by monitoring their physiological parameters or metabolites [4].

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2.3. Application prospects
Algal sensors have the advantages of high sensitivity, real-time, non-invasive and low cost. These sensors can be used in ocean acidification monitoring, marine protected area management, environmental research, and other fields. In addition, algal sensors can be combined with other monitoring technologies and sensors to provide more comprehensive monitoring and assessment of ocean acidification.

3. Shellfish sensors
Shellfish can reflect changes in environmental pH through changes in their shells' oxygen isotope ratios and carbon isotope composition. These sensors can measure the degree of ocean acidification by analyzing isotopic ratios in the shells or molluscan tissues of shellfish. Shellfish sensors have high accuracy and stability and can be used for long-term monitoring [6].

3.1. Principle of operation
Shellfish sensors use changes in oxygen isotope ratios and carbon isotope compositions in shells or molluscan tissues to indirectly measure changes in environmental pH. The pH of the environment influences the chemical composition of shells and molluscan tissues of shellfish growth. Ocean acidification leads to an increase in the solubility of carbon dioxide in water, causing changes in the carbon isotopic composition of *shells and tissues of shellfish.*

3.2. Technical possibilities

3.2.1. Isotopic analysis. Shellfish sensors infer changes in environmental pH by analyzing the carbon isotopic composition in shells or tissues of shellfish. The oxygen isotopic composition influences the oxygen isotopic composition in shellfish shells in the surrounding water. In contrast, the carbon isotopic composition is related to the concentration of carbon dioxide in the surrounding water column. Changes in the degree of acidification in the environment can be inferred from measurements of isotopic ratios in shells or tissues of shellfish [6].

3.2.2. Sample collection and analysis. Performing shellfish sensor analysis requires collecting shell or mollusk tissue samples of shellfish and performing appropriate chemical processing and isotopic analysis. The isotopic content of shellfish shells is usually measured by mass spectrometry techniques (e.g., stable isotope mass spectrometry).

3.2.3. Application areas. Shellfish sensors can be applied to the monitoring and assessing ocean acidification. The impact of acidification on shellfish growth and ecosystems can be understood. Shellfish sensors are widely used in protecting and managing marine ecosystems, assessing the risk of regional ocean acidification, and developing related policies.

3.3. Application prospects
Shellfish sensors still face some challenges in practical applications, such as the difficulty of sample collection, complexity and accuracy of analysis. In addition, standardized methods and further development of data analysis techniques are the future directions of shellfish sensor research [7]. However, shellfish sensors have great potential in ocean acidification research as a non-invasive and sustainable monitoring method.

4. Coral sensor
Using corals as biosensors to detect ocean acidification is a very promising area of research. Corals are very sensitive creatures in Marine ecosystems, and they are very sensitive to changes in the Marine environment, especially changes in pH [8]. Ocean acidification is caused by increased carbon dioxide

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in the atmosphere, which dissolves in seawater to form carbonic acid, causing the pH of seawater to drop.

Using corals as biosensors can assess ocean acidification by observing how corals respond to ocean acidification. A common approach is to look at physiological indicators such as coral growth rate, bone morphology and chemical composition [9]. Ocean acidification directly impacts the physiological processes of corals, so it is possible to assess the degree of acidification of seawater by monitoring these indicators.

In addition, using coral gene expression can also be used as a biosensor to detect ocean acidification. Ocean acidification causes changes in many genes in the coral genome that can act as acidification indicators. Changes in carbon dioxide concentrations in seawater can be assessed by analyzing changes in coral gene expression.

It is important to note that using coral as a biosensor is still in the research stage, with many challenges and limitations. For example, accurately interpreting corals' physiological indicators and gene expression changes needs more in-depth research. In addition, interference from other environmental factors also needs to be considered. However, harnessing the potential of corals as biosensors could provide important information to better understand the effects of ocean acidification.

4.1. How it workss

Coral sensors use the physiological and chemical response of corals to reflect changes in environmental conditions. The physiological processes of corals are affected by environmental pH, and their growth rate, composition of skeletal compounds, and oxygen isotope composition may change [10]. By analyzing these characteristics, it is possible to infer the degree of acidification and health of the environment to which the coral is exposed.

4.2. Technical possibilities

4.2.1. Skeletal compound analysis. The skeletons of corals are important indicators for recording environmental changes. Coral skeletal compounds (e.g., calcareous structures) are closely related to the environment's pH and carbon isotopic composition. Analysis of composition, microstructure and isotopic composition in coral skeletons provides insight into the effects of ocean acidification and other environmental changes on corals [11].

4.2.2. Growth rate monitoring. environmental acidification may affect the growth rate of corals. By monitoring changes in coral growth rates, changes in pH of the surrounding water column can be inferred. The calcium-carbon balance involved in corals has been used in some studies to estimate changes in environmental pH [12].

4.2.3. Temperature and light analysis. Coral sensors can also monitor temperature and light changes. Ambient temperature and light conditions impact corals' physiological processes and their relationship with symbiotic algae. Analysis of coral temperature and light response can provide insight into other environmental changes that coexist with environmental acidification.Coral biosensor can realize real-time monitoring and rapid response of environmental parameters [13]. Corals have high sensitivity and response speed to environmental changes. They can respond to external environmental changes in a short time, so as to achieve real-time data collection and monitoring.

4.3. Application prospects

Coral sensors can be used in ocean acidification monitoring, coral health assessment, climate change research and environmental monitoring. These sensors provide real-time monitoring and assessment of coral ecosystem health and environmental stress.

5. Conclusion

Ocean acidification biosensor technology is a promising method to monitor ocean acidification. Using fluorescent protein as a marker, the technology can accurately monitor ocean pH changes and provide fast, real-time measurement results. Fluorescent protein biosensors have the following advantages: easy to use, high sensitivity, and low cost. By designing and optimizing fluorescent proteins, more accurate and reliable monitoring of ocean acidification can be achieved.

Current studies have demonstrated the potential of fluorescent protein biosensors in ocean acidification monitoring. Researchers have successfully designed a variety of fluorescent protein biosensors and conducted indoor and outdoor experimental validation. These results show that fluorescent protein biosensors can detect ocean acidification quickly and accurately and work stably under different environmental conditions.

However, fluorescent protein biosensor technology still faces challenges, including selecting suitable fluorescent proteins, optimizing sensor design, and handling complex environmental samples. In addition, for ocean acidification monitoring, further research is needed to verify the consistency and reliability of fluorescent protein biosensors with traditional chemical analysis methods.

In the future, continuing to advance the research and development of fluorescent protein biosensor technology will help better understand ocean acidification's impact and provide accurate data support for Marine environmental protection and management decisions. Further optimizing the performance of fluorescent protein biosensors, improving their sensitivity and stability, and carrying out application validation in real Marine environments will be the focus of future research. This will help build a more complete monitoring network for ocean acidification and provide a stronger scientific basis for ocean protection and sustainable development.

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