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OPINION ARTICLE

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Light for food biosensing

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ABSTRACT

Light is everywhere and visible/near-infrared light can effectively and directly achieve an in-situ accurate response of spectral information during the food quality decay process, light biosensing with neuromorphic computing would be more and more flexible, simple, and smart to realize the food quality assurance and monitoring. It would be useful to reveal the characteristics of flexible artificial neural synapses and their inherent relationship with neural behavior and perception signals, construct an artificial neural biomimetic recognition model between biosensing signals and quality decay states, and form its recognition mechanism in future research.

KEYWORDS

Food biosensing; Neuromorphic computing; Food quality and safety; Light sensing

ARTICLE HISTORY

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Introduction

With the increasing living standards of the people, their demands for food quality are becoming higher and higher. Foods are rich in variety and have high nutritional value. The freshness, perishability, and short shelf life of most foods make them susceptible to infection by different pathogens and microorganisms in long-term storage, leading to decay and deterioration.

Moreover, it is difficult to achieve quantitative and high-precision online biosensing and recognition of the spoiled foods quality through visual and intuitive means. However, traditional foods' online quality biosensing mainly relies on wireless sensing technology to indirectly obtain micro-environmental parameters such as temperature, self-respiration, metabolic oxygen, and carbon dioxide in various process stages. However, through preliminary experiments by the team and research by relevant experts, it has been found that although online quality biosensing could be indirectly achieved through cold chain micro-environmental parameters, its online biosensing of food quality still lacks accuracy and could not directly reflect the in-situ quality [1-3]. Therefore, in-depth research on the mechanism and methods of high-precision in-situ online biosensing for the freshness and perishability of foods is an important foundation and guarantee for ensuring a stable and safe food supply.

Spectroscopic analysis with different lights, such as visible/near-infrared light, is becoming more popular for food non-destructive biosensing [4-6]. The food quality parameters will be gradually varied with their decay process, and the variations in their quality parameters will also cause direct variations in visible/near-infrared light spectral information, exhibiting in situ spectral characteristic responses [7-9]. The visible/near-infrared photoelectric sensitive devices can effectively and directly achieve an in-situ accurate response of spectral information during the quality parameter variation process, and the spectral response signal has strong resistance to external interference and non-destructive characteristics, making it suitable for non-destructive in-situ online biosensing for foods. However, the current visible/near-infrared spectroscopy detection is still mainly in the form of handheld and desktop instruments, which have problems such as large detection hardware volume, high cost, high work energy consumption, insufficient accuracy, and offline detection. It cannot be applied to online quality biosensing for foods throughout the entire supply chain process. It is necessary to integrate and construct flexible in-situ spectroscopy sensing devices to compensate for these shortcomings. At the same time, the coupling mechanism between light spectral biosensing response signals and quality under different temperature environments is not yet clear, which makes the existing quality analysis methods not ideal for the coupling relationship. It is necessary to build a more effective coupling correlation model to improve the accuracy and dynamic effectiveness of online biosensing for foods. Therefore, how to effectively achieve flexible in-situ online spectral biosensing for foods, explore the in-situ response characteristics of flexible in-situ spectral biosensing devices with foods, reveal the coupling correlation law and mechanism between flexible in-situ spectral biosensing signals and quality, establish a coupling correlation model between flexible in-situ spectral biosensing signals and quality, and clarify the mechanism of flexible in-situ spectral biosensing are the fundamental keys.

The intelligent and accurate identification and classification of quality decay states (fresh/semi fresh/rotten) can effectively evaluate the quality and safety of foods in their respective links, making it easy to take corresponding measures at any time to minimize losses and improve their economic value. For the intelligent and accurate identification of the quality decay state by flexible in-situ spectral biosensing, in addition to establishing its coupling correlation model, it is also necessary to establish an intelligent recognition model between the in-situ spectral biosensing response signal and the

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quality state. The intelligent recognition and classification of the quality decay state of traditional foods usually use models such as artificial neural networks, support vector machines, cluster analysis, genetic algorithms. The common feature of these models is that they are based on nonlinear machine learning modeling, which requires a series of operations such as preprocessing, training, model parameter validation, and optimization of spectral data collection samples, ultimately achieving high accuracy in identifying and classifying the quality decay state. However, the traditional machine learning modeling process relies on the von Neumann architecture that separates data information storage and computational processing to complete data interaction [10]. Its modeling process is complex, data storage and computation are large, work power consumption is high, and computation speed is slow, which is not conducive to the real-time online transmission, processing, and modeling of foods dense spectral data. Therefore, based on the coupling correlation model between flexible in-situ spectral biosensing signals and quality, further constructing an intelligent, simple, fast, low-power, and high-precision food quality decay state recognition model is an important means to improve the food safety and economy.

Flexible artificial neural synaptic devices, as a key basic unit of artificial input into the nervous system, can simulate the synaptic behavior of organisms and rely on distributed and parallel networks of artificial receptors, artificial synapses, and artificial neurons to achieve simpler, faster, lower power consumption, and more intelligent data computation and processing than traditional separated data acquisition, storage, and computing schemes [11-13]. The integration of flexible artificial neural synaptic devices and neuromorphic computing methods can effectively achieve the intelligent, simple, fast, low-power, and high-precision construction of the food quality decay state recognition model. Revealing the characteristics and neural behavior of flexible artificial neural synapses and the inherent relationship between flexible in situ spectral biosensing signals, constructing a flexible artificial neural recognition model between flexible in situ spectral biosensing signals and food quality decay states, and forming a flexible artificial neural recognition mechanism is the basic premise.

In the preliminary research work [2,14,15], battery-free wireless sensing has been proposed to ensure full in-situ uninterrupted continuous dynamic biosensing for foods. Based on sensing electronic technology and battery-free wireless backscatter communication technology, it can construct battery-free wireless sensor components without an external battery power supply, and achieve dynamic online biosensing for foods through wireless radio frequency energy supply and transmission. Compared with traditional wireless radio frequency and existing active wireless sensing online biosensing technology, it has more characteristics such as battery-free, non-destructive, small and low-cost, flexible and deployable, and wireless dynamic online biosensing. It avoids the need for manual unpacking and replacement once the battery energy is depleted in traditional methods, Subsequently, the problem of delayed battery replacement leads to interruption and the impact of secondary packaging on the food quality during the replacement process. Therefore, by fully utilizing flexible battery-free wireless sensing technology, integrating flexible in situ spectral biosensing, artificial neural synaptic devices, coupling associations, and artificial neural recognition models, a flexible battery-free wireless artificial neural spectral in situ online biosensing device for foods can be constructed, which can effectively form an accurate in situ online biosensing method for foods.

It would be useful to reveal the characteristics of flexible artificial neural synapses and their inherent relationship with neural behavior and perception signals, construct an artificial neural biomimetic recognition model between biosensing signals and quality decay states, and form its recognition mechanism in future research. A flexible battery-free wireless artificial neural spectral biosensing device for foods and its online biosensing method would be constructed and obtained. It would also provide the theoretical guidance and scientific basis for the development and application of smart in-situ online food biosensing in the future. Light biosensing would be more and more flexible, simple, and smart to be easily applied for food quality and safety, such as fruits, vegetables, meat, and aquatic products in our daily lives.

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Disclosure Statement

No potential conflict of interest was reported by the author.

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