Optical biosensors for microbial toxin detection

Microbial toxins, a kind of secondary metabolites generated by microorganisms in the process of growth and reproduction, are widely found around the world and could pose significant risks to human health, economics and ecological environment with both acute and chronic effects. Microbial toxins could be classified into three categories depending on the microbial species: (1) mycotoxins produced by fungal species; (2) alga toxins generated by algae in marine, brackish and fresh water; (3) bacterial toxins emerging from bacteria . Most bacterial toxins are proteins that could be detected and destroyed by human immune system, while mycotoxins and alga toxins are mostly compounds with stable physical and chemical properties and could remain stable in human bodies and environment for a long time, causing more harm than bacterial toxins . Mycotoxins originating from many filamentous fungal species are characterized with high resistance in nature and easily retain in foods or other commodities at ultralow level. Considering their extremely teratogenic, mutagenic, immunosuppressive and carcinogenic properties, many countries and organizations have set strict standards for maximum mycotoxin residue on common commodities . Algal toxins can bioaccumulate via food chain and consumed by humans, leading to vomiting, diarrhea, nausea, paralysis, convulsion, respiratory arrest and death . Consequently, ultrasensitive detection of fungal and algal toxins is necessary to protect human health.

Traditional assays for these microbial toxins involve chromatographic techniques coupled to diverse detectors such as high-performance thin-layer chromatography (HPTLC), gas chromatography (GC), high-performance liquid chromatography (HPLC), liquid chromatography-mass spectrometry (LC-MS) and immuno-chemical strategies including radioimmunoassay (RIA), enzyme-linked immunosorbent analysis (ELISA), lateral flow immunochromatographic assay (LFICA), etc. However, most of these methods are not suitable for point-of-care testing (POCT) due to their high cost, high maintenance requirements, professional operation or tedious procedures, thus limiting their wide application .

With the need of on-the spot and real-time detection for microbial toxin, optical biosensors are deemed as novel technologies to revolutionize the analysis strategies for microbial toxins detection. These analytical devices integrate recognition elements (enzyme, antigen/antibody, aptamer and cell) with a physical optical transducer, whereby the interaction between the targets and recognition elements is translated into identifiable optical signal forms proportional to the target concentration . The optical biosensors could be classified as fluorescent (FL), colorimetric (CM), chemiluminescent (CL), electrochemiluminescent (ECL), surface plasmon resonance (SPR) and surface-enhanced Raman (SERS) biosensors.

Compared with electrochemical biosensors and other biosensors, optical biosensors have several obvious advantages, such as immune to electromagnetic interference, less sample matrix effect, simple to operate, high signal-to-noise ratio, and suitable for on-site detection of microbial toxins .

Up to now, some reviews have been made and focused on the detection principle and progress of optical biosensors and their applications for clinical and health monitoring , airborne pathogen detection , cancer detection as well as biomarker testing . Although several previous reviews of optical biosensors for microbial toxins detection have been published, they have some outdated literatures or focused on narrow topic from different views or focused on narrow topic from different views . In addition, the new design principles of optical biosensors and recent advances on their application for microbial toxins detection are not well presented. Therefore, in this work, a critical review was organized to highlight the recent advances (2014–2023) in optical biosensors for microbial toxins (mycotoxin and algae toxin) detection. The basic principle, progress, advantages and disadvantages of optical biosensors within past five years were given special attention and systematically discussed. This comprehensive review provides beneficial insights to broad application of optical biosensors for researchers and analysts in various fields such as environmental monitoring, food safety and pharmaceutical industry.