Next-Generation Electrochemical Sensors for Food Safety

Orawon Chailapakul*

Electrochemistry and Optical Spectroscopy Center of Excellence (EOSCE), Department of Chemistry, Faculty of Science, Chulalongkorn University, Bangkok, 10330, Thailand

*Correspondence e-mail: corawon@chula.ac.th

ABSTRACT:
Food safety remains one of the most pressing challenges in ensuring public health, sustaining consumer confidence, and supporting economic development. Globalization of the food supply chain, coupled with rapid urbanization, has increased the risk of contamination events, whether from chemical residues, heavy metals, or pathogenic microorganisms. Conventional analytical methods—while highly reliable—are often centralized, labor-intensive, and slow, limiting their utility in real-time monitoring. Electrochemical sensors offer a transformative alternative by enabling rapid, low-cost, and on-site detection. Our research journey illustrates the evolution of this field. Early work focused on the direct quantification of electroactive substances, but as the need for biological recognition grew, we developed strategies that integrated molecular recognition elements, nanomaterials, and advanced device architectures. This led to two notable innovations. First, paper-based electrochemical devices functionalized with nanomaterials allow rapid and label-free detection of foodborne pathogens, offering simplicity and portability for field use. Second, wireless aptasensors based on laser-induced graphene, decorated with silver nanocorals, demonstrate unprecedented sensitivity and selectivity. These devices support multiplex detection with ultra-low limits of detection and seamless integration with smartphones, bridging the gap between laboratory precision and everyday usability. Beyond the laboratory, these next-generation biosensors have broad implications. They empower regulatory agencies to monitor contaminants more effectively, provide industries with tools to ensure quality control, and equip consumers with the ability to verify food safety at the point of need. For ASEAN nations in particular—where diverse food systems, cross-border trade, and emerging economies intersect—such innovations are crucial to strengthening resilience, supporting sustainable food supply chains, and safeguarding public health. Looking ahead, the integration of electrochemical sensors with digital technologies, artificial intelligence, and data-sharing platforms will open new frontiers in predictive food safety monitoring. This plenary lecture will explore not only the scientific breakthroughs but also the broader vision of how next-generation electrochemical biosensors can transform global food safety, creating more transparent, secure, and sustainable systems for the future.

KEYWORDS:
food safety, electrochemical biosensor, paper-based device, laser-induced graphene, aptasensor