Chapter 10
Biosensors for Rapid and On-Site Detection of Food Contaminants

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ABSTRACT

Food safety has become a worldwide concern because of the rising frequency of contamination by pathogens, toxins, pesticides, heavy metals, and other harmful substances. Traditional detection techniques, though precise, tend to involve time-consuming protocols, advanced equipment, and skilled operators, and hence are not appropriate for on-site and rapid applications. In this regard, biosensors have become potent analytical tools with high sensitivity, specificity, and portability for real-time food contaminant detection. Recent progress in nanotechnology, microfluidics, and signal amplification methods has improved the performance and utility of biosensors in many food matrices significantly. The present chapter discusses the most recent trends in biosensor technologies regarding their design, sensing mechanism, and real-world implementation for rapid and on-site monitoring of food

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safety. In addition, their challenges and future directions for commercial deployment are also addressed, focusing on the development of cost-efficient, user-friendly, and multiplexed detection platforms.

1. INTRODUCTION

1.1 Overview of Food Safety and Contamination Issues

Judicial aspects of food safety serve as a basic requirement for public health together with economic security and development sustainability(Fung et al., 2018). Global population increases along with expanding industrial food production have unleashed enormous dangers of food contamination. Food contamination describes the existence of dangerous biological and chemical and physical elements within food which contributes to safety and quality deterioration leading to health problems from illnesses through severe outcomes such as deaths. The World Health Organization reports that foodborne diseases infect around 600 million individuals each year and cause approximately 420,000 related casualties globally(Almaary, 2023). These contaminants arise from multiple origins which include raw materials for production and agricultural practices as well as processing environments and packaging materials and storage and transportation systems(Lebelo et al., 2021). Undercooked meat and dairy products and fresh produce serve as the main sources of outbreaks leading to foodborne illnesses caused by microbial pathogens that consist of *Salmonella* spp., *Listeria monocytogenes, Campylobacter jejuni*, and pathogenic strains of *Escherichia coli.*

Chemical contaminants made up of pesticide residues, heavy metals including lead and cadmium, and industrial pollutants like dioxins together with PCBs put people at risk for long-term health problems that involve cancer development and endocrine disruption and neurotoxicity. Developing countries that have weaker regulatory systems become at higher risk for the fungal toxins known as mycotoxins along with allergens since proper monitoring is limited(Chilaka et al., 2022). Environmentally damaging events have made it imperative to develop accurate and speedy methods for food detection which protects the entire food supply chain.

1.2 Importance of Rapid and On-Site Detection

Food testing utilizes traditional analytical methods based on microbial culture techniques together with Gas Chromatography (GC) and High-Performance Liquid Chromatography (HPLC) and Enzyme-Linked Immunosorbent Assay (ELISA) and Mass Spectrometry (MS) methods which authorities consider as the definitive stan-