Chapter 3
Integrative Forensic Methods in Food Contaminant Detection and Identification

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ABSTRACT

Food safety is one of the crucial global alarming spreading issue at very fast pace. Therefore, it requires continuous monitoring of contaminants by robust and integrative forensic approaches for the accurate and precise identification and quantification of contaminants in various food matrices. In addition, different types of approaches are employed for the investigation of contaminants in food i.e. conventional analytical and integrative forensic approaches. Conventional analytical approaches are often not capable of identifying and detecting complex emerging contaminants such as pharmaceutical residues specifically antibiotics, pesticides, microplastics, nano-materials etc. Thus, integrative forensic approaches syndicate different advanced

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analytical techniques—such as hyphenated techniques (i.e. LC-MS/MS and GC-MS), molecular techniques (i.e. DNA barcoding), isotopic fingerprinting, biosensor etc. with multidisciplinary tools including chemometrics and geographic information systems (GIS). These advance strategies have several advantages over conventional analytical techniques in terms of accurate and precise identification and quantification of analyte at molecular level in complex food matrices, authentication of food origin, and comprehensive contamination profiling. Furthermore, the introduction of portable lab-on-a-chip technology and real-time data analytics improves on-site detection and rapid decision-making. Moreover, Forensic integrative approaches also significant to tackle some serious problems like tracing of food fraud, labelling of food, unintentional contamination etc. which can help to strengthen regulatory policy and framework, trail of civil cases, delivery of justice, consumer protection. This chapter will explore the collaboration among food scientists, forensic experts, and policymakers globally to develop robust and comprehensive standard operating procedure for handling and analysis of food sample by adopting integrative forensic approach. Moreover, it also covers emerging trends, technological innovations, challenges and ethical considerations in forensic identification and quantification of food contaminants, highlighting the need for interdisciplinary innovations to ensure food integrity, safety, and traceability in an increasingly complex food supply chain. It also aligns with United Nations Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), and SDG 12 (Responsible Consumption and Production).

1. INTRODUCTION

Over the past decade, forensic science has established persistence and instrumental presence within the criminal justice system, emerging as an important pillar of the scientific investigation and delivery of justice of both civil and criminal cases through the different applications of forensic science (G. Sharma et al., 2017). In addition, the expansion of applications of forensic science from management of the crime scene, scientific proceeding of the crime scene, handling of physical evidence to scientific investigation of traditional as well as emerging forms of crime like digital forensic, cybercrime, identity theft, sextortion, forensic accounting, cross border terrorism, clandestine laboratories, environmental forensics, microbial forensic, disputed paternity, food adulteration and contamination etc. (Chango et al., 2024). This expansion emphasizes the crucial role of an integrative forensic science approach, particularly in the qualitative and quantitative analysis of food contaminants and adulterants, thereby ensuring public health and safety (Ziani et al., 2025). Moreover, the detection, identification and quantification of contami-