Revealing Spatiotemporal Transmission of Aflatoxin-Related Health Burdens: A Deep Reinforcement Learning Framework for Optimizing Food Safety Monitoring

Zhengcong Wang[1, *], Xuan Wang[2], Tao Xiong[1], Wendong Zhang[3], Xinxin Wang[4], Lili Nie[5]

[1]Laboratory for Intelligent Food Security Governance, Huazhong Agricultural University, Wuhan, China

[2]Faculty of Science, Vrije University Amsterdam, North Holland, Netherlands

[3]Dyson School of Applied Economics and Management, Cornell University, Ithaca, USA

[4]Wageningen Food Safety Research, Wageningen, Netherlands

[5]Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China

Email addresses

zhengcong_wang@mail.hzau.edu.cn (Zhengcong Wang)

[*]Corresponding author

Abstract

Aflatoxin B1 (AFB1), a Group 1 carcinogen, is among the most hazardous naturally occurring chemicals, yet its effective management remains challenging due to the dynamic and spatial complexity of modern food supply chains. Conventional monitoring frameworks focus mainly on legal-threshold compliance, but they fail to capture mycotoxin transmission across regions and seasons, limiting their effectiveness under resource constraints. We propose FRAME (Foodborne hazard Risk Assessment and Monitoring Enhancement), a mycotoxin monitoring optimization framework that integrates source-attributed disease burden estimation with reinforcement learning–based (Deep Q-Network, DQN) allocation of monitoring resources for AFB1. Based on more than 110,000 monitoring records from China's peanut and peanut oil supply chains (2015–2022) with other multi-source datasets, our analysis shows that interprovincial production sources contribute 52% more to local disease burdens than local production, and spring/autumn contamination increases risks by 24%. Optimizing monitoring through FRAME achieves a 25–percentage point improvement in burden reduction compared with conventional programs, using fewer resources. Beyond AFB1, FRAME is transferable to other mycotoxin hazards such as ochratoxin A in cereals, fumonisins in maize, and zearalenone in edible oils, offering policymakers an outcome-oriented and resource-efficient framework for hazard governance.

Keywords

Aflatoxin B1 (AFB1), Mycotoxin Risk Assessment, Food Safety Monitoring, Reinforcement Learning, Deep Q-Network (DQN), Food Supply Chain Risk, Disease Burden Analysis, Peanut Supply Chain Safety