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Beyond the zero-risk illusion: negotiating food safety in a One Health era

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An Editorial on the Frontiers in Science Lead Article
Balancing food safety and sustainability: trade-off risk assessments and predictive modeling

Key points

- Moving beyond the zero-risk illusion is essential for proportionate, science-based food safety governance.
- Fit-for-purpose, context-sensitive approaches can align food safety with sustainability with One Health objectives without compromising public health protection.
- Advanced stochastic modeling approaches that explicitly incorporate variability and uncertainty are essential for conducting robust trade-off risk assessments and supporting risk managers in making discrete decisions anchored to risk-based metrics.

The zero-risk illusion in food safety

Food safety is often framed around the implicit expectation that food should be as free from risk as possible. Advances in hygiene, processing and preservation technologies, genome sequencing, high-resolution mass spectrometry, analytical performance, regulation, and surveillance have reduced the burden of foodborne disease worldwide. Yet paradoxically, these same advances have intensified societal and regulatory pressure toward the pursuit of zero risk (1). Scientific reality tells a different story. All foods inherently carry a residual risk (2). Increasingly sensitive sampling schemes and analytical methods now detect hazards at ever lower levels, but the ability to detect a hazard does not necessarily correspond to a meaningful public health risk (3). It may also generate unintended consequences, including food waste, supply-chain disruptions, and environmental burdens.

In their Frontiers in Science lead article, Wiedmann et al. (4) argue that zero-risk thinking is neither achievable nor desirable. Instead, food safety governance must move toward proportionate, risk-based decision-making that explicitly acknowledges trade-offs. This argument arrives at a pivotal moment. Food safety is now firmly embedded within broader sustainability, food security, and One Health agendas. Safety can no longer be pursued in isolation from environmental, social, and economic objectives. Acknowledging the limits of zero-risk thinking is not a weakening of protection; it reflects a transition toward more transparent, science-based, and balanced decision-making.

The limits of current predictive tools in a One Health context

Predictive modeling and quantitative risk assessment have transformed food safety over recent decades. These tools support hazard identification, exposure assessment, risk characterization, and risk-based management decisions (5). As described by Wiedmann et al. (4), they have transformed our capacity to anticipate and mitigate foodborne risks. However, as food safety challenges become more intertwined with environmental sustainability, resource constraints, climate variability, and global trade, the limitations of existing predictive frameworks become more apparent. Many tools remain hazard-centric or focused on single-risk outcomes. While the One Health concept has gained widespread recognition, its practical implementation often remains fragmented. Human, animal, plant, and environmental dimensions are frequently assessed separately rather than in an integrated manner (6). As a result, current predictive modeling approaches may struggle to capture system-level trade-offs. Actions taken to reduce risk may inadvertently amplify others, for example by increasing energy use, food waste or inequities in access to safe food. In a rapidly changing global landscape characterized by climate disruptions and supply-chain instability, siloed decision-making risks are becoming increasingly ineffective. Addressing contemporary food safety challenges therefore requires not only more advanced models and data repositories but also multidisciplinary frameworks capable of integrating diverse data streams, values, and objectives. Without explicit consideration of trade-offs and co-benefits, One Health risks remain a conceptual aspiration rather than a fully operational approach to governance.

Risk negotiation as the next paradigm

As food safety becomes embedded within broader goals of food security, sustainability, and social stability, risk management can no longer be treated as a technical exercise. Decisions about acceptable levels of risk inevitably involve value judgments and prioritization across competing objectives. Quantitative approaches have already demonstrated that interventions in areas such as cold-chain management may reduce foodborne illness while affecting energy consumption or food waste (7). Such analyses illustrate that trade-offs are inherent, not exceptional.

Within this context, risk negotiation emerges as a necessary evolution of food safety governance. Risk negotiation does not imply compromise without rigor. Rather, it refers to a structured, evidence-based process that makes trade-offs explicit and assessable. By integrating predictive modeling with trade-off risk assessment, the framework proposed by Wiedmann et al. (4) supports decision-making under complexity and uncertainty.

Importantly, this approach does not aim to seek universal solutions. It enables fit-for-purpose decisions that reflect the characteristics of specific hazards, food matrices, production systems, and populations. This shift is consistent with developments in international guidance. Work within the Codex Alimentarius framework, including JEMRA (Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment) deliberations on water use in food production (8, 9), reflects a gradual transition from strictly hazard-based criteria toward risk-based and context-dependent approaches. Equivalent levels of public health protection may be achieved through different control strategies, depending on local conditions and constraints. Proportionality and flexibility should not be viewed as weaknesses. They are essential features of effective food safety systems operating within complex global environments.

One food system, diverse realities

Global food systems operate across highly diverse production, environmental, and socio-economic contexts. Differences in climate, infrastructure, regulatory capacity, and resource availability shape risk profiles and management options. Yet food safety standards often aspire to uniformity. The rigid application of hazard-based criteria across all contexts may disproportionately affect regions with limited resources, even where safe and sustainable production is feasible. This is not an argument for lowering protection standards. Rather, it recognizes that equivalent levels of public health protection can be achieved through different, context-appropriate pathways.

Risk-based and fit-for-purpose approaches allow flexibility while maintaining health-based objectives. Trade-off risk assessment provides a structured means to distinguish between unacceptable risks and tolerable residual risks, anchored in scientific evidence. Such tools are particularly important for enabling safe global food trade while supporting equity and sustainable goals. In this sense, proportionality is not a compromise, but a prerequisite for resilient and inclusive food safety governance.

Risk negotiation, governance, and trust

The move toward risk negotiation inevitably raises questions about governance and legitimacy. Balancing health protection, sustainability and economic viability involves multiple actors and interests. The challenge is not whether diverse stakeholders should participate, but how participation can be structured to ensure transparency, accountability, and trust. Within the framework proposed by Wiedmann et al. (4), risk assessment produces distributions of risk that reflect both variability and uncertainty (10). Effective risk analysis requires making these dimensions explicit. Risk managers must translate stochastic outputs into discrete decisions, such as approving, restricting, recalling, or accepting residual risk, anchored to risk-based metrics. This task is inherently complex, when decisions are subject to heightened scrutiny and stakeholder engagement.

Within a structured risk negotiation framework, predictive modeling and trade-off assessment provide a shared analytical foundation. When assumptions, uncertainties, and trade-offs are transparent, the scope for arbitrary or reactive decision-making is reduced. In this sense, participation strengthens rather than weakens food safety systems by enhancing legitimacy and fostering shared ownership of decisions. Inclusive governance does not imply dilution of regulatory authority. Rather, it strengthens legitimacy by clarifying responsibilities and anchoring decisions in evidence. However, a clear delineation of responsibilities, combined with robust conflict-of-interest management and transparent communication, remains essential.

Maintaining public trust will depend not only on demonstrating that risks are managed, but also that decisions are proportionate, justified, and responsive to context.

Conclusions

Food safety is a wicked problem operating within a complex and evolving global system. The pursuit of zero risk, while intuitively appealing, is neither scientifically grounded nor practically sustainable. As food systems confront climate change, resource constraints, and increasing interdependence, governance models must evolve accordingly. They must also be fit-for-purpose, calibrated to the nature, scale, and context of the risk, rather than driven by aspirational but unattainable absolutes.

Risk negotiation, supported by advanced predictive modeling and explicit trade-off assessment, offers a pathway forward. It allows food safety objectives to be aligned with sustainability, equity, and resilience without compromising public health protection. In this framework, flexibility is not a weakening of standards, but a strengthening of rational and transparent decision-making.

The question is no longer whether zero risk is attainable, but whether food safety systems are prepared to embrace a more mature paradigm, one that acknowledges residual risk, makes trade-offs explicit and anchors decisions in both evidence and societal values.

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Author contributions

AA: Conceptualization, Writing – original draft, Writing – review & editing.

SB-C: Writing – original draft, Writing – review & editing.

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The authors declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The authors declared that generative AI was used in the creation of this manuscript. During the preparation of this manuscript, the authors used ChatGPT (version 5.2, OpenAI) to assist with English language editing and to improve clarity and conciseness in specific sections of the text. Following the use of this tool, the authors carefully reviewed, revised, and validated the manuscript in its entirety and take full responsibility for the accuracy, integrity, and content of the published article.

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