

Editorial

Artificial intelligence and the future of integrated food systems

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Artificial Intelligence (AI) has emerged as a transformative force across the agri-food continuum, fundamentally redefining how food is produced, processed, distributed, and consumed. In the context of a rapidly growing global population and increasing environmental pressures, the need for resilient and sustainable food systems has never been more urgent. AI offers unprecedented capabilities in predictive analytics, automation, and real-time decision-making, enabling more efficient resource utilization and improved food security outcomes (Zatsu *et al.*, 2024; Reitano *et al.*, 2025). The agri-food sector continues to face persistent challenges, including climate variability, supply chain inefficiencies, post-harvest losses, and food safety risks. Notably, post-harvest losses account for nearly one-third of global food production, representing a critical inefficiency within the system (Shao and Marwa, 2025). AI-driven technologies, ranging from machine learning models to intelligent sensing systems, are increasingly being deployed to address these issues, offering scalable solutions that enhance productivity while maintaining sustainability. This editorial synthesizes current evidence on AI applications across agriculture and food systems, highlighting key challenges, stakeholder roles, policy implications, and emerging opportunities that are shaping the future of intelligent food systems.

Despite the transformative potential of AI, its integration into agri-food systems remains uneven and constrained by multiple structural and systemic challenges. One of the most pressing concerns is the disparity in technology adoption across regions and sectors. For instance, AI adoption in agriculture varies significantly depending on infrastructure readiness, digital literacy, and institutional support, with some regions demonstrating advanced diffusion while others remain at early stages (Huda *et al.*, 2026). Another critical issue lies in the accessibility and affordability of AI technologies. High implementation costs, limited digital infrastructure, and a lack of skilled human resources continue to hinder widespread adoption, particularly in low-resource settings (Kurdyś-Kujawska *et al.*, 2025; Shao and Marwa, 2025). Additionally, data-related challenges, including poor data quality, lack of standardization, and limited interoperability, pose significant barriers to effective AI deployment (Ding *et al.*, 2025; Liu *et al.*, 2026). Food safety remains a major concern within the agri-food sector. Traditional detection methods are often slow and inefficient, whereas AI-based systems offer real-time monitoring and predictive capabilities. However, issues related to model transparency, regulatory compliance, and consumer trust must be addressed to ensure responsible implementation (Singh, 2025; Naseem and Rizwan, 2025). Moreover, ethical and governance challenges, including data privacy, algorithmic bias, and accountability, continue to shape stakeholder perceptions and influence adoption trajectories (Manning *et al.*, 2022). Collectively, these challenges underscore the need for a balanced approach that integrates technological innovation with robust governance frameworks.

The successful integration of AI into agri-food systems requires coordinated efforts across a diverse set of stakeholders, including researchers, industry players, policymakers, and local communities. Each stakeholder group plays a distinct yet interconnected role in shaping the trajectory of AI adoption. Researchers and scientists are central to advancing AI methodologies, developing robust models, and ensuring the scientific validity of AI applications. Their work spans multiple domains, including crop monitoring, food safety, and supply chain optimization, often leveraging interdisciplinary approaches that integrate biology, engineering, and data science (Esmaeily *et al.*, 2024; Mao *et al.*, 2026). In particular, recent advances in computer vision and deep learning have enabled the development of non-invasive and high-accuracy food safety assessment systems. For example, fluorescence imaging combined with convolutional neural networks (CNNs) has been applied to detect aflatoxin contamination in cocoa beans, achieving classification accuracy of up to approximately 96% (Sadimantara *et al.*, 2024). Similarly, deep learning approaches using low-cost imaging systems have demonstrated strong capabilities in detecting and classifying the purity of high-value agricultural products. Such approaches have been applied to high-value commodities, including Luwak coffee beans. CNN-based models have achieved validation accuracy of up to 89.65% and testing accuracy of around 85%, confirming their effectiveness as rapid, non-destructive, and real-time authentication tools (Hendrawan *et al.*, 2022). Beyond detection and monitoring, AI is increasingly being applied to optimize product design and consumer-oriented innovation. For instance, the integration of artificial neural networks (ANN) with Kansei engineering has enabled the prediction and optimization of intelligent food packaging (IFP) designs for beef products by simultaneously modelling consumer emotional responses and packaging attributes. This approach has demonstrated very high predictive performance, with R^2 values approaching 0.99 (Sakir *et al.*, 2026). Furthermore, ANN-based approaches have shown strong capabilities in predicting physicochemical properties of agricultural products using non-destructive sensing techniques. For example, bioelectrical properties combined with ANN modelling have been used to predict moisture content, sucrose, and invert sugar in sugarcane with low prediction error, suggesting that AI can complement, and in some cases partially substitute, conventional destructive and time-consuming analytical methods (Sucipto *et al.*, 2018). These developments reinforce the role of AI as a unifying framework for integrating sensing, predictive modelling, and real-time decision-making in agri-food systems. Industry stakeholders, including agri-tech companies and food manufacturers, play a critical role in translating research innovations into practical solutions. AI-enabled technologies, such as intelligent packaging, real-time quality monitoring systems, and predictive maintenance tools, are increasingly being adopted to enhance efficiency and competitiveness (Balta *et al.*, 2026; Houshmandi *et al.*, 2026). Policymakers and regulators are equally important in establishing frameworks that ensure the ethical, safe, and equitable deployment of AI. This includes developing standards for data governance, promoting public–private partnerships, and supporting infrastructure development to bridge digital divides (Huda *et al.*, 2026; Singh, 2025). Communities and consumers also influence AI adoption through their perceptions, acceptance, and behavioral responses. Consumer trust, particularly regarding AI-driven food innovations, is shaped by transparency, safety assurances, and perceived benefits (Reitano *et al.*, 2025). Finally, interdisciplinary collaboration is essential to address complex challenges such as climate change, food security, and sustainability. The integration of AI with domains such as genomics, energy systems, and environmental science further highlights the need for holistic, systems-level approaches (Kamran *et al.*, 2026; Wang *et al.*, 2026).

To unlock the full potential of AI in agri-food systems, strategic and policy-driven interventions are essential. First, sustained investments in digital infrastructure are critical to enabling scalable AI adoption, particularly in rural and underserved regions. Enhanced connectivity, cloud computing capabilities, and access to affordable technologies form the foundation of digital transformation (Huda *et al.*, 2026). Second, capacity-building initiatives focused on AI literacy and workforce development are equally important. Training programs that equip stakeholders with the necessary skills to develop, deploy, and manage AI systems can accelerate adoption and reduce knowledge gaps (Reitano *et al.*, 2025). Third, policy frameworks must prioritize data governance to ensure data quality, interoperability, and security. Establishing standardized data protocols and promoting data-sharing mechanisms can enhance the effectiveness of AI systems while safeguarding privacy and ethical considerations (Manning *et al.*, 2022; Liu *et al.*, 2026). Fourth, fostering public–private partnerships is crucial for driving innovation and scaling AI solutions. Collaborative initiatives that integrate expertise from academia, industry, and government can facilitate the development of context-specific solutions tailored to regional needs (Huda *et al.*, 2026). Finally, aligning AI strategies with global sustainability agendas, such as the Sustainable Development Goals (SDGs), can help ensure that technological advancements contribute to broader societal objectives, including food security, environmental sustainability, and economic resilience (Reitano *et al.*, 2025). Recent advancements in AI technologies are opening new frontiers in agri-food systems. One notable development is the emergence of embodied and agentic AI, which integrates perception, decision-making, and

physical action to enable autonomous and adaptive operations across the food supply chain (Wang *et al.*, 2026; Gavai and Heringa, 2026). Innovations in intelligent packaging and sensor technologies are also transforming food safety and quality monitoring. AI-enabled systems, such as pH-sensitive packaging and volatile compound sensors, provide real-time insights into food freshness, thereby reducing waste and enhancing consumer safety (Zhang *et al.*, 2025; Balta *et al.*, 2026). In agriculture, AI-driven precision technologies, including computer vision, IoT integration, and predictive analytics, are improving crop monitoring, disease detection, and resource management. For example, AI-based image recognition systems have demonstrated high accuracy in detecting crop diseases, enabling timely interventions and improving yields (Zhang, 2025). Furthermore, the integration of AI with emerging technologies, such as CRISPR gene editing and high-throughput phenotyping, is transforming crop breeding by significantly reducing development timelines and enhancing resilience to climate change (Kamran *et al.*, 2026). Collectively, these developments indicate that AI is evolving beyond conventional automation toward adaptive, context-aware, and self-optimizing systems, reinforcing its role as a catalyst for systemic, data-driven transformation in agri-food systems.

Ethical approval and informed consent

Not applicable.

Data availability

Not applicable.

Conflict of interest

None to declare.

Author's contribution

Conceptualization, writing – original draft, review and editing: Yusuf Hendrawan. The author approved the final version.

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