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Integrating Smart Value Chains for Sustainable Food and Beverage Production: A Systematic Literature Review of Technologies, Practices, and Performance Outcomes

Ngadi Permana[1], Mia Cristy Patricia[2]
[1]STIE Kasih Bangsa, Indonesia, ngadi.permana@stiekasihbangsa.ac.id
[2]STIE Kasih Bangsa, Indonesia, mia@stiekasihbangsa.ac.id

ABSTRACT*. This study provides a systematic literature review on the integration of smart value chains in sustainable food and beverage production, focusing on enabling technologies, managerial practices, and performance outcomes. Drawing on peer-reviewed articles from major academic databases, the review synthesizes current knowledge on digital innovations such as the Internet of Things (IoT), blockchain, artificial intelligence (AI), and big data analytics in enhancing transparency, efficiency, and sustainability across value chains. The findings reveal that smart technologies significantly improve resource efficiency, traceability, and environmental performance, while also supporting economic and social sustainability goals. However, challenges related to high implementation costs, technological complexity, and limited stakeholder collaboration remain critical barriers. This study contributes by offering a comprehensive framework linking technologies, practices, and outcomes, and highlights future research directions for advancing sustainable and resilient food systems.*

Keywords *Smart value chains, Sustainable food production, Digital technologies, Food and beverage industry, Systematic literature review*

INTRODUCTION

The global transition toward sustainable development has significantly reshaped industrial paradigms, particularly within the food and beverage (FoodBev) sector, which is inherently dependent on natural resources and complex supply chain systems. Increasing environmental concerns, resource scarcity, and rising food demand have intensified the need for more efficient, resilient, and sustainable production systems (Gustavsson et al., 2011). In this context, the integration of smart value chains has emerged as a transformative approach that leverages digital technologies, circular economy principles, and innovative operational practices to enhance sustainability performance across the FoodBev industry (Telukdarie et al., 2024).

Smart value chains refer to digitally enabled, interconnected systems that optimize the flow of materials, information, and resources throughout the entire production lifecycle. These systems are increasingly powered by Industry 4.0 technologies such as artificial intelligence (AI), big data analytics, the Internet of Things (IoT), and natural language processing (NLP), which collectively facilitate real time decision making, predictive analytics, and process optimization (Laskurain-Iturbe et al., 2021; Gupta et al., 2021). The application of these technologies within FoodBev value chains is particularly crucial given the sector's high levels of food loss and waste, which account for

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*Ngadi Permana, ngadi.permana@stiekasihbangsa.ac.id

approximately one third of global food production (Gustavsson et al., 2011). Consequently, integrating smart technologies into value chains offers substantial opportunities to reduce inefficiencies, minimize waste, and improve overall sustainability outcomes. Generative Artificial Intelligence has the potential to revolutionize Human Resource Management, but its success heavily depends on the organization's readiness to adapt to technological changes, as well as its commitment to ensuring fair and ethical implementation (Yulianti, G., et al, 2024).

The concept of sustainability in the FoodBev sector is closely aligned with the principles of the circular economy (CE), which emphasizes resource efficiency, waste minimization, and the continuous reuse and recycling of materials (Ghisellini et al., 2018). Circular economy practices in FoodBev production include the valorization of by products, recovery of nutrients, and conversion of waste streams into value added products (Campos et al., 2020; Skendi et al., 2020). For instance, agro industrial residues such as fruit pomace, cereal bran, and coffee husks have been successfully transformed into bioactive compounds, bioenergy, and functional food ingredients, thereby contributing to both environmental sustainability and economic value creation (Garcia-Lomillo & Gonzalez-SanJose, 2017; Oliveira & Franca, 2015). These practices highlight the potential of integrating circular strategies within smart value chains to create more sustainable and resilient FoodBev systems. Supplier engagement, adoption of green technologies, and collaboration with stakeholders, is crucial for improving operational efficiency, reducing environmental impact, and enhancing the company's reputation (Ruslaini & Eri Kusnanto, 2020).

Digitalization plays a pivotal role in enabling the transition toward smart and circular value chains. Advanced digital tools facilitate the monitoring, analysis, and optimization of production processes, enabling organizations to identify inefficiencies and implement targeted interventions (Bressanelli et al., 2018). For example, AI driven analytics and NLP based systems can be used to identify alternative uses for waste streams and recommend sustainable production practices (Telukdarie et al., 2024). Additionally, IoT technologies enable real time tracking of raw materials and products, enhancing transparency and traceability across the supply chain (Persis et al., 2021). These capabilities not only improve operational efficiency but also support compliance with international standards such as those established by FAO/WHO Codex Alimentarius

(FAO/WHO, 2022). Digitalization plays a significant role in driving technological innovation in the Micro, Small, and Medium Enterprises sector (Chaidir, M., et al, 2024).

Despite the growing adoption of digital technologies and circular economy practices, the integration of smart value chains in the FoodBev sector remains fragmented and uneven. Several challenges hinder effective implementation, including limited digital skills, high initial investment costs, technological complexity, and organizational resistance to change (Akyazi et al., 2020; Govindan & Hasanagic, 2018). Furthermore, the lack of standardized frameworks and performance measurement systems complicates the assessment of sustainability outcomes, making it difficult for organizations to evaluate the effectiveness of their initiatives (Ertz et al., 2019). These challenges underscore the need for a comprehensive understanding of the technologies, practices, and performance outcomes associated with smart value chains.

A systematic literature review (SLR) provides a robust methodological approach to synthesize existing knowledge and identify research gaps in this domain. Previous studies have examined various aspects of sustainability in the FoodBev sector, including food waste management (de Oliveira et al., 2021), circular economy implementation (Principato et al., 2019), and digital transformation (Happonen & Ghoreishi, 2022). However, there remains a lack of integrated analyses that simultaneously consider the interplay between smart technologies, circular practices, and performance outcomes within FoodBev value chains. Addressing this gap is essential for developing holistic strategies that can effectively drive sustainability transitions in the sector.

Moreover, the importance of performance outcomes cannot be overlooked when evaluating the effectiveness of smart value chains. Sustainability performance in the FoodBev sector encompasses environmental, economic, and social dimensions, often referred to as the triple bottom line (Gupta et al., 2021). Environmental outcomes include reductions in greenhouse gas emissions, energy consumption, and waste generation, while economic outcomes relate to cost savings, resource efficiency, and value creation. Social outcomes, on the other hand, involve job creation, improved working conditions, and enhanced food security (Gower & Schroder, 2016). Understanding how smart value chain integration influences these outcomes is critical for informing policy and managerial decision making.

In addition, the role of skills and human capital is increasingly recognized as a key enabler of smart and sustainable value chains. The transition to Industry 4.0 requires a workforce equipped with digital competencies and interdisciplinary knowledge to effectively implement and manage advanced technologies (Akyazi et al., 2020). Sector specific initiatives, such as the FoodBev Sector Education and Training Authority (SETA), emphasize the need for aligning skills development with emerging technological and sustainability requirements (FoodBev SETA, 2020). This highlights the importance of integrating human resource considerations into the design and implementation of smart value chains.

Given these considerations, this study aims to conduct a systematic literature review on the integration of smart value chains for sustainable FoodBev production. Specifically, the review seeks to (1) identify key technologies enabling smart value chains, (2) examine circular economy practices adopted within FoodBev systems, and (3) analyze the resulting performance outcomes across environmental, economic, and social dimensions. By synthesizing insights from existing literature, this study contributes to a deeper understanding of how smart value chains can drive sustainability in the FoodBev sector and provides a foundation for future research and practical implementation.

Ultimately, the integration of smart value chains represents a critical pathway toward achieving sustainable FoodBev production in an increasingly complex and resource constrained world. By leveraging digital technologies, embracing circular economy principles, and focusing on comprehensive performance outcomes, organizations can transform traditional production systems into more efficient, resilient, and sustainable models. This systematic literature review aims to advance scholarly discourse and support practitioners in navigating the evolving landscape of sustainable FoodBev value chains.

LITERATURE REVIEW

The integration of smart value chains in the food and beverage (FoodBev) industry has emerged as a critical research domain, driven by increasing sustainability pressures, digital transformation, and the need for improved operational efficiency. A systematic qualitative literature review reveals that smart value chains defined as digitally enabled, data driven, and sustainability oriented supply networks play a pivotal role in enhancing environmental, economic, and social performance outcomes across the FoodBev sector (Telukdarie et al., 2024). These systems leverage Industry 4.0 technologies, circular economy principles, and advanced management practices to address longstanding inefficiencies and sustainability challenges.

Smart Value Chains and Digital Transformation. The concept of smart value chains is closely linked to Industry 4.0, which integrates technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and blockchain into production and supply chain processes (Akyazi et al., 2020). These technologies enable real time monitoring, predictive analytics, and automated decision making, thereby improving transparency and traceability in food systems (Bressanelli et al., 2018). Prior studies demonstrate that digitalization enhances coordination among supply chain actors, reduces transaction costs, and minimizes waste, ultimately contributing to sustainable production systems (Telukdarie et al., 2024).

In the FoodBev industry, digital transformation also supports compliance with food safety standards and regulatory requirements. For example, blockchain technology has been shown to improve traceability by providing immutable records of product origins and processing stages, which is essential for ensuring food quality and safety (Akyazi et al., 2020). Furthermore, big data analytics facilitates demand forecasting and inventory optimization, reducing overproduction and food waste (Chan et al., 2021). These findings highlight the critical role of digital technologies in enabling smart value chains.

Circular Economy Practices in Food and Beverage Production. A key dimension of smart value chains is the integration of circular economy (CE) practices, which aim to minimize waste and maximize resource efficiency. The FoodBev sector generates significant amounts of by-products and waste, creating opportunities for valorization and resource recovery (Campos et al., 2020). Studies on agro industrial by products, such as grape pomace and wheat bran, demonstrate their potential for reuse in food, pharmaceutical, and bioenergy applications (Beres et al., 2017; Apprich et al., 2014).

The adoption of CE practices within smart value chains has been shown to improve environmental performance by reducing greenhouse gas emissions, water usage, and landfill waste (Telukdarie et al., 2024). For instance, coffee processing waste can be transformed into bioactive compounds with antifungal properties, illustrating how waste streams can be converted into value added products (Alvarado-Ambriz et al., 2020).

Similarly, fruit processing by products can be repurposed through innovative biorefinery approaches, contributing to sustainable production systems (Campos et al., 2020).

Digital technologies further enhance CE implementation by enabling better tracking and management of material flows. For example, IoT sensors can monitor waste generation in real time, while data analytics can identify opportunities for resource optimization (Bressanelli et al., 2018). These integrated approaches demonstrate the synergy between digitalization and circularity in smart value chains.

Sustainable Practices and Environmental Performance. Sustainability in FoodBev production encompasses environmental, economic, and social dimensions. Environmental sustainability focuses on reducing pollution, conserving resources, and mitigating climate change impacts. Research indicates that smart value chains contribute to environmental sustainability by improving energy efficiency, reducing emissions, and optimizing resource utilization (Telukdarie et al., 2024).

For example, studies on industrial effluents highlight the importance of monitoring and controlling chemical discharges to prevent environmental contamination (Boudjellaba et al., 2016). Smart technologies enable continuous monitoring of environmental parameters, allowing companies to detect and address issues proactively. Additionally, sustainable sourcing practices, supported by digital traceability systems, ensure that raw materials are obtained responsibly, reducing the environmental footprint of production processes (Akyazi et al., 2020).

Economic sustainability is achieved through cost reduction, efficiency gains, and value creation. Smart value chains enable companies to optimize production processes, reduce waste, and improve product quality, leading to increased profitability (Telukdarie et al., 2024). Social sustainability, on the other hand, involves ensuring fair labor practices, food safety, and community well-being. Digital technologies facilitate transparency and accountability, enabling stakeholders to monitor compliance with social standards.

Skills and Organizational Capabilities. The successful implementation of smart value chains requires the development of new skills and organizational capabilities. Industry 4.0 technologies demand a workforce with expertise in data analytics, digital systems, and advanced manufacturing processes (Akyazi et al., 2020). Studies emphasize the importance of upskilling and reskilling employees to adapt to the changing technological landscape.

Organizational culture and leadership also play a crucial role in driving digital transformation and sustainability initiatives. Companies must adopt a strategic approach to integrating smart technologies and sustainability practices, aligning them with business objectives and stakeholder expectations (Telukdarie et al., 2024). Collaborative partnerships among supply chain actors are essential for sharing knowledge, resources, and best practices, thereby enhancing the overall effectiveness of smart value chains.

Performance Outcomes of Smart Value Chains. The literature identifies several key performance outcomes associated with the adoption of smart value chains in the FoodBev industry. These include improved operational efficiency, enhanced product quality, reduced environmental impact, and increased customer satisfaction (Telukdarie et al., 2024). Empirical studies demonstrate that companies implementing digital and circular practices achieve significant reductions in waste and energy consumption, while also improving supply chain resilience.

Moreover, smart value chains contribute to achieving global sustainability goals, such as the United Nations Sustainable Development Goals (SDGs), particularly SDG 12 on responsible consumption and production (Champions 12.3, 2018). By integrating sustainability into value chain operations, companies can create long term value for stakeholders and contribute to broader societal objectives.

Despite the potential benefits, the adoption of smart value chains faces several challenges. These include high implementation costs, technological complexity, and resistance to change within organizations (Akyazi et al., 2020). Additionally, the lack of standardized frameworks and metrics for measuring sustainability performance complicates the evaluation of smart value chain initiatives.

Another significant challenge is data security and privacy, particularly in the context of digital technologies such as blockchain and IoT. Ensuring the integrity and confidentiality of data is critical for maintaining trust among supply chain participants (Chan et al., 2021). Furthermore, small and medium-sized enterprises (SMEs) often face resource constraints that limit their ability to adopt advanced technologies and sustainability practices.

METHODS

This study adopts a qualitative systematic literature review (SLR) approach to examine the integration of smart value chains for sustainable food and beverage (FoodBev) production, focusing on technologies, practices, and performance outcomes. A systematic literature review is a rigorous and transparent method for identifying, evaluating, and synthesizing existing research evidence to answer specific research questions (Systematic Literature Review) (Tranfield et al., 2003). This approach is particularly suitable for emerging interdisciplinary topics such as smart value chains, where knowledge is dispersed across multiple domains including supply chain management, sustainability, and digital transformation (Kitchenham & Charters, 2007).

The study follows established SLR guidelines proposed by David Tranfield et al. (2003), which emphasize three main phases: planning, conducting, and reporting the review. The qualitative nature of this review enables an in depth exploration of conceptual developments, theoretical frameworks, and empirical findings related to smart value chains in the FoodBev industry (Snyder, 2019). Unlike quantitative meta analysis, this approach focuses on interpretive synthesis, allowing the identification of patterns, themes, and relationships across studies (Petticrew & Roberts, 2006).

A comprehensive and systematic search strategy was employed to ensure the inclusion of relevant and high quality studies. Academic databases were used as primary sources due to their extensive coverage of peer reviewed literature (Mongeon & Paul-Hus, 2016). These databases are widely recognized for their reliability and comprehensiveness in capturing scholarly publications across disciplines.

The search process was conducted using a combination of keywords and Boolean operators to maximize coverage. Key search terms included: "smart value chain," "digital supply chain," "Industry 4.0," "food and beverage industry," "sustainability," "circular economy," "IoT," "blockchain," and "performance outcomes." Boolean operators such as "and" and "or" were applied to refine search results and ensure relevance (Kitchenham & Charters, 2007).

To ensure the quality and relevance of selected studies, specific inclusion and exclusion criteria were applied. The inclusion criteria were: Peer-reviewed journal articles published in English; Studies focusing on smart value chains, digital transformation, or sustainability in the FoodBev sector; Empirical or conceptual studies addressing technologies, practices, or performance outcomes; Publications within the last 10–15 years to ensure contemporary relevance.

Exclusion criteria included: Non-peer-reviewed sources such as editorials, opinion pieces, and conference abstracts without full papers; Studies unrelated to the FoodBev industry; Articles lacking methodological rigor or clear findings. The application of these criteria ensures the reliability and validity of the review by focusing on high-quality and relevant literature (Petticrew & Roberts, 2006).

The study selection process followed the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) framework to ensure transparency and replicability (Page et al., 2021). The process involved four main stages: identification, screening, eligibility, and inclusion. Identification: Initial database searches yielded a large pool of articles. Screening: Titles and abstracts were reviewed to remove irrelevant studies. Eligibility: Full-text articles were assessed against inclusion criteria.Inclusion: Final studies were selected for qualitative synthesis. This structured approach minimizes bias and enhances the credibility of the review process (Moher et al., 2009).

Data extraction was conducted systematically using a structured data extraction form. Key information collected from each study included: authors, publication year, research objectives, methodology, technologies used (e.g., IoT, AI, blockchain), sustainability practices (e.g., circular economy, waste reduction), and reported performance outcomes (e.g., efficiency, environmental impact, economic benefits).

A qualitative coding approach was applied to categorize findings into thematic areas. The coding process followed principles of thematic analysis, enabling the identification of recurring patterns and relationships across studies (Braun & Clarke, 2006). Themes were iteratively refined to ensure consistency and coherence.

The analysis employed a thematic synthesis approach, which integrates findings from multiple studies into coherent themes and conceptual frameworks (Thomas & Harden, 2008). This approach is particularly effective for qualitative SLRs, as it allows for the interpretation of complex and heterogeneous data.

Three main analytical dimensions were identified: Technologies (e.g., IoT, AI, blockchain, big data analytics); Practices (e.g., circular economy, sustainable sourcing, waste valorization); Performance outcomes (e.g., environmental, economic, and social impacts).

The synthesis process involved comparing findings across studies, identifying similarities and differences, and developing an integrated understanding of how smart value chains contribute to sustainability in the FoodBev sector (Snyder, 2019).

To ensure the reliability of the review, a quality assessment of selected studies was conducted using established criteria, including methodological rigor, clarity of research design, and validity of findings (Kitchenham & Charters, 2007). Studies with weak methodological foundations or insufficient evidence were excluded to maintain the integrity of the review.

Additionally, triangulation was applied by comparing findings across multiple sources to enhance credibility and reduce bias (Tranfield et al., 2003). This process ensures that conclusions are supported by consistent evidence from different studies.

Despite its strengths, the SLR methodology has certain limitations. First, the review is restricted to English language publications, which may exclude relevant studies in other languages. Second, the reliance on published literature may introduce publication bias, as studies with positive results are more likely to be published (Petticrew & Roberts, 2006). Third, the qualitative nature of the analysis limits the ability to quantify effect sizes or statistically compare results. However, these limitations are mitigated through a comprehensive search strategy, rigorous selection criteria, and systematic analysis procedures, ensuring the robustness of the findings.

RESULTS

The systematic qualitative literature review on Integrating Smart Value Chains for Sustainable Food and Beverage Production reveals a converging body of evidence highlighting the transformative role of digital technologies, sustainable practices, and performance oriented frameworks in reshaping agri food systems (Kamilaris et al., 2019; Wolfert et al., 2017). The synthesis of selected studies demonstrates that smart value chains enabled by Industry 4.0 technologies significantly enhance transparency, efficiency, and sustainability outcomes across food and beverage production systems (Verdouw et al., 2021; Klerkx et al., 2019).

Adoption of Smart Technologies in Food Value Chains. The findings indicate that technologies such as the Internet of Things (IoT), blockchain, artificial intelligence (AI), and big data analytics are central to the development of smart value chains in the food and beverage sector (Kamilaris et al., 2019; Zhang et al., 2020). IoT based monitoring systems enable real time data collection on crop conditions, processing environments, and logistics, thereby improving operational efficiency and reducing waste (Wolfert et al., 2017).

Blockchain technology has been widely identified as a critical enabler of traceability and transparency, particularly in addressing food safety concerns and supply chain integrity (Tian, 2017; Galvez et al., 2018). Empirical studies show that blockchain based systems enhance consumer trust by providing verifiable information on product origin, quality, and sustainability attributes (Saberi et al., 2019).

Artificial intelligence and machine learning applications further support predictive analytics in demand forecasting, quality control, and risk management, leading to improved decision making across the value chain (Zhang et al., 2020; Javaid et al., 2022). The integration of big data analytics allows firms to optimize resource allocation and minimize inefficiencies, contributing to both economic and environmental sustainability (Coble et al., 2018).

Sustainable Practices in Smart Value Chains. The review also highlights the increasing integration of sustainability oriented practices within smart value chains, including circular economy principles, resource efficiency strategies, and sustainable sourcing (Geissdoerfer et al., 2017; Borrello et al., 2017). Circular economy practices, such as waste valorization and by product reuse, have been shown to significantly reduce environmental impacts while creating additional economic value (Borrello et al., 2017).

Sustainable agricultural practices supported by digital technologies such as precision farming enable optimized use of inputs like water, fertilizers, and energy, thereby reducing environmental footprints (Gebbers & Adamchuk, 2010; Klerkx et al., 2019). Studies further indicate that smart irrigation systems and sensor based nutrient management contribute to increased productivity while conserving natural resources (Wolfert et al., 2017).

In addition, ethical sourcing and sustainable procurement practices are increasingly facilitated by digital traceability tools, ensuring compliance with environmental and social standards (Galvez et al., 2018; Saberi et al., 2019). This integration supports the achievement of sustainability certifications and enhances corporate reputation in global markets (Porter & Kramer, 2011).

Performance Outcomes of Smart Value Chain Integration. The literature consistently demonstrates that the integration of smart technologies and sustainable practices leads to improved performance outcomes across three key dimensions: economic, environmental, and social performance (Elkington, 1997; Verdouw et al., 2021).

From an economic perspective, smart value chains improve productivity, reduce operational costs, and enhance supply chain resilience (Coble et al., 2018; Javaid et al., 2022). Real time data analytics and automation enable firms to respond more effectively to market fluctuations and disruptions, thereby increasing competitiveness (Klerkx et al., 2019).

Environmental performance improvements are primarily driven by reduced resource consumption, minimized waste, and lower greenhouse gas emissions (Geissdoerfer et al., 2017). Studies show that precision agriculture and optimized logistics significantly contribute to reducing the carbon footprint of food production systems (Gebbers & Adamchuk, 2010).

Social performance outcomes include improved food safety, enhanced transparency, and increased consumer trust (Tian, 2017; Saberi et al., 2019). Smart value chains also support inclusive development by enabling smallholder farmers to access digital platforms, market information, and financial services (Klerkx et al., 2019).

Integration Challenges and Barriers. Despite the positive outcomes, the review identifies several challenges that hinder the effective implementation of smart value chains. Technological barriers include high implementation costs, lack of interoperability, and limited digital infrastructure, particularly in developing regions (Klerkx et al., 2019; Verdouw et al., 2021).

Organizational challenges, such as resistance to change, lack of digital skills, and inadequate knowledge sharing, also impede adoption (Wolfert et al., 2017). Furthermore, concerns related to data privacy, cybersecurity, and governance frameworks pose significant risks in digitalized value chains (Saberi et al., 2019).

Institutional and regulatory barriers, including inconsistent standards and lack of policy support, further limit the scalability of smart value chain initiatives (Geissdoerfer et al., 2017). These findings suggest the need for coordinated efforts among stakeholders to address these challenges and promote sustainable transformation.

Overall, the results indicate that integrating smart technologies with sustainability practices creates synergistic effects that enhance value chain performance in the food and beverage sector (Verdouw et al., 2021). The alignment of technological innovation with sustainability objectives is critical for achieving long-term resilience and competitiveness (Porter & Kramer, 2011).

The literature also emphasizes the importance of a systems approach, where technological, organizational, and institutional factors are considered simultaneously to ensure successful implementation (Klerkx et al., 2019). This holistic perspective is essential for maximizing the benefits of smart value chains and addressing the complex challenges of sustainable food production.

DISCUSSION

The findings of this systematic qualitative literature review demonstrate that the integration of smart value chains in sustainable food and beverage production represents a multidimensional transformation driven by digital technologies, sustainability oriented practices, and performance optimization mechanisms across the agri food system (Akella et al., 2023; Yogarajan et al., 2023). The discussion synthesizes these findings by critically comparing them with prior empirical and review based studies, highlighting convergence, divergence, and emerging research implications.

Digital Technologies as Core Enablers of Smart Value Chains. The results confirm that digital technologies particularly IoT, blockchain, and AI serve as foundational enablers of smart value chains by enhancing data integration, traceability, and decision making capabilities (Astuti & Hidayati, 2023; Chandan et al., 2023). These findings align with prior research showing that IoT based systems improve real time monitoring and resource optimization across agricultural production and logistics processes (Astuti & Hidayati, 2023).

Furthermore, the review highlights that blockchain technology strengthens transparency and trust within agri food supply chains by enabling immutable and decentralized data sharing (Fiore & Mongiello, 2023; Ambrozie, 2023). This is consistent with earlier findings indicating that blockchain enhances traceability, reduces fraud, and improves food safety assurance (Yogarajan et al., 2023; Chandan et al., 2023).

However, the present study extends previous literature by emphasizing the synergistic integration of multiple technologies rather than isolated adoption, demonstrating that combined IoT blockchain ecosystems significantly improve supply chain coordination and reduce food waste through real-time data synchronization (Journal of Cleaner Production, 2023). This finding supports and expands earlier conceptual models that advocated integrated digital infrastructures for smart agriculture (Elegbeleye et al., 2024).

Sustainability Practices and Circular Value Creation. The discussion reveals that sustainability practices embedded in smart value chains go beyond efficiency improvements and contribute to systemic transformation toward circular economy models (Akella et al., 2023). These findings are consistent with previous studies that emphasize the role of digital technologies in enabling sustainable resource management, waste reduction, and environmentally responsible production (Chandan et al., 2023).

Compared to earlier research, this study provides stronger evidence that sustainability outcomes are not merely by products of technological adoption but are actively designed through integrated practices such as precision agriculture, waste valorization, and sustainable sourcing (Yogarajan et al., 2023). This supports the argument that smart value chains function as socio technical systems that align environmental and economic objectives simultaneously.

In contrast, some earlier studies have treated sustainability as a secondary outcome of efficiency gains rather than a strategic objective (Fiore & Mongiello, 2023). The present review challenges this perspective by demonstrating that sustainability considerations are increasingly embedded at the design stage of value chain transformation, particularly in response to global sustainability frameworks such as the Sustainable Development Goals (SDGs) (Chandan et al., 2023).

Performance Outcomes: Economic, Environmental, and Social Dimensions. The findings show that smart value chain integration produces measurable improvements across triple bottom line dimensions economic, environmental, and social performance (Akella et al., 2023). Economically, the integration of smart technologies enhances operational efficiency, reduces transaction costs, and improves market responsiveness through data driven decision making (Yogarajan et al., 2023).

This aligns with prior research demonstrating that digital supply chain systems reduce inefficiencies and enable predictive analytics for demand forecasting and inventory management (Astuti & Hidayati, 2023). Additionally, environmental performance improvements are reflected in reduced resource consumption, minimized waste, and lower emissions, particularly through precision agriculture and optimized logistics (Journal of Cleaner Production, 2023).

Socially, the findings highlight improved transparency, enhanced food safety, and increased consumer trust as key outcomes of smart value chain adoption (Ambrozie, 2023) . These results are consistent with previous studies indicating that blockchain-based traceability systems enable consumers to verify product origin and quality, thereby strengthening trust in food systems (Fiore & Mongiello, 2023) .

However, this study advances prior literature by demonstrating that performance outcomes are interdependent rather than isolated, suggesting that improvements in one dimension (e.g., transparency) can simultaneously enhance economic and environmental outcomes. This integrated perspective provides a more holistic understanding of value creation in smart food systems.

A comparative analysis with eight prior studies reveals both alignment and divergence in findings: Akella et al. (2023) found that blockchain adoption enhances collaboration and trust but is constrained by regulatory and infrastructure barriers , which is consistent with this study's identification of governance challenges. Yogarajan et al. (2023) emphasized transparency and cost reduction benefits of blockchain , aligning with the present findings on economic and social performance improvements. Astuti & Hidayati (2023) highlighted IoT's role in improving traceability and logistics efficiency , supporting this study's conclusion on data-driven decision-making.

Chandan et al. (2023) linked blockchain adoption to achieving sustainability goals in food supply chains , reinforcing the sustainability dimension identified in this review. Fiore & Mongiello (2023) identified increased visibility and consumer trust through blockchain , which is consistent with the social performance outcomes found here. Ambrozie (2023) emphasized transparency and compliance benefits of blockchain integration , aligning with governance and traceability findings. Journal of Cleaner Production (2023) demonstrated that IoT-blockchain integration reduces food waste and improves resource efficiency , supporting the environmental performance outcomes of this study. Elegbeleye et al. (2024) highlighted the synergistic role of IoT and blockchain in enhancing resilience and sustainability , which directly corroborates this study's emphasis on integrated technological ecosystems. Despite strong alignment, this study contributes additional insights by integrating these fragmented findings into a unified smart value chain framework that links technologies, practices, and performance outcomes systematically.

The discussion identifies several critical barriers that persist across studies, including high implementation costs, lack of technical expertise, interoperability issues, and insufficient regulatory frameworks (Akella et al., 2023; Astuti & Hidayati, 2023). These findings are consistent with prior literature that highlights the complexity of adopting advanced technologies in fragmented agri-food systems (Yogarajan et al., 2023).

Moreover, the review underscores the importance of institutional support and stakeholder collaboration in overcoming these challenges, echoing earlier studies that emphasize the role of governance and policy frameworks in facilitating digital transformation (Chandan et al., 2023) .

However, this study extends previous research by identifying the need for integrated capability development, including digital literacy, organizational change management, and cross-sector partnerships, as critical success factors for smart value chain implementation.

From a theoretical perspective, this study contributes to the literature by proposing a holistic framework that integrates technology adoption, sustainability practices, and performance outcomes within a unified smart value chain model. This extends prior research that often examines these elements in isolation (Fiore & Mongiello, 2023).

Practically, the findings suggest that stakeholders in the food and beverage sector should adopt a systems approach to digital transformation, ensuring alignment between technological investments and sustainability objectives (Akella et al., 2023). Policymakers are also encouraged to develop supportive regulatory environments and standardization frameworks to facilitate technology adoption and interoperability across value chains (Yogarajan et al., 2023).

The discussion highlights several areas for future research, including the need for empirical validation of integrated smart value chain models, investigation of technology adoption in developing economies, and exploration of governance mechanisms for data sharing and interoperability (Akella et al., 2023; Yogarajan et al., 2023).

Additionally, future studies should examine the socio-economic implications of digital transformation, particularly its impact on smallholder farmers and inclusive development within global food systems (Chandan et al., 2023).

CONCLUSION

This systematic qualitative literature review on integrating smart value chains for sustainable food and beverage production highlights the transformative role of digital technologies, innovative practices, and performance oriented frameworks in advancing sustainability across agri food systems. The findings demonstrate that smart value chains enabled by technologies such as Internet of Things (IoT), blockchain, big data analytics, and artificial intelligence significantly enhance transparency, traceability, operational efficiency, and environmental performance within food and beverage production systems (Verdouw et al., 2016; Kamilaris et al., 2019).

The review reveals that the integration of digital technologies into value chains fosters real time monitoring and data driven decision making, which are critical for optimizing resource use and reducing waste (Wolfert et al., 2017). In particular, IoT based systems allow for precision agriculture and smart logistics, thereby minimizing energy consumption and improving productivity (Zhang et al., 2020). Similarly, blockchain technology contributes to enhanced supply chain transparency and trust among stakeholders, supporting food safety and ethical sourcing practices (Tian, 2017; Saberi et al., 2019).

From a managerial perspective, the adoption of smart practices such as circular economy principles, sustainable sourcing, and collaborative partnerships further strengthens the sustainability performance of value chains (Geissdoerfer et al., 2017). The literature indicates that firms implementing circular strategies, including recycling, reuse, and waste valorization, achieve improved environmental outcomes while maintaining economic viability (Kirchherr et al., 2017). Moreover, collaboration among supply chain actors enhances knowledge sharing and innovation, which are essential for addressing complex sustainability challenges (Beske et al., 2014).

In terms of performance outcomes, the review identifies three key dimensions: environmental, economic, and social sustainability. Smart value chains contribute to reduced greenhouse gas emissions, lower food waste, and efficient resource utilization (FAO, 2019). Economically, they improve cost efficiency, market competitiveness, and value creation (Porter & Heppelmann, 2014). Socially, enhanced transparency and traceability improve consumer trust and support ethical labor practices (Aung & Chang, 2014).

Furthermore, the synthesis highlights that the success of smart value chains depends on enabling factors such as digital infrastructure, regulatory support, organizational readiness, and stakeholder engagement (Klerkx et al., 2019). Without these supporting conditions, the implementation of advanced technologies may face significant barriers, particularly in developing economies where technological capabilities and institutional frameworks are still evolving.

Overall, this review underscores that integrating smart technologies and sustainable practices within value chains is not merely an operational improvement but a strategic transformation. It aligns food and beverage production systems with global sustainability goals, particularly those related to responsible consumption and production, climate action, and food security. The findings provide a comprehensive understanding of how smart value chains can serve as a critical pathway toward achieving sustainable and resilient agri food systems.

LIMITATION

Despite its contributions, this study has several limitations that should be acknowledged. First, as a qualitative systematic literature review, the findings are inherently dependent on the scope and selection of existing studies. Although rigorous inclusion and exclusion criteria were applied, there is a possibility that relevant studies were omitted due to database limitations or publication bias, particularly studies published in non English languages or in less accessible sources (Tranfield et al., 2003).

Second, the review primarily relies on secondary data and previously published research, which may limit the ability to capture the most recent technological advancements and emerging trends in smart value chains. Given the rapid evolution of digital technologies such as artificial intelligence and blockchain, some insights may quickly become outdated (Kamilaris et al., 2019).

Third, there is a lack of empirical consistency across the reviewed studies in terms of methodologies, measurement indicators, and contextual settings. This heterogeneity makes it challenging to generalize findings or establish standardized frameworks for evaluating the performance of smart value chains (Seuring & Müller, 2008).

Fourth, many of the studies included in the review are concentrated in developed countries, which may limit the applicability of the findings to developing regions. Differences in infrastructure, regulatory environments, and technological readiness can significantly influence the implementation and effectiveness of smart value chains (Klerkx et al., 2019).

Fifth, while the review identifies key technologies and practices, it does not quantitatively assess their relative impact on sustainability outcomes. Future research could benefit from integrating meta-analytical approaches to provide more precise estimates of the effectiveness of specific interventions.

Lastly, the study does not deeply explore the socio cultural and behavioral aspects influencing the adoption of smart value chains, such as consumer preferences, organizational culture, and resistance to change. These factors are critical for understanding the real world implementation challenges and should be addressed in future research.

Based on these limitations, future studies are encouraged to: Conduct empirical and case based research to validate the conceptual findings of this review. Explore the adoption of smart value chains in developing countries and emerging markets. Develop standardized metrics for measuring sustainability performance in digitalized value chains. Investigate the role of policy and governance in facilitating smart value chain integration.

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