

## Article

# The role of blockchain technology in promoting transparency for sustainable food supply chain infrastructure in South Africa

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**Abstract:** The food supply chain in South Africa faces significant challenges related to transparency, traceability, and consumer trust, exacerbated by growing concerns about food safety, quality, and sustainability. As these concerns grow, there is an increasing need for innovative solutions to address these issues. Blockchain technology has emerged as a promising tool that can enhance the transparency and accountability of the food supply chain. This study sought to explore how blockchain technology might revolutionize the development of sustainable food supply chain infrastructure in South Africa. The study found that blockchain technology used in the food supply chain creates an immutable and decentralized ledger of transactions that has the capacity to provide real-time, end-to-end visibility of food products from farm to table. This increased transparency can help mitigate risks associated with food fraud, contamination, and inefficiencies in the supply chain. The implementation of blockchain can improve supply chain efficiency and foster trust among stakeholders, including farmers and food suppliers. This technology used and/or applied in South Africa can reshape the agricultural sector by improving production and distribution processes. Its integration in the food supply chain infrastructure can equally improve data management and increase transparency between farmers and food suppliers. There is a need for policymakers and scholars in the fields of service delivery and food security to conduct more research in blockchain technology and its roles in creating a more transparent, efficient, and trustworthy food supply chain infrastructure that addresses food supply problems in South Africa. The paper adopted a qualitative methodology to collect data, and document and content analysis techniques were used to interpret collected data. This study lays the groundwork for further investigation into blockchain's potential to shape the future of food supply networks.

**Keywords:** blockchain technology; food supply chain infrastructure; transparency; food safety and consumer trust; fraud prevention and agricultural innovation

## 1. Introduction

The food supply chain is a complex network that involves various stakeholders, including farmers, processors, distributors, retailers, and consumers (Toromade et al., 2024). In South Africa, this intricately woven system faces significant challenges, such as food fraud, inefficiencies, and a lack of transparency (Oriekhoe et al., 2024). These issues not only undermine consumer confidence but also pose serious risks to food safety and public health. In one well-known instance in South Africa, numerous children lost their lives after eating snacks from unauthorized stores called “spaza shops”. These tragic events have highlighted the serious vulnerabilities in food supply chains, especially in the informal sector, resulting in deaths and major illnesses among young children from different schools. In addition to having disastrous health effects, these incidents damage public confidence in food safety standards. More efficient food

tracking and safety systems are desperately needed, as seen by the failure to quickly identify and address the source of these pollutants (Tang et al., 2024).

As the demand for accountability and traceability in food sourcing continues to grow, innovative technological solutions are becoming essential. Blockchain technology has emerged as a promising tool to enhance transparency in the food supply chain (Abass et al., 2024). Its decentralized and immutable nature allows for the secure recording of transactions and the tracking of products from origin to distribution. By providing a transparent ledger accessible to all stakeholders, blockchain can significantly improve traceability, reduce fraud, and foster trust among consumers and producers alike, enabling more informed decision-making (Toromade et al., 2024).

In South Africa, the agricultural sector is vital for economic development and food security. However, the existing supply chain processes often lack the necessary transparency to assure consumers of the authenticity and safety of food products (Toromade et al., 2024). The integration of blockchain technology offers a pathway to address these concerns, facilitating more efficient operations and better compliance with safety standards. This study explores the role of blockchain technology in promoting transparency within the South African food supply chain. It aims to assess the potential benefits and challenges of adopting this innovative solution and provide insights into how blockchain can transform the landscape of food safety and consumer trust in the region. Through a comprehensive analysis, the study seeks to contribute to the existing body of knowledge by providing empirical evidence on the effectiveness of blockchain technology in enhancing transparency and accountability in the food supply chain, thereby addressing critical gaps identified in previous studies. The food supply chain in South Africa may become much more transparent and accountable if blockchain technology were used for smart contracting, record traceability, and distribution monitoring. But to realize these benefits, obstacles like technological adoption and governmental restrictions must be addressed.

The objective of this study was to explore and assess the role of blockchain technology in promoting transparency for sustainable food supply chain infrastructure in South Africa. The research question it sought to answer was, to what extent can blockchain technology address the issues related to the lack of transparency within the food supply chain infrastructure that hinders the possibility of achieving food security in South Africa? To answer this question and achieve the objective, this study was structured as follows: The first section serves as an introduction, the second section explains the research methodology used to collect and analyze data, the third section discusses the findings in relation to the study's objectives, and the fourth section offers concluding remarks and recommendations for policymakers and future studies in service delivery, agriculture, and food supply chain infrastructure in South Africa.

## **2. Research methodology**

The use of qualitative methodology was significant in this study because it helped understand human social behavior towards problems and challenges within the food supply chain in South Africa. It equally helped to explore people's experiences, perceptions, and meanings when it comes to the use of blockchain technology. This is

because qualitative methodology was understood as the study that helps a researcher to understand the nature of phenomena, including their quality and different manifestations, and the perspectives from which they can be perceived (Philipsen and Vernooij-Dassen, 2007). This methodology proffered a more guided opportunity to collect data in the form of words retrieved from existing literature instead of numbers (Punch, 2013). For this reason, the methodology was adopted in this study to comprehend factors that make people in South Africa view an inadequate and/or unstable food supply chain as influencing food insecurity, thus posing threats to their livelihoods.

Qualitative methodology helped to understand and explain why a person's skills or understanding of blockchain technology might bring about a positive impact on the food supply chain. Qualitative research methodology enabled the collection of real ideas from food security, food supply chain, blockchain technology, and demographics. Data for this study was primarily collected from secondary sources, which included published articles, academic journals, books, reports, and monographs available in the public domain. Utilizing secondary qualitative data analysis allowed for the extraction of insights that primary data collection might not have provided. According to Heaton (2008), analyzing secondary qualitative data is a credible method for generating new knowledge, as it circumvents the challenges associated with firsthand data collection.

The sources of secondary data were diverse, ensuring a broad range of perspectives on food security, the food supply chain, and blockchain technology. The study adopted a qualitative research approach because it allowed flexibility with a more relaxed data eligibility criteria to allow heterogeneous data types (Glasgow, 2013). This approach minimized inconsistencies during data interpretation and adhered to ethical principles while maintaining a focused research aim on the core elements of blockchain technology in the South African food supply chain (Baldwin et al., 2022). The secondary analysis maximized the value of existing literature on the subject, allowing for comprehensive insights relevant to the research objectives (Chatfield, 2020). In the context of the role of blockchain technology in promoting transparency in the food supply chain in South Africa, secondary data provided enough data that was used to achieve insights that answered the research question and objective of this study.

In this study, content analysis and thematic analysis serve as crucial methodologies for gathering and synthesizing data from the existing literature regarding the role of blockchain technology in enhancing transparency within sustainable food supply chain infrastructure, specifically focusing on the South African context (Kamilaris et al., 2019). Content analysis, in this context, involves a systematic examination of textual or visual content to quantify the presence of certain keywords, themes, or concepts related to blockchain, transparency, sustainability, and food supply chains (Aldag, 2020). This method enables researchers to identify recurring patterns, trends, and relationships within literature, providing a quantitative overview of the research landscape (Chen et al., 2020). Patton (2002) describes qualitative content analysis as a process that reduces qualitative material to identify core consistencies and meanings. Hsieh and Shannon (2005) view it as a method for the subjective interpretation of text data through systematic classification, coding, and

identification of themes or patterns. This technique was employed to describe and classify data from the literature review into patterns relevant to the study's objectives and research questions. Content analysis is significant because it allows for the examination of various data types collected from observations and print media such as articles, books, or manuals without bias (Hsieh and Shannon, 2005).

This study also conducted a thematic analysis to understand the processes, benefits, and challenges of blockchain adoption in food supply chains, identifying multiple themes related to adoption processes, benefits, and challenges (Chen et al., 2020). Thematic analysis is a qualitative method used to identify, analyze, and report patterns (themes) within data. It is particularly useful in exploring complex issues like the integration of blockchain technology in food supply chains. This approach allows researchers to delve deeper into specific aspects of blockchain technology, such as its potential to enhance sustainability and traceability in food supply chains (Chandan et al., 2023). Thematic analysis helps in organizing and interpreting data to provide a comprehensive understanding of how blockchain can be leveraged to improve transparency and sustainability in the food supply chain infrastructure, particularly in regions like South Africa where these issues are critical.

### **3. Literature review**

The South African food supply chain is critically hindered by a lack of transparency, which impedes efforts to achieve food security and combat poverty. This extensive network, comprising producers, wholesalers, retailers, and consumers, is essential for the nation's economy; however, issues such as food safety, quality control, and traceability persist. Novakovic et al. (2019) emphasize that this opacity not only erodes consumer trust but also poses significant risks to public health and sustainability. In recent years, the Food and Agriculture Organization (FAO) further pointed out the necessity of transparency to enhance food safety and bolster consumer confidence.

Blockchain technology emerges as a promising solution to these transparency challenges. By providing a decentralized and immutable ledger, blockchain can significantly enhance traceability and accountability within the food supply chain, thus improving its overall integrity (Novakovic et al., 2019). However, the adoption of such innovations is contingent upon addressing the multifaceted challenges South Africa faces, including climate change, which disproportionately affects rural areas like KwaZulu-Natal. Here, water scarcity has severely impacted agricultural productivity, underscoring the need for effective governance and the integration of indigenous knowledge systems to develop adaptive strategies (Leonard, 2022).

Urban centers in South Africa also grapple with food supply challenges exacerbated by rapid urbanization and inadequate policy frameworks. The inefficiencies of the global food system are mirrored in these urban areas, where access to nutritious food is severely limited (Van Der Merwe, 2011). Informal settlements like Umlazi Township face unique barriers, such as land inaccessibility and high unemployment, contributing to malnutrition and food insecurity. Collaborative initiatives to allocate municipal land for food production and engage local industries in urban agriculture are essential for mitigating these issues (Mkhize et al., 2023).

Dietary shifts towards processed foods and sugar-sweetened beverages further complicate the public health landscape. Despite advancements in manufacturing practices, there is a notable lack of innovation in technologies that could enhance food security. Indigenous crops and food waste recovery offer promising avenues for improvement but require collaborative efforts among industry, academia, and government (Ronquest-Ross and Sigge, 2024). Climate change continues to pose a high risk to food security across sub-Saharan Africa, affecting food availability, accessibility, and affordability. South Africa's ability to adapt to these changes is hindered by weak institutions and limited access to technology. An integrated policy approach is necessary to protect arable land and invest in technologies that mitigate risks to food systems (Masipa, 2017).

Moreover, South Africa's struggle with food sovereignty, where control over food supply chains influences food choices, highlights the importance of addressing political, economic, and social factors to ensure long-term food security (Li et al., 2023). Addressing political, economic, and social factors is essential for unlocking the potential for food sovereignty and ensuring long-term food security. This requires a comprehensive understanding of the complex issues surrounding food sovereignty and its impact on South Africa's future (Lucantoni and Domarle, 2023). The dichotomy between the dominant agro-industrial system and the informal sector leads to trade-offs that undermine agro-biodiversity and dietary diversity. Integrating underutilized indigenous crops could promote a sustainable food system while supporting employment and environmental goals (Mabhaudhi et al., 2018). The achievement of the Sustainable Development Goal of zero hunger is further obstructed by policy implementation challenges and the effectiveness of food security interventions. Evaluating progress and addressing shortcomings in these initiatives is crucial for enhancing governance and policy in the food sector (Vyas-Doorgapersad, 2024).

### **3.1. Challenges in the South African food supply chain infrastructure**

The South African food supply chain faces a multitude of challenges that significantly undermine its efficiency, safety, and transparency. As one of the largest economies in Africa, South Africa's agricultural sector is crucial not only for domestic food security but also for export revenue. However, the complexities of the food supply chain, coupled with socio-economic disparities and regulatory hurdles, create an environment rife with inefficiencies and vulnerabilities.

The South African food supply chain faces numerous challenges, particularly highlighted by the COVID-19 pandemic. The pandemic disrupted international travel and global logistics, leading to shortages and increased prices for basic food items in South Africa. This situation underscored the importance of investing in local supply chains and technology to build resilience against such shocks. Large food retailers in South Africa have been able to mitigate some of these impacts by focusing on local supply development, which suggests a shift towards more localized supply chain models could be beneficial in the post-pandemic world (Omoruyi et al., 2022). Additionally, the pandemic has highlighted the need for more resilient food systems that can withstand global disruptions, emphasizing the importance of local versus international supply chain models (Omoruyi et al., 2022).

The rise of supermarkets and changes in procurement practices have marginalized small-scale farmers, who struggle to meet the requirements of large retailers. Initiatives to integrate these farmers into urban markets are necessary but require a multi-actor approach to be successful (Dannenburg, 2013). South Africa's food system is split between a dominant agro-industrial sector and an informal sector, which undermines smallholder producers. There has been a shift towards processed foods and away from vegetables, contributing to public health issues like obesity and malnutrition. The food industry has been slow to adopt novel technologies that could address these issues (Ronquest-Ross and Sigge, 2024). Smallholders face challenges such as lack of infrastructure, access to credit, and market integration. Policy interventions are needed to support infrastructure investment, improve access to inputs, and provide training (Cuevas Garcia-Dorado et al., 2021). Urban poor face significant barriers to food access due to the spatial distribution of retail outlets and the nutritional quality of available food. New retail distribution models could improve food security for these populations (Tuomala and Grant, 2022).

The lack of transparency in South Africa's food supply chain is also another major challenge. The food supply chain in South Africa is a vital component of the nation's economy, underpinning food security and supporting livelihoods. In recent years, the issue of food supply chain transparency has gained significant attention globally, and South Africa is no exception. As a nation striving for food security and sustainable development, South Africa faces a multitude of challenges that hinder transparency within its food supply chains. The other challenge is the complexity and fragmentation of supply chains. The food supply chain in South Africa is characterized by its complexity and fragmentation, which pose significant challenges to achieving transparency. The involvement of numerous stakeholders, each with specific roles, complicates the traceability and accountability of food products. This complexity is exacerbated by the need to manage risks and recalls efficiently, as well as to satisfy consumer demand for transparency regarding food safety and origin (Astill et al., 2019).

Regulatory compliance, food fraud, and safety concerns are other issues within South Africa's food supply chain. Regulatory compliance is a major challenge in achieving transparency in South Africa's food supply chains. The lack of standardized regulations and the need for alignment with international standards complicate efforts to ensure transparency. Moreover, the enforcement of existing regulations is often inconsistent, leading to gaps in accountability and traceability (Montecchi et al., 2021). Food fraud and safety are critical issues that undermine transparency in the food supply chain. Incidents of food fraud, such as mislabeling and adulteration, erode consumer trust and highlight the need for robust systems to ensure food integrity. Ensuring food safety requires comprehensive monitoring and rapid response mechanisms to address contamination and other safety concerns (Beulens, 2005). Moreover, there have been issues of consumers demanding transparency regarding the safety, origin, and sustainability of their food. This demand is driven by past food scandals and a growing awareness of environmental and social issues. Meeting these consumer expectations requires effective communication and information systems that provide clear and accurate data about food products (Ojogiwa and Mubangizi, 2023).

Effective governance and coordination among supply chain actors are essential for achieving transparency. However, the lack of integrated information systems and the presence of numerous intermediaries' complicate efforts to streamline operations and ensure consistent information flow. This lack of coordination can lead to inefficiencies and reduced transparency (Kraft and Kellner, 2022). Sustainability is a key component of transparency in food supply chains. The need to address environmental issues, such as resource wastage and carbon emissions, is critical for achieving sustainable supply chains. However, balancing sustainability with economic viability remains a challenge, requiring innovative solutions and strategic investments (Chandan et al., 2023).

There have also been socio-economic and limited resources/funds challenges. Economic and social factors, such as poverty, unemployment, and limited access to resources, further complicate transparency efforts in South Africa. These challenges impact the ability of small and medium enterprises (SMEs) to invest in transparency-enhancing technologies and practices, thereby affecting the overall transparency of the supply chain (Ojogiwa and Mubangizi, 2023). The lack of adequate infrastructure and resources is a significant barrier to achieving transparency in the food supply chain. This includes limitations in transportation, storage, and processing facilities, which hinder the efficient movement and tracking of food products. Addressing these infrastructure gaps is crucial for improving transparency (Kraft and Kellner, 2022).

Cultural and institutional factors also play a role in the challenges faced by South Africa's food supply chains. Resistance to change, lack of awareness, and limited institutional support can impede the adoption of transparency-enhancing practices and technologies. Overcoming these barriers requires targeted education and policy interventions (Montecchi, 2021). Financial constraints, particularly for SMEs, limit the ability to invest in transparency-enhancing technologies and practices. Access to funding and financial support is necessary to overcome these constraints and enable the adoption of innovative solutions that enhance transparency (Kraft and Kellner, 2022). The openness of the food supply chain is seriously threatened by climate change, which has an impact on food availability and agricultural output. To maintain the resilience and transparency of food supply chains, adaptive methods are required due to the rising frequency of extreme weather events and shifting climatic circumstances (Chandan et al., 2023).

Effective data management and integration are critical for achieving transparency in food supply chains. However, the lack of standardized data formats and the challenges of integrating data from diverse sources complicate efforts to create a unified and transparent information system. Addressing these data challenges is essential for improving traceability and accountability (Trienekens et al., 2012). Building trust and fostering collaboration among supply chain stakeholders is essential for achieving transparency. However, the presence of competing interests and the lack of trust can hinder collaborative efforts. Developing mechanisms to enhance stakeholder trust and cooperation is crucial for improving transparency (Beulens, 2005). The issues of transparency in food supply chains require deliberate interventions and effective policy. To support transparency initiatives, this entails creating policies that are appropriate for the situation, encouraging public-private

collaborations, and funding research and development (Ojogiwa and Mubangizi, 2023).

### **3.2. The Fundamentals of blockchain technology**

The digital age has witnessed the emergence of blockchain technology, which is fundamentally transforming how transactions and data management are conducted. Essentially, blockchain is a distributed and decentralized ledger technology that guarantees data security and integrity without requiring a central authority. This technology is defined by its essential features of decentralization, immutability, and transparency, which together improve the security and dependability of digital transactions (Namasudra et al., 2021). The design of blockchain consists of a series of blocks, with each block holding a record of transactions. These blocks are connected through cryptographic hashes, guaranteeing that once information is recorded, it cannot be changed retroactively without the agreement of the network.

Baiod et al. (2021) state that this immutability is a cornerstone of blockchain's security, making it an ideal solution for applications requiring high levels of trust and transparency. A prominent use of blockchain technology is in cryptocurrencies, with Bitcoin serving as the first platform. The capability of blockchain to enable secure transactions between peers without intermediaries has transformed not only the financial industry but also opened avenues for the creation of various other cryptocurrencies and digital assets (Yuan and Wang, 2018). Aside from cryptocurrencies, blockchain technology is being explored for numerous applications in different sectors. In the healthcare sector, blockchain technology can securely maintain and distribute patient records, guaranteeing data privacy and integrity. Likewise, in supply chain management, blockchain offers a clear and immutable record of product origins, improving traceability and responsibility (Namasudra et al., 2021).

Blockchain technology is making notable progress as it offers a decentralized and secure framework, effectively tackling numerous security and scalability issues encountered by IoT networks. This integration is viewed as an essential move towards establishing a more secure and efficient IoT ecosystem (Ali et al., 2018). Despite its promise, blockchain technology encounters numerous challenges that must be overcome to realize its full potential. Scalability continues to be a major concern, as existing blockchain networks often find it difficult to manage high volumes of transactions effectively. Additionally, energy consumption, privacy concerns, and regulatory hurdles are critical areas that require ongoing research and development (Makridakis and Christodoulou, 2019).

The consensus mechanisms employed in blockchain networks are crucial for their functioning, guaranteeing that all participants concur with the status of the ledger. Different consensus mechanisms, like Proof of Work (PoW) and Proof of Stake (PoS), have been created, each offering unique benefits and drawbacks. These mechanisms play a vital role in upholding the security and integrity of smart contracts and represent another groundbreaking aspect of blockchain technology, allowing for automated and self-executing agreements without requiring intermediaries. These contracts are designed to carry out certain actions once predetermined conditions are satisfied,

optimizing processes and minimizing the risk of human error (Vanmathi et al., 2024). As blockchain technology advances, its combination with other rising technologies like Artificial Intelligence (AI) and cloud computing is anticipated to promote additional innovation. These synergies may result in the creation of more advanced applications, improving the functionality and impact of blockchain in multiple industries (Vanmathi et al., 2024).

According to Novakovic et al. (2019), blockchain technology serves as a decentralized, immutable ledger that enables secure and transparent transactions across various sectors, including the food supply chain. By recording each transaction in a manner that is both traceable and resistant to alteration, blockchain fosters trust among consumers and producers alike. This transparency is particularly crucial in South Africa, where issues such as food fraud and safety concerns are prevalent. For instance, farmers can document their practices, as well as the origins of their products, creating an unbroken chain of information accessible to all stakeholders in the food supply chain. The application of blockchain can significantly enhance the traceability of food products from farm to fork, ensuring that consumers can make informed choices about their purchases (Novakovic et al., 2019). Consequently, the integration of blockchain technology holds substantial promise for improving food safety and trust in South Africa's agricultural landscape.

### **3.2.1. Blockchain technology and its key features relevant to supply chains**

In recent years, blockchain technology has emerged as a transformative force within supply chains, particularly in enhancing transparency and accountability. Essentially, blockchain functions as a decentralized ledger where transactions are recorded in a secure and immutable manner, making it nearly impossible for data tampering to occur (Novakovic et al., 2019). One of its key features is traceability, which allows stakeholders to track the movement of goods throughout the supply chain, providing detailed records that can be accessed in real-time (Balcioğlu et al., 2024). This characteristic is especially crucial in the food supply chain in South Africa, where ensuring the origin and safety of food is paramount. Furthermore, smart contracts enable automatic transactions based on defined conditions, streamlining processes and reducing delays. These elements collectively contribute to a more transparent food supply chain, addressing key issues such as fraud and inefficiency, as outlined in recent studies conducted by leading institutions on the subject (Novakovic et al., 2019).

A key characteristic of blockchain in supply chains is its capacity to improve transparency. Through the provision of a decentralized and unchangeable record of transactions, blockchain enables all stakeholders in the supply chain to access identical information, decreasing the likelihood of discrepancies and fraud. This openness is vital for guaranteeing the authenticity and quality of products, as it allows stakeholders to trace the origin and path of products (Pournader et al., 2020). Blockchain enhances supply chain efficiency by optimizing processes and minimizing the reliance on intermediaries. Smart contracts, which are contracts that execute themselves with the terms coded directly into them, streamline transactions and lower the time and expenses related to manual processing. This results in swifter and more effective supply chain processes (Du et al., 2020).

Furthermore, blockchain technology facilitates sustainable supply chain management in addition to operational advantages. Businesses may guarantee adherence to ethical and environmental standards by using blockchain technology, which offers a transparent and verifiable record of transactions. As customers and regulators expect organizations to be more accountable and sustainable, this is becoming more and more crucial (Park and Li, 2021). Another important aspect is how blockchain improves data security. The decentralized nature of technology and cryptographic security features shield private data against manipulation and unwanted access. Given how important data integrity and privacy are in supply chain finance, this is especially advantageous (Paliwal et al., 2020).

### **3.2.2. Role of blockchain technology**

Blockchain technology offers promising solutions for enhancing transparency in food supply chains by providing a secure, immutable, and traceable ledger. Its implementation can reduce fraud, improve traceability, and increase stakeholder trust. However, the adoption of blockchain technology requires overcoming technical and infrastructural challenges (Hamdan et al., 2022). Traceability systems are vital for ensuring transparency in food supply chains. These systems enable the tracking of food products from production to consumption, providing critical information about their origin, safety, and quality. Implementing effective traceability systems requires investment in technology and infrastructure (Chandan et al., 2023).

Globalization has increased the complexity of food supply chains, making transparency more challenging. The global flow of raw materials and products necessitates robust systems to ensure traceability and accountability across borders. Addressing the challenges posed by globalization is essential for achieving transparency (Astill et al., 2019). It enhances continuous monitoring and evaluation, which are crucial tools for maintaining transparency in food supply chains. This involves regularly assessing the effectiveness of transparency initiatives and making necessary adjustments to address emerging challenges. Developing comprehensive monitoring systems is essential for ensuring ongoing transparency (Montecchi, 2021).

## **4. Discussion of the findings**

The potential of blockchain technology to transform food supply chains is becoming more widely acknowledged, especially in South Africa. By improving the food supply chain's efficiency, traceability, and transparency, blockchain presents a possible solution to these problems (Mavilia and Pisani, 2022). Blockchain may ensure that all food production and distribution-related transactions and data are safely documented and readily available by offering a decentralized and immutable ledger, hence enhancing supply chain management (Shahid et al., 2020).

Conversely, certain studies present a more skeptical viewpoint. For example, Kshetri (2018) indicates that although blockchain-based traceability systems provide significant advantages, they might be challenging for small and medium enterprises (SMEs) to adopt because of technical intricacies and elevated expenses. Likewise, Treiblmaier (2018) observes that blockchain integration within supply chains remains nascent, and numerous firms encounter difficulties concerning scalability and interoperability, potentially hindering the effectiveness of tools such as smart contracts

and distribution monitoring. In the domain of blockchain technology within the agri-food supply chain, scalability pertains to the system's capacity to effectively manage rising transaction volumes as the supply chain expands, while interoperability guarantees smooth data transfer among various platforms and participants to uphold transparency and traceability (Johnson et al., 2023).

Despite these challenges, the consensus in the literature agrees with the study's findings, as blockchain technology has been widely recognized for its potential to improve transparency, traceability, and accountability in the food supply chain.

The first finding of this study indicated that the use of blockchain technology in South Africa's food supply chains can enhance food safety and traceability. Furthermore, Saberi et al. (2019) corroborate the distribution monitoring findings by asserting that real-time surveillance of food transportation parameters, such as temperature and location, is essential to guarantee that goods fulfill legal and quality standards. This traceability is essential in stopping food fraud and maintaining adherence to safety standards, which is especially significant in a nation where food safety issues are common (Li et al., 2023). Incorporating blockchain into the food supply chain enables real-time tracking of food conditions while being transported, thereby improving both the food supply chain and food safety (Kaur et al., 2022). In South Africa, where there are uncertainties about trust in food quality and safety, blockchain offers a transparent system that allows all stakeholders to confirm the authenticity and quality of food items (Menon et al., 2021).

This transparency fosters trust among consumers and may result in heightened demand for food produced locally, which advantages local farmers and producers. The application of blockchain in South Africa's food supply chains may also result in considerable cost reductions and enhancements in efficiency. Through the automation of processes and minimizing the reliance on intermediaries, blockchain has the potential to decrease transaction expenses and enhance operational efficiency (Li et al., 2023). This effectiveness is especially advantageous for small and medium-sized enterprises (SMEs) in South Africa, which frequently encounter elevated operational expenses and restricted resources (Katsikouli et al., 2021). Moreover, blockchain can improve coordination and collaboration among supply chain participants, resulting in more efficient and agile supply chains (Kramer et al., 2021). Despite its potential benefits, the adoption of blockchain in South Africa's food supply chains is not without challenges.

The second finding of this study indicated that a deficiency in technical knowledge and comprehension of blockchain technology among stakeholders is a significant obstacle, both in South Africa and throughout the global South (Srivastava and Dashora, 2022). This lack of understanding can obstruct the successful use and application of blockchain solutions in the food supply chain, thereby worsening food insecurity and hindering the progress toward sustainable development. Additionally, the results of this research indicated that challenges concerning scalability, privacy, and regulatory adherence need to be tackled to facilitate the effective incorporation of blockchain technology into current supply chain frameworks (Srivastava and Dashora, 2022).

The third finding of this study also showed that the need for significant investment in infrastructure and technology to support blockchain applications is

another challenge that is affecting the process of digitizing the food supply chain in South Africa. For example, for numerous South African farmers and producers, especially those in rural areas, the cost of implementing blockchain technology can be prohibitive (Mavilia and Pisani, 2022). To overcome this barrier, government support and public-private partnerships may be necessary to provide the necessary resources and training to facilitate blockchain adoption (Srivastava and Dashora, 2022). As such, blockchain technology emerges as an essential tool in building robust and transparent supply chains that can adapt to modern demands and consumer expectations.

The fourth finding showed that adopting blockchain technology in the food supply chain can address food security challenges in South Africa, such as lack of efficiency and reliability. Blockchain technology in the food supply chain can promote the efficiency and reliability of the food supply chain infrastructure. By ensuring that food products are delivered safely and efficiently, blockchain contributes to the overall food security of the region (Mwewa et al., 2024). While blockchain offers numerous benefits, its adoption in South Africa faces challenges such as high costs, limited technical expertise, and inadequate infrastructure. Addressing these barriers requires collaborative efforts from governments, private stakeholders, and international organizations to provide affordable and scalable solutions (Kamilaris et al., 2019). The integration of blockchain enhances the capabilities of the food supply chain by providing real-time data on product conditions and locations. This integration is crucial for improving traceability and ensuring the quality and safety of food products (Tang et al., 2024). Blockchain technology increases consumer trust by providing transparent information about the origin and journey of food products. As blockchain promotes transparency, it encourages consumer engagement and promotes positive attitudes towards the food supply chain (Cozzio et al., 2023).

Thus, it can be asserted that embracing blockchain technology is a component of the wider digital transformation occurring in South Africa's food supply chain. Utilizing digital tools, stakeholders can enhance their operations and adjust to the evolving requirements of the global market (Kamilaris et al., 2019). Blockchain technology aids in economic growth in South Africa by improving the efficiency and transparency of the food supply chain. Enhanced supply chain processes result in greater productivity and competitiveness, vital for the region's economic growth (Cozzio et al., 2023).

Utilizing blockchain technology can help cultivate a more robust and fair food system. The intricacies of the supply chain, spanning production and processing to distribution and retail, necessitate creative approaches that improve transparency and responsibility. Technological innovations, including the Internet of Things and blockchain-based systems, present hopeful opportunities to tackle these issues. The combination of these technologies can improve data collection, handling, and examination, resulting in a more transparent and responsible food supply chain (Astill et al., 2019). Blockchain technology has been lauded for its potential to transform the food industry by offering a secure and immutable system for tracking food products from the origin to the final consumer (Demestichas et al., 2020; Ellahi et al., 2023). The inherent features of blockchain, including transparency and immutability, create a reliable and traceable system that can address the shortcomings of traditional supply chain management.

Traceability systems are essential for addressing food safety issues, as they allow for the quick identification and management of food safety events. Certification can serve as a screening tool to ensure that suppliers meet high traceability standards, thus reducing the risk of adverse selection and enhancing food safety levels (Sub and Wang, 2019). The adoption of traceability technology, such as blockchain, can significantly reduce contamination risks and food waste. However, it also introduces challenges, such as potential exploitation through strategic pricing by downstream buyers.

Despite these challenges, the consensus in the literature agrees with the study's findings, as blockchain technology has been widely recognized for its potential to improve transparency, traceability, and accountability in the food supply chain (Dong et al., 2023). In the South African context, traceability systems are particularly important for products with a strong regional identity, such as Karoo Lamb. Consumers increasingly demand assurance about the origin of their food, and traceability systems can provide the necessary guarantees to meet this demand (Van der Merwe, 2012).

Digital technology plays a pivotal role in developing effective traceability systems in perishable food supply chains. A cost-sharing mechanism among supply chain members can facilitate the implementation of these systems, making them more economically viable and beneficial for all parties involved (Dash et al., 2022). The integration of traceability systems in African food supply chains is crucial for guaranteeing the origin of products. This is particularly important in a consumer-driven market where the connection between product and origin is highly valued. Blockchain technology offers a promising solution for enhancing traceability in food supply chains. It provides a transparent and immutable ledger that can improve sustainability and traceability, helping to achieve the United Nations Sustainable Development Goals (Chandan et al., 2023). Radio Frequency Identification (RFID) technology is another tool that can enhance traceability in food supply chains, particularly in fisheries. RFID systems provide real-time tracking and ensure the integrity and transparency of product information, thereby increasing consumer trust (Rahman et al., 2021).

Finally, traceability should be considered an integral part of logistics management in food supply chains. It requires a comprehensive understanding of numerous factors, including economic, legal, technological, and social issues, to develop effective and full-chain traceability systems (Bosona and Gebresenbet, 2013). Blockchain technology enables rapid identification of contamination sources, allowing for swift recalls and minimizing the impact of foodborne illnesses. This capability is particularly beneficial in South Africa, where food safety is a critical concern (Tang et al., 2024). Blockchain streamlines various processes within the food supply chain by automating transactions and reducing the need for intermediaries. The immutable nature of blockchain records fosters trust among all participants in the food supply chain. By ensuring that data cannot be altered or tampered with, blockchain builds confidence among producers, distributors, retailers, and consumers, which is vital for the smooth functioning of the supply chain (Kamilaris et al., 2019).

Moreover, blockchain technology helps in reducing food waste by improving inventory management and ensuring that food products are distributed efficiently. By providing accurate data on product shelf life and location, blockchain enables better

decision-making regarding the distribution and sale of food products (Li et al., 2023). In South Africa, SMEs play a crucial role in the agri-food sector. Blockchain technology offers these enterprises tools to improve their operations, such as smart contracts and production tracking, which enhance their competitiveness and sustainability in the market (Mavilia and Pisani, 2022). Blockchain facilitates compliance with food safety regulations by providing a transparent and verifiable record of all transactions and processes within the supply chain. This capability is particularly important in South Africa, where regulatory compliance is essential for market access and consumer protection (Mwewa et al., 2024). Blockchain supports sustainable practices in the food supply chain by enabling better resource management and reducing environmental impact. By providing detailed data on production and distribution processes, blockchain helps stakeholders make informed decisions that promote sustainability (Mukherjee et al., 2022).

This finding emerges from previous studies that have shown that the adoption of blockchain-based traceability systems can significantly improve food safety, reduce the risk of fraud, and enhance consumer trust in the food supply chain (Demestichas et al., 2020; Ellahi et al., 2023). This finding is supported by Essien et al. (2024), who argued that there is an interconnected nature of challenges that hinder the effectiveness of the supply chain. Adopting blockchain technology within the food supply chain would lead to robust security measures and ensure compliance. It has been noted that robust security is essential to protect sensitive information and build trust among stakeholders (Nurgazina et al., 2021) within the food supply chain. There, the adoption of blockchain technology within the food supply chain enhances transparency by enabling real-time data sharing across the supply chain infrastructure. It enables and allows for better traceability and automation of processes, reducing transaction costs and ensuring fair pricing for farmers (Astill et al., 2019). Blockchain technology devices can collect data from various stages of the supply chain and provide stakeholders with a transparent view of food production and distribution.

A lack of technical knowledge and minimal awareness of blockchain's advantages pose major obstacles to its adoption. The research concurs with Mwewa et al. (2024), who contended that educational projects and training courses on blockchain technology and other digital tools can cultivate essential skills and understanding among stakeholders. It can aid in the adoption of these technologies within the food supply chain in South Africa, thereby promoting the sustainable management of food security and supply, ultimately tackling hunger and poverty. Niyitunga and Musya (2024) contended that achieving sustainable development relies on effectively tackling hunger and poverty. Support from regulators is crucial for the effective implementation of blockchain technology within the food supply chain. Policymakers must establish structures that encourage blockchain utilization while guaranteeing adherence to quality benchmarks and tackling concerns like data privacy and security (Khan et al., 2025). Blockchain technology can additionally facilitate sustainable methods in the food supply chain by allowing the tracing of product ingredients and encouraging the adoption of recyclable packaging (Bai et al., 2022). This would diminish food waste and loss, thereby enhancing food availability, utilization, stability, and accessibility.

This makes blockchain technology upgrade current information systems within the food supply chain through transparency, which promotes sustainable food delivery services. It would facilitate the exchange of information among stakeholders, enhancing transparency and sustainability in the supply chain (Weigum et al., 2011). It would further enhance the resilience of supply chains against disruptions. The use of blockchain would strengthen food supply chain infrastructure and foster collaboration throughout the supply chain (Nurgazina et al., 2021). This would therefore improve transparency by providing insights into supply chain operations as well as identifying areas for improvement. Ojogiwa and Mubangizi (2023) argued that it would lead to more informed decision-making and enhanced supply chain efficiency.

However, adopting blockchain technology in South Africa's food supply chain faces several potential obstacles that could impede progress. Notably, a lack of infrastructure and technological expertise presents significant challenges, particularly in rural areas where access to digital tools is limited. This technological divide can hinder farmers' ability to participate in a blockchain system, affecting overall transparency within the supply chain. Additionally, regulatory frameworks are often inadequate or unclear, posing risks for stakeholders who may be hesitant to invest in blockchain solutions. Moreover, fragility within the commitment to innovation among agribusinesses further complicates the situation, as seen in a parallel analysis of the agricultural sector in China, where drivers of innovation are classified to enhance growth (Zhu et al., 2023). Thus, fostering a supportive environment for blockchain adoption is crucial, especially given that consumers are now demanding transparency and traceability in food sourcing (Cruz et al., 2024).

As awareness grows and educational initiatives are implemented, stakeholders are likely to become more receptive to adopting innovative technologies. Furthermore, increased collaboration between government, the private sector, and academia can foster an environment conducive to technological advancement. Investments in infrastructure and the development of supportive regulatory frameworks will be crucial in overcoming current obstacles. As successful pilot projects demonstrate the efficacy of blockchain in enhancing traceability and efficiency, broader adoption may follow. Ultimately, with concerted efforts to address these challenges, blockchain technology has the potential to revolutionize South Africa's food supply chain, ensuring greater transparency and sustainability for the future.

## **5. Conclusion**

This study demonstrated that blockchain implementation, notably through smart contracts, record traceability, production tracking, and distribution monitoring, improves transparency in the food supply chain. The findings are valuable for both policymakers and practitioners, demonstrating how blockchain technology can increase transparency, trust, operational efficiency, and regulatory compliance in the food business. These findings imply that blockchain not only addresses transparency concerns but also lays the groundwork for improved collaboration among supply chain actors by establishing a shared, immutable log of transactions. Blockchain technology presents a transformative opportunity to enhance transparency within South Africa's

food supply chain. By providing a decentralized and immutable ledger, blockchain facilitates real-time tracking of food products from farm to consumer, addressing critical issues such as food safety, quality assurance, and stakeholder trust.

The study highlights the need for policymakers to create a legislative climate that promotes blockchain implementation, especially for SMEs facing challenges such as food theft and inefficient supply chains. Blockchain technology can help practitioners establish traceability, combat counterfeiting, and reduce the risk of non-compliance with food safety requirements. Furthermore, blockchain use is consistent with global trends toward sustainable supply chains, according to Saberi et al. (2019), who claim that blockchain can promote more ethical sourcing and lower environmental impacts by improving supply chain visibility.

Despite the promising advantages, the successful adoption of blockchain in South Africa's food supply chain is not without challenges. Barriers such as a lack of technical expertise, high initial costs, inadequate infrastructure, and regulatory uncertainties must be addressed to harness the full potential of this technology. Furthermore, fostering collaboration among stakeholders and creating supportive policy frameworks will be essential for overcoming these obstacles. As South Africa navigates its food security challenges, embracing blockchain technology presents an opportunity to build a more resilient and sustainable food system. By enhancing transparency, blockchain can contribute to achieving key goals, including zero hunger and poverty reduction, aligning with the broader objectives of the Sustainable Development Goals. Ultimately, the integration of blockchain into the food supply chain not only has the potential to improve domestic food security but also positions South Africa as a leader in promoting transparency in global food systems.

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## References

- Abass, T., Eruaga, M. A., Itua, E. O., & Bature, J. T. (2024). Advancing food safety through iot: real-time monitoring and control systems. *International Medical Science Research Journal*, 4(3), 276–283. <https://doi.org/10.51594/imsrj.v4i3.919>
- Aldag, M. C. (2020). The Use of Blockchain Technology in Agriculture. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Krakowie*, 4(982), 7–17. <https://doi.org/10.15678/znuek.2019.0982.0401>
- Ali, M. S., Vecchio, M., Pincheira, M., et al. (2019). Applications of Blockchains in the Internet of Things: A Comprehensive Survey. *IEEE Communications Surveys & Tutorials*, 21(2), 1676–1717. <https://doi.org/10.1109/comst.2018.2886932>
- Astill, J., Dara, R. A., Campbell, M., et al. (2019). Transparency in food supply chains: A review of enabling technology solutions. *Trends in Food Science & Technology*, 91, 240–247. <https://doi.org/10.1016/j.tifs.2019.07.024>
- Bai, C., Quayson, M., & Sarkis, J. (2022). Analysis of Blockchain's enablers for improving sustainable supply chain transparency in Africa cocoa industry. *Journal of Cleaner Production*, 358, 131896. <https://doi.org/10.1016/j.jclepro.2022.131896>
- Baiod, W., Light, J., & Mahanti, A. (2021). Blockchain Technology and its Applications Across Multiple Domains: A Survey. *Journal of International Technology and Information Management*, 29(4), 78–119. <https://doi.org/10.58729/1941-6679.1482>

- Balcıoğlu, Y. S., Çelik, A. A., & Altındağ, E. (2024). Integrating Blockchain Technology in Supply Chain Management: A Bibliometric Analysis of Theme Extraction via Text Mining. *Sustainability*, 16(22), 10032. <https://doi.org/10.3390/su162210032>
- Baldwin, J. R., Pingault, J.-B., Schoeler, T., et al. (2022). Protecting against researcher bias in secondary data analysis: challenges and potential solutions. *European Journal of Epidemiology*, 37(1), 1–10. <https://doi.org/10.1007/s10654-021-00839-0>
- Beulens, A. J. M., Broens, D.-F., Folstar, P., et al. (2005). Food safety and transparency in food chains and networks Relationships and challenges. *Food Control*, 16(6), 481–486. <https://doi.org/10.1016/j.foodcont.2003.10.010>
- Bosona, T., & Gebresenbet, G. (2013). Food traceability as an integral part of logistics management in food and agricultural supply chain. *Food Control*, 33(1), 32–48. <https://doi.org/10.1016/j.foodcont.2013.02.004>
- Calitz, P. A. (2016). Framework for a voluntary traceability system for beef [PhD thesis]. University of the Free State.
- Chandan, A., John, M., & Potdar, V. (2023). Achieving UN SDGs in Food Supply Chain Using Blockchain Technology. *Sustainability*, 15(3), 2109. <https://doi.org/10.3390/su15032109>
- Chatfield, S. (2020). Recommendations for Secondary Analysis of Qualitative Data. *The Qualitative Report*, 25(3), 833–842.
- Chen, S., Liu, X., Yan, J., et al. (2020). Processes, benefits, and challenges for adoption of blockchain technologies in food supply chains: a thematic analysis. *Information Systems and E-Business Management*, 19(3), 909–935. <https://doi.org/10.1007/s10257-020-00467-3>
- Chod, J., Trichakis, N., Tsoukalas, G., et al. (2020). On the Financing Benefits of Supply Chain Transparency and Blockchain Adoption. *Management Science*, 66(10), 4378–4396. <https://doi.org/10.1287/mnsc.2019.3434>
- Cruz, A. M., Cruz, E., Morais, R. (2024). Towards a blockchain-based traceability platform for the fruit and vegetables value chain. *IEEE*.
- Cuevas Garcia-Dorado, S., Queenan, K., Shankar, B., et al. (2021). Using Qualitative System Dynamics Analysis to Promote Inclusive Livestock Value Chains: A Case Study of the South African Broiler Value Chain. *Frontiers in Sustainable Food Systems*, 5. <https://doi.org/10.3389/fsufs.2021.670756>
- Dannenberg, P. (2014). The rise of supermarkets and challenges for small farmers in South African food value chains. *Economia agro-alimentare*, 3, 15–34. <https://doi.org/10.3280/ecag2013-003003>
- Dash, A., Sarmah, S. P., Tiwari, M. K., et al. (2022). Modeling traceability in food supply chain. *Benchmarking: An International Journal*, 30(9), 3408–3443. <https://doi.org/10.1108/bij-03-2022-0156>
- Demestichas, K., Peppes, N., Alexakis, T., et al. (2020). Blockchain in Agriculture Traceability Systems: A Review. *Applied Sciences*, 10(12), 4113. <https://doi.org/10.3390/app10124113>
- Du, M., Chen, Q., Xiao, J., et al. (2020). Supply Chain Finance Innovation Using Blockchain. *IEEE Transactions on Engineering Management*, 67(4), 1045–1058. <https://doi.org/10.1109/tem.2020.2971858>
- Ellahi, R. M., Wood, L. C., & Bekhit, A. E.-D. A. (2023). Blockchain-Based Frameworks for Food Traceability: A Systematic Review. *Foods*, 12(16), 3026. <https://doi.org/10.3390/foods12163026>
- Essien, A., Chukwukelu, G. O., Kazantsev, N., et al. (2023). Unveiling the factors influencing transparency and traceability in agri-food supply chains: an interconnected framework. *Supply Chain Management: An International Journal*, 29(3), 602–619. <https://doi.org/10.1108/scm-02-2023-0083>
- Glasgow, R. E. (2013). What Does It Mean to Be Pragmatic? Pragmatic Methods, Measures, and Models to Facilitate Research Translation. *Health Education & Behavior*, 40(3), 257–265. <https://doi.org/10.1177/1090198113486805>
- Hamdan, I. K. A., Aziguli, W., Zhang, D., et al. (2022). Forecasting blockchain adoption in supply chains based on machine learning: evidence from Palestinian food SMEs. *British Food Journal*, 124(12), 4592–4609. <https://doi.org/10.1108/bfj-05-2021-0535>
- Heaton, J. (2008). Secondary analysis of qualitative data: An overview. *Historical Social Research/Historische Sozialforschung*, 33(3), 33–45.
- Hsieh, H.-F., & Shannon, S. E. (2005). Three Approaches to Qualitative Content Analysis. *Qualitative Health Research*, 15(9), 1277–1288. <https://doi.org/10.1177/1049732305276687>
- Kamilaris, A., Fonts, A., & Prenafeta-Boldó, F. X. (2019). The rise of blockchain technology in agriculture and food supply chains. *Trends in Food Science & Technology*, 91, 640–652. <https://doi.org/10.1016/j.tifs.2019.07.034>
- Kanjere, J. (2021). A Blockchain-enabled System to enhance Food Traceability in Local Food Supply Chains (FSCs) suitable for Small Co-operatives in South Africa [Master's thesis]. University of Cape Town.

- Katsikouli, P., Wilde, A. S., Dragoni, N., et al. (2020). On the benefits and challenges of blockchains for managing food supply chains. *Journal of the Science of Food and Agriculture*, 101(6), 2175–2181. Portico. <https://doi.org/10.1002/jsfa.10883>
- Kaur, A., Singh, G., Kukreja, V., et al. (2022). Adaptation of IoT with Blockchain in Food Supply Chain Management: An Analysis-Based Review in Development, Benefits and Potential Applications. *Sensors*, 22(21), 8174. <https://doi.org/10.3390/s22218174>
- Khan, S. A. R., Sheikh, A. A., Shamsi, I. R. A., et al. (2025). The Implications of Artificial Intelligence for Small and Medium-Sized Enterprises' Sustainable Development in the Areas of Blockchain Technology, Supply Chain Resilience, and Closed-Loop Supply Chains. *Sustainability*, 17(1), 334. <https://doi.org/10.3390/su17010334>
- Kraft, S. K., & Kellner, F. (2022). Can Blockchain Be a Basis to Ensure Transparency in an Agricultural Supply Chain? *Sustainability*, 14(13), 8044. <https://doi.org/10.3390/su14138044>
- Kramer, M. P., Bitsch, L., & Hanf, J. (2021). Blockchain and Its Impacts on Agri-Food Supply Chain Network Management. *Sustainability*, 13(4), 2168. <https://doi.org/10.3390/su13042168>
- Leonard, L. (2022). Climate Change Impacts and Challenges of Combating Food Insecurity in Rural Somkhele, KwaZulu-Natal, South Africa. *Sustainability*, 14(23), 16023. <https://doi.org/10.3390/su142316023>
- Li, K., Lee, J.-Y., & Gharehgozli, A. (2021). Blockchain in food supply chains: a literature review and synthesis analysis of platforms, benefits and challenges. *International Journal of Production Research*, 61(11), 3527–3546. <https://doi.org/10.1080/00207543.2021.1970849>
- Lucantoni, D., & Domarle, J. (2023). Unlocking food security and livelihoods: the transformative power of agroecology among vulnerable smallholder farmers in Kembata Tembaro, Ethiopia. *Agroecology and Sustainable Food Systems*, 47(9), 1341–1371. <https://doi.org/10.1080/21683565.2023.2230931>
- Mabhaudhi, T., Chibarabada, T. P., Chimonyo, V. G. P., et al. (2018). Mainstreaming Underutilized Indigenous and Traditional Crops into Food Systems: A South African Perspective. *Sustainability*, 11(1), 172. <https://doi.org/10.3390/su11010172>
- Makridakis, S., & Christodoulou, K. (2019). Blockchain: Current Challenges and Future Prospects/Applications. *Future Internet*, 11(12), 258. <https://doi.org/10.3390/fi11120258>
- Masipa, T. S. (2017). The impact of climate change on food security in South Africa: Current realities and challenges ahead. *Jàmá: Journal of Disaster Risk Studies*, 9(1). <https://doi.org/10.4102/jamba.v9i1.411>
- Mavilia, R., & Pisani, R. (2021). Blockchain for agricultural sector: The case of South Africa. *African Journal of Science, Technology, Innovation and Development*, 14(3), 845–851. <https://doi.org/10.1080/20421338.2021.1908660>
- Mayring, P. (2000). Qualitative content analysis. *Forum: Qualitative Social Research*, 1(2).
- Menon, S., & Jain, K. (2024). Blockchain Technology for Transparency in Agri-Food Supply Chain: Use Cases, Limitations, and Future Directions. *IEEE Transactions on Engineering Management*, 71, 106–120. <https://doi.org/10.1109/tem.2021.3110903>
- Mkhize, X., Mthembu, B. E., & Napier, C. (2023). Transforming a local food system to address food and nutrition insecurity in an urban informal settlement area: A study in Umlazi Township in Durban, South Africa. *Journal of Agriculture and Food Research*, 12, 100565. <https://doi.org/10.1016/j.jafr.2023.100565>
- Montecchi, M., Plangger, K., & West, D. C. (2021). Supply chain transparency: A bibliometric review and research agenda. *International Journal of Production Economics*, 238, 108152. <https://doi.org/10.1016/j.ijpe.2021.108152>
- Mukherjee, A. A., Singh, R. K., Mishra, R., et al. (2021). Application of blockchain technology for sustainability development in agricultural supply chain: justification framework. *Operations Management Research*, 15(1–2), 46–61. <https://doi.org/10.1007/s12063-021-00180-5>
- Mwewa, T., Lungu, G., Turyasingura, B., et al. (2024). Blockchain Technology: A Review Study on Improving Efficiency and Transparency in Agricultural Supply Chains. *Jurnal Galaksi*, 1(3), 178–190. <https://doi.org/10.70103/galaksi.v1i3.46>
- Namasudra, S., Deka, G. C., Johri, P., et al. (2020). The Revolution of Blockchain: State-of-the-Art and Research Challenges. *Archives of Computational Methods in Engineering*, 28(3), 1497–1515. <https://doi.org/10.1007/s11831-020-09426-0>
- Niyitunga, E. B., & Musya, J. K. (2024). Dependency syndrome within Africa's international relations: A hindrance to sustainable development in Africa. *Journal of Infrastructure, Policy and Development*, 8(9), 7052. <https://doi.org/10.24294/jipd.v8i9.7052>
- Novakovic, T., Rammel, C., Voshmgir, S. (2019). Sustainable Development Report: Blockchain, the Web3 & SDGs. Research Institute for Cryptoeconomics.

- Nurgazina, J., Pakdeetrakulwong, U., Moser, T., et al. (2021). Distributed Ledger Technology Applications in Food Supply Chains: A Review of Challenges and Future Research Directions. *Sustainability*, 13(8), 4206. <https://doi.org/10.3390/su13084206>
- Ojogiwa, O. T., & Mubangizi, B. (2023). Navigating the Complex Terrain of Food Security in Decentralised Systems: Insights from South Africa and Nigeria. *The African Journal of Governance and Development (AJGD)*, 12(2), 141–160. <https://doi.org/10.36369/2616-9045/2023/v12i2a9>
- Oriekhoe, O. I., Oyeyemi, O. P., Bello, B. G., et al. (2024). Blockchain in supply chain management: A review of efficiency, transparency, and innovation. *International Journal of Science and Research Archive*, 11(1), 173–181. <https://doi.org/10.30574/ijrsra.2024.11.1.0028>
- Otewa, C. (2023). Exploring the potential of blockchain technology to enhance triple bottom line sustainability in sustainable supply chain management [Master's thesis]. Lappeenranta–Lahti University of Technology LUT.
- Paliwal, V., Chandra, S., & Sharma, S. (2020). Blockchain Technology for Sustainable Supply Chain Management: A Systematic Literature Review and a Classification Framework. *Sustainability*, 12(18), 7638. <https://doi.org/10.3390/su12187638>
- Park, A., & Li, H. (2021). The Effect of Blockchain Technology on Supply Chain Sustainability Performances. *Sustainability*, 13(4), 1726. <https://doi.org/10.3390/su13041726>
- Patton, M. Q. (2002). *Qualitative Research and Evaluation Methods*: CA. Sage Publishers.
- Philipsen, H., Vernooij-Dassen, M. (2007). Qualitative research: useful, indispensable, and challenging. ResearchGate.
- Pournader, M., Shi, Y., Seuring, S., et al. (2019). Blockchain applications in supply chains, transport and logistics: a systematic review of the literature. *International Journal of Production Research*, 58(7), 2063–2081. <https://doi.org/10.1080/00207543.2019.1650976>
- Punch, K. F. (2013). *Introduction to social research: Quantitative and qualitative approaches*. London: Sage.
- Rahman, L. F., Alam, L., Marufuzzaman, M., et al. (2021). Traceability of Sustainability and Safety in Fishery Supply Chain Management Systems Using Radio Frequency Identification Technology. *Foods*, 10(10), 2265. <https://doi.org/10.3390/foods10102265>
- Ronquest-Ross, L.-C., & Sigge, G. O. (2024). South Africa's food system: An industry perspective on past, present and future applications of science and technology. *South African Journal of Science*, 120(7/8). <https://doi.org/10.17159/sajs.2024/16536>
- Saberi, S., Kouhizadeh, M., Sarkis, J., et al. (2018). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, 57(7), 2117–2135. <https://doi.org/10.1080/00207543.2018.1533261>
- Saurabh, S., & Dey, K. (2021). Blockchain technology adoption, architecture, and sustainable agri-food supply chains. *Journal of Cleaner Production*, 284, 124731. <https://doi.org/10.1016/j.jclepro.2020.124731>
- Shahid, A., Almogren, A., Javaid, N., et al. (2020). Blockchain-Based Agri-Food Supply Chain: A Complete Solution. *IEEE Access*, 8, 69230–69243. <https://doi.org/10.1109/access.2020.2986257>
- Sivalakshmi, P., Shanthi, K. G., Sangeethalakshmi, K., et al. (2023). Smart auction system flow model for Agro-Based sector farmers using blockchain technology. *Materials Today: Proceedings*, 80, 1891–1896. <https://doi.org/10.1016/j.matpr.2021.05.634>
- Srivastava, A., & Dashora, K. (2022). Application of blockchain technology for agrifood supply chain management: a systematic literature review on benefits and challenges. *Benchmarking: An International Journal*, 29(10), 3426–3442. <https://doi.org/10.1108/bij-08-2021-0495>
- Sun, S., & Wang, X. (2019). Promoting traceability for food supply chain with certification. *Journal of Cleaner Production*, 217, 658–665. <https://doi.org/10.1016/j.jclepro.2019.01.296>
- Tang, A., Tchao, E. T., Agbemenu, A. S., et al. (2024). Assessing blockchain and IoT technologies for agricultural food supply chains in Africa: A feasibility analysis. *Heliyon*, 10(15), e34584. <https://doi.org/10.1016/j.heliyon.2024.e34584>
- Toromade, A. S., Soyombo, D. A., Kupa, E., & Ijomah, T. I. (2024). Technological innovations in accounting for food supply chain management. *Finance & Accounting Research Journal*, 6(7), 1248–1258. <https://doi.org/10.51594/farj.v6i7.1315>
- Treiblmaier, H. (2018). The impact of the blockchain on the supply chain: a theory-based research framework and a call for action. *Supply Chain Management: An International Journal*, 23(6), 545–559. <https://doi.org/10.1108/scm-01-2018-0029>
- Trienekens, J. H., Wognum, P. M., Beulens, A. J. M., et al. (2012). Transparency in complex dynamic food supply chains. *Advanced Engineering Informatics*, 26(1), 55–65. <https://doi.org/10.1016/j.aei.2011.07.007>

- Tuomala, V., & Grant, D. B. (2021). Exploring supply chain issues affecting food access and security among urban poor in South Africa. *The International Journal of Logistics Management*, 33(5), 27–48. <https://doi.org/10.1108/ijlm-01-2021-0007>
- Van Der Merwe, C. (2011). Challenges to urban food supply in South Africa. Issue brief no, 55.
- Van der Merwe, M. (2012). Evaluating traceability systems within the South African sheep meat supply chain [Master's thesis]. University of Pretoria (South Africa).
- Vanmathi, C., Farouk, A., Alhammad, S. M., et al. (2024). The Role of Blockchain in Transforming Industries Beyond Finance. *IEEE Access*, 12, 148845–148867. <https://doi.org/10.1109/access.2024.3468611>
- Vyas-Doorgapersad, S. (2024). Food security state and challenges in South Africa. *Insights into Regional Development*, 6(3), 23–26. <https://doi.org/10.70132/q7863983559>
- Weigum, P. N., Bremmers, H., Trienekens, J. H., et al. (2011). Systems for sustainability and transparency of food supply chains – Current status and challenges. *Advanced Engineering Informatics*, 25(1), 65–76. <https://doi.org/10.1016/j.aei.2010.06.001>
- Wu, M., Wang, K., Cai, X., et al. (2019). A Comprehensive Survey of Blockchain: From Theory to IoT Applications and Beyond. *IEEE Internet of Things Journal*, 6(5), 8114–8154. <https://doi.org/10.1109/jiot.2019.2922538>
- Yuan, Y., & Wang, F.-Y. (2018). Blockchain and Cryptocurrencies: Model, Techniques, and Applications. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, 48(9), 1421–1428. <https://doi.org/10.1109/tsmc.2018.2854904>
- Zhu, K. (2023). Drivers of innovation and development of high-yield agribusiness in China (Spanish). *Revista de Economía Mundial*, (63), 139–162. <https://doi.org/10.33776/rem.vi63.7400>