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A framework for the adoption of blockchain technology for food traceability in the South African fast-moving consumer goods industry

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Orientation: South Africa's fast-moving consumer goods (FMCG) sector faces food traceability challenges because of fragmented systems, manual procedures and poor information sharing. Technologies such as enterprise resource planning (ERP), quick response codes and radio-frequency identification often operate in silos, limiting interoperability and food safety.

Research purpose: This article proposes a blockchain-based framework grounded in network theory that integrates existing technologies with blockchain to provide decentralised, end-to-end traceability across the supply chain.

Motivation for the study: Fragmented systems, manual procedures and poor supply chain information sharing in South Africa's FMCG sector compromise traceability, affecting both safety and efficiency. This study addresses the blockchain integration gap by proposing a network theory-based blockchain framework for secure, end-to-end traceability.

Research design, approach and method: The study employed a qualitative, interpretivist approach, using purposive and snowball sampling to conduct semi-structured interviews and focus groups with participants from food manufacturing FMCG companies with active global company prefixes (GCPs) in Gauteng, South Africa. Data were analysed using content analysis with ATLAS.ti.

Main findings: Three findings emerged: (1) limited information sharing undermines traceability and safety, (2) ERP systems lack farm-to-fork capabilities, and (3) non-integrated systems cause inefficient tracking and recalls.

Practical/managerial implications: Fast-moving consumer goods companies must integrate traceability technologies and automate data collection to strengthen food safety, recalls and consumer trust.

Contribution/value added: The study recommends technology adoption, inter-organisational adoption and investment in integrated traceability systems. The proposed framework supports food safety, consumer trust and supply chain resilience.

Keywords: blockchain technology; supply chain; food traceability; transparency; food safety; decentralisation; interoperability; network theory.

Introduction

Food supply chains consist of a complex network of producers, distributors and retailers, working together to ensure food products are available for consumption (Haji et al. 2020). However, traditional traceability systems depend on manual, basic enterprise resource planning (ERP) systems and non-integrated technologies such as quick response (QR) codes, radio-frequency identification (RFID), wireless sensor networks (WSN) and deoxyribonucleic acid (DNA) barcoding (Galvez, Mejuto & Simal-Gandara 2018; Kamble, Gunasekaran & Arha 2019; Menon 2019; Tian 2016). The lack of integration of these technologies results in limited visibility in the food supply chain and an increased risk to food safety (Kollia, Stevenson & Kollias 2021). In the South African fast-moving consumer goods (FMCG) industry, these challenges are worsened by regulatory complexities and the reluctance to share information across supply chain participants (Oghazi et al. 2018).

These operational limitations pose managerial challenges as supply chain managers are under pressure to improve food traceability, comply with regulations and respond to consumer demands

of transparency. Without farm-to-fork food traceability, businesses face a lack of supply chain visibility, reputational damage, increased recall time and costs, and the loss of consumer trust. Effective food traceability is not merely a logistical concern but a fundamental management responsibility, directly impacting risk mitigation, brand integrity and operational resilience.

Consumers are increasingly demanding ethical practices, product authenticity and transparency in food (Fancisco & Swason 2018). The demand for verifiable food origins, sustainability-related certifications that verify sustainable and ethical production processes, and compliance with religious dietary laws (for example, halal and kosher) has increased and resulted in food producers being compelled to find more effective traceability systems (Rejeb et al. 2020). Blockchain technology has emerged as a potential disruptor in the South African FMCG industry as it provides a decentralised, tamper-proof and transparent record of information from farm-to-fork (Casino, Dasaklis & Patsakis 2019; Galvez et al. 2018; Kamble et al. 2019; Tian 2016).

Unlike traditional traceability systems that function in silos and lack interoperability across the supply chain (Galvez et al. 2018; Kamble et al. 2019), blockchain technology enables interoperability by integrating different traceability technologies, creating a ledger that is shared, unified and serves as a single source of truth that is accessible to all stakeholders. Blockchain will become a centralised point of access for all stakeholders to access, but it will remain decentralised as different stakeholders will be able to add information to the database from their decentralised areas or respective nodes. Therefore, information such as production conditions, temperature and supply chain movements is then validated by the network through consensus mechanisms to ensure immutability, transparency and enhanced consumer trust in food safety and traceability (Casado-Vara et al. 2018; Kamilaris, Fonts & Prenafeta-Boldú 2019).

While existing literature extols the benefits of digital transformation, it offers limited insight into integrating blockchain technology with legacy systems (Ancillai et al. 2023; Casino et al. 2019; Menon & Jain 2021). Furthermore, research remains predominantly focused on the technical features of blockchain (Casino et al. 2019; Yli-Huumo et al. 2016) or its high-level adoption frameworks which focus on adoption drivers, conceptual models and organisational readiness (Molati, Ilorah & Moeti 2021), with scant attention paid to its interoperability with established traceability technologies like QR codes, RFID and ERP systems because existing studies focus on implementation challenges or isolated application use cases rather than interoperability (Demestichas et al. 2020; Feng et al. 2020; Mavilia & Pisani 2022) Consequently, managers lack clear guidance for implementation of blockchain-based traceability systems, as alternative solutions like upgraded ERPs fail to provide the decentralised, secure collaboration required for multi-stakeholder supply chains (Kamble et al. 2019). This study bridges this gap by developing a practical framework that integrates blockchain with existing technologies to create a seamless farm-to-fork traceability system, providing South African FMCG managers with a clear pathway to a more secure and integrated traceability infrastructure.

The article is organised as follows: the introduction discusses the traceability challenges in the South African FMCG industry, focusing on fragmented systems and the limitations of existing technologies. The literature review explores traditional traceability systems, their limitations, the concept of interoperability and the purpose of blockchain technology in enhancing food traceability. The interpretivist paradigm, the use of focus groups and interviews for data collection and content analysis, is covered in the explanation of the methodology. The findings of the study are followed by a proposed blockchain-based framework that was informed by network theory, aimed at improving end-to-end traceability through interoperability. The study concludes with a summary of the findings and recommendations for enhancing food traceability in the South African FMCG industry.

Literature review

To enhance food safety, quality and authenticity, traceability in food supply chains is important. As food moves through the supply chain, traceability technologies such as RFID, QR codes, DNA barcoding and WSNs are important in tracking and tracing movement and authenticity; however, they also have limitations such as environmental factors, readability problems and the incapacity of providing item-level tracking. These limitations highlight how important it is to improve the integration of different traceability technologies to enhance real-time and reliable tracking and tracing of food products from farm to fork. This literature review explores current traceability technologies, their limitations, and the potential of other solutions, such as blockchain technology, to overcome the existing challenges and to enhance the effectiveness of food traceability technologies.

Limitations of traditional traceability technologies

Conventional traceability technologies such as RFID, QR codes, DNA barcoding, WSN and ERP systems are usually applied at different stages of the supply chain. However, they also present limitations in terms of environmental conditions, line of sight constraints and the inability to track food products at the ingredient level.

Readability and environmental challenges

Factors such as metals and liquids, line of sight, read range and durability can affect how traceability systems provide information, which may affect the accuracy of the information retrieved, recorded and shared (Kumari et al. 2015). Radio-frequency identification is widely recognised for tracking information in the supply chain, but it is not commonly used in the food and beverage industry because

radio-frequency waves do not reflect metals, and liquids absorb radio-frequency waves, making it challenging to read tags placed on their surface (Barge et al. 2019; Kumari et al. 2015). As a result, the water content in food and the presence of aluminium in food's packaging, such as aluminium foil boxes, glass bottles and jars, pose a challenge for food traceability and hinder information sharing (Barge et al. 2019).

In contrast to RFID, QR codes can be used in all stages of the supply chain as they can be placed on any food packaging (including metals and liquids) (Rotsios et al. 2022). To monitor the quality and safety of products, traceability systems should be able to withstand harsh environmental conditions such as sunlight and natural hazards, which could affect the functionality of the traceability technology (Abenavoli et al. 2016; Kumari et al. 2015). Abenavoli et al. (2016) state that QR codes were problematic in terms of the readability of barcodes because of their resistance to harsh environmental temperatures and external factors, including dirt, humidity and twisting (the physical distortion of the QR code), resulting in reduced reading accuracy, interrupting the supply chain and hampering the sharing of food product information.

Line of sight auto-ID technology needs a reading device to see a data carrier, and there can be no physical obstruction between the auto-ID technology and the reading device (Itemit 2022).

Quick response codes experience readability challenges as they require a line of sight for the information of food products to be captured or read, resulting in historic food information, processing and distribution information being lost to the supply chain where the line of sight was unclear. Radio-frequency identification does not require visual contact; however, passive RFID and QR codes are more likely to experience human error because each product must be scanned manually (Itemit 2022).

Enterprise resource planning systems experience problems with readability, especially with complex data, as a result of inconsistent formats and legacy systems, leading to difficulties in data extraction and interpretation (Bandara et al. 2024; Friedman Corporation 2024; Schwarz 2022). Consequently, supply chain managers are hindered in making data-driven decisions regarding inventory, risk and food quality, as they lack the accurate, real-time data required for these critical functions.

Challenges in item-level tracking

Yiannas (2018) states that food product recalls in recent years have been caused by single ingredients, and these recalls can last for more than a month because of inefficient traceability systems. Tracking the finished product may be difficult and time-consuming because a unique ID is generated for every supply chain participant to trace product history further (Tarjan et al. 2014; Westerkamp, Victor & Küpper 2018). While RFID is typically applied to final products, it offers limited visibility into individual ingredients, which are often the source of safety issues, thereby complicating recalls (Tian 2016). Similarly, QR codes are rarely effective for recalls as they are affixed to packaging rather than the product itself. In contrast, blockchain technology enables precise, item-level tracking to overcome these limitations (Arora 2019).

Blockchain technology establishes a decentralised, tamper-proof and transparent platform for farm-to-fork traceability. However, its effectiveness is contingent upon integration with other tracking technologies. For instance, QR codes enable consumers to scan a product and instantly access detailed information – such as its ingredients, shelf-life and origin – stored on the blockchain. Similarly, DNA barcoding allows for the precise tracing of grains; a unique DNA marker applied at the farm level can be identified at the feed mill and beyond, creating a verifiable biological trail. When this biomarker data is recorded on the blockchain, every transaction is securely linked back to its source. For supply chain managers, understanding how to synergise these technologies is critical. Such integration is fundamental to achieving robust traceability, enabling efficient recalls and ensuring operational accountability by providing all stakeholders with accurate, timely and accessible food information.

Interoperability in traceability systems

Interoperability is the ability of different technological systems or software programmes to communicate seamlessly for exchanging, interpreting and utilising data; for full supply chain digital traceability to improve the safety of the global food system (Hardt, Flett & Howell 2017). From a logistics and supply chain management perspective, interoperability refers to the ability of independent networks to mutually conduct business with one another to leverage the functionality of other networks (Khan & Abonyi 2022; Pan et al. 2021). Interoperability enables the integration of different technologies such as RFID, QR codes, WSN, DNA barcoding, ERP systems and blockchain technology to ensure the: (1) tracking and tracing of information about a food product, (2) in all the stages of the supply chain, (3) in real-time, and (4) to meet safety and quality standards.

The seafood industry faces challenges such as inaccurate storage of data, improper storage, illegal fishing and product mislabelling, all of which have a negative impact on consumer trust (Kamath 2018). This serves as an example of how blockchain technology is able to enhance traceability in food supply chains. For instance, Hyperledger Sawtooth, a blockchain platform for managing distributed ledgers, integrates sensors (attached to fish) to monitor the origin, temperature, humidity and environmental conditions of food (Tse et al. 2017). The consumer then has access to a complete record of information to enhance integrity and trust for all supply chain role-players (Tse et al. 2017).

Figure 1 demonstrates a hybrid way of how traceability systems can complement each other to bring about a traceability system that stores authentic food information in a decentralised ledger.

Figure 1 demonstrates that no single traceability technology can provide farm-to-fork traceability without integrating with other technologies (Menon & Jain 2021). Although blockchain technology can store authentic information that cannot be tampered with, it cannot tag, identify and store information on its own but needs a tag system such as RFID and QR codes to identify and store product information (Bux et al. 2022; Kamilaris et al. 2019; Tian 2016; Wang, He & Wu 2022). Radio-frequency identification, WSN and blockchain technology are used in conjunction with an agri-food traceability system, where RFID tracks information during production, processing, warehousing, distribution and sales, and blockchain technology ensures reliable and authentic information (Tian 2016; Wang et al. 2022). Blockchain technology could be utilised throughout all the supply chain stages, from farm-to-fork and can be stored in the decentralised ledger (Bux et al. 2022). Therefore, a primary management function is to strategically select, integrate and govern this suite of complementary technologies to achieve end-to-end visibility and operational control.

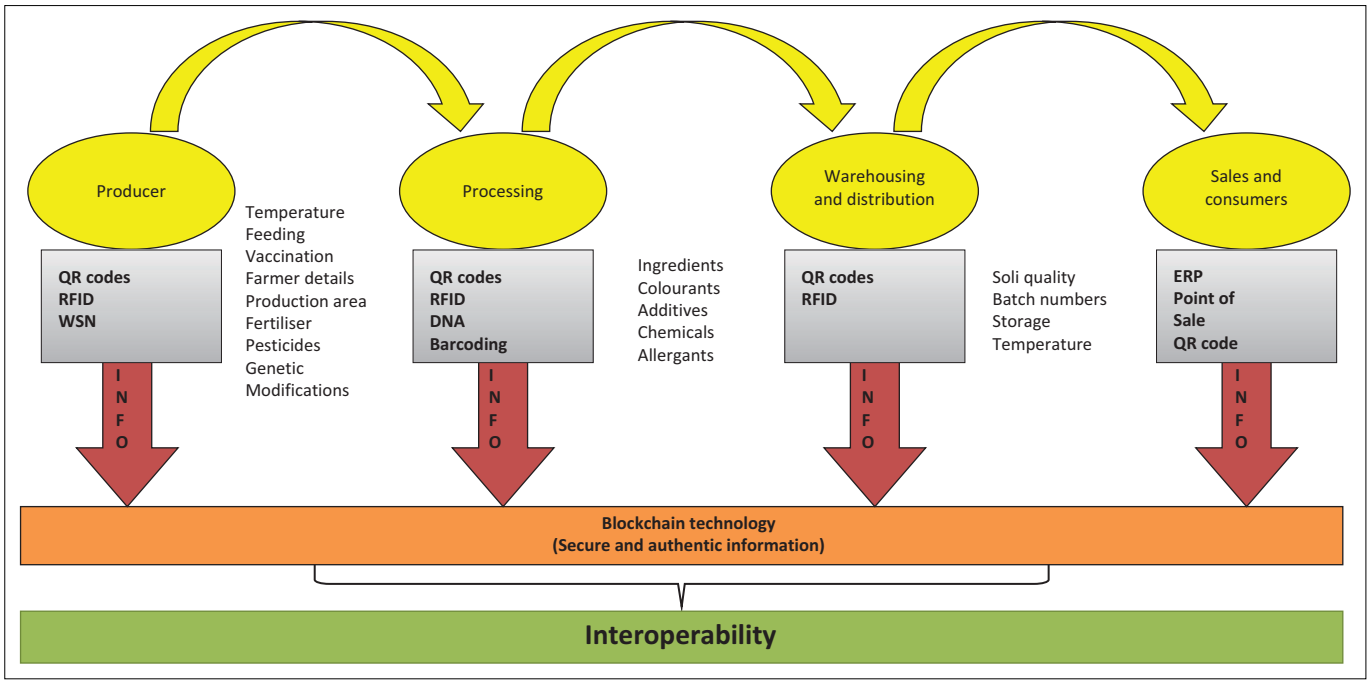
Theoretical framework

This study is grounded in the network theory, which analyses how nodes such as companies, technologies and individuals are interconnected to exchange and validate data in a decentralised food supply chain. (Hardt et al. 2017; Treiblmaier 2018). The network theory highlights the importance of these connections whereby data flow between the nodes in real-time, enabling role-players to access and share information across various stages of the food supply chain. For example, RFID and blockchain nodes are connected through digital links to verify the movement of food to ensure transparency (Hardt et al. 2017).

In a decentralised supply chain, multiple role-players such as farmers, distributors, retailers and consumers can contribute data while verifying one another's contributions. The network theory aims to understand inter-organisational relationships by focusing on relationships amongst different nodes in the food supply chain as well as mutual trust through cooperative exchange processes (Treiblmaier 2018). The distributed trust enhances traceability and reduces the risk of manipulation and tampering, which is vital for blockchain technology integration in the South African FMCG industry (Tse et al. 2017). Therefore, by applying a network theory lens, management's core function shifts from overseeing linear chains to actively governing a dynamic web of relationships, ensuring data interoperability and collaborative trust across all traceability partners.

Research methods and design

Guided by an interpretivist paradigm, this study employed a phenomenological design to explore the lived experiences of participants with blockchain technology for food traceability within South Africa's FMCG industry. A qualitative methodology was deemed to be appropriate as it facilitated an in-depth understanding of participants' perceptions and reflections regarding implementing traceability systems (Smith, Larkin & Flowers 2021). The study population was drawn from 180 food and beverage manufacturers in



DNA, deoxyribonucleic acid; ERP, enterprise resource planning; RFID, radio-frequency identification; QR, quick response; WSN, wireless sensor networks.

FIGURE 1: Integration of food supply chain traceability systems.

TABLE 1: Overview of interview participants.

Participant ID	Company (pseudonym)	Position
P1	Company A	Planning manager and managing director
P2	Company A	Quality assurance supervisor
P3	Company A	Quality assurance manager
P4	Company A	Distribution and receiving supervisor
P5	Company B	Supply planning manager
P6	Company B	Quality and safety lead for sub-Saharan Africa
P7	Company B	Site quality supervisor
P8	Company B	Warehouse and supervisor
P9	Company C	Logistics manager
P10	Company C	SHEQ coordinator
P11	Company C	Logistics manager
P12	Company C	Warehouse and logistics supervisor

ID, identification; SHEQ, safety, health, environment, and quality.

Gauteng, South Africa, selected from a broader pool of 1853 FMCG companies possessing active Global Company Prefixes (GCPs) and employing at least 500 people. Gauteng was chosen as the research site because of its economic significance and high concentration of FMCG activity. A purposive sampling strategy was utilised to select both organisations and participants, ensuring the inclusion of individuals with relevant knowledge and experience in the research area (Creswell 2012; Polit & Beck 2012). The target sample size was not predetermined; instead, data collection continued until saturation was reached (Polit & Beck 2012). This process culminated in 12 in-depth, semi-structured interviews with staff from food manufacturing FMCG organisations that held active GCPs, as summarised in Table 1. This sample size falls within the range generally considered to be sufficient for qualitative interview-based research, which typically comprises 5 participants – 25 participants (Creswell 2013; Saunders 2013). Participants were categorised into strategic and operational roles, all possessing a minimum of 3 years of relevant industry experience.

Four focus groups consisting of four participants in each (16 participants in total) were conducted, using snowball sampling (Creswell 2012). Interviewees from FMCG companies referred additional participants, which included consumers, farmers and blockchain experts, to ensure diverse focus group participants who provide a holistic view of the supply chain, traceability issues and the benefits of blockchain technology.

Data collection

The data were collected using in-depth semi-structured interviews and focus groups. Interview and focus group guides were developed from the research objectives and the theoretical lens, which is based on the network theory. Interviews were conducted at the respective FMCG companies and online using Microsoft Teams. All interviews and focus groups were recorded with participant consent and were later transcribed verbatim.

Data analysis

The data were analysed using inductive content analysis through the ATLAS.ti 22 and 24 software (ATLAS.ti Scientific Software Development GmbH, Berlin, Germany). The process followed the method proposed by Elo and Kyngäs (2008), which involves preparation, organising and reporting qualitative data. Open coding was applied to allow themes to emerge naturally from the data (Braun & Clarke 2006; Elo & Kyngäs 2008). The codes were grouped to generate themes. The reporting process was done by summarising the findings and demonstrating the information from participants with quotes (Braun & Clarke 2006).

Interviews, focus groups and literature contributed to triangulation, which supports the study's trustworthiness (Patton 1999). Triangulation minimised researcher bias and enhanced the credibility of findings (Patton 1999).

Trustworthiness and ethical considerations

This study adhered to the trustworthiness criteria of credibility, transferability, dependability, confirmability and authenticity (Lincoln & Guba 1985). Credibility was ensured through member checking and triangulation. Transferability was supported by providing detailed descriptions to ensure that other studies can be conducted in similar contexts. Dependability was maintained through an audit trail, and confirmability was established through triangulation to ensure that data were interpreted in an unbiased manner, and open-ended questions were used during interviews and focus groups. Authenticity was maintained through accurately representing all the participants' perspectives.

Research limitations

Some limitations affected the research process. The participating FMCG companies were based in Gauteng; this therefore means that the findings of this study may limit the generalisability of findings for other provinces in South Africa. Furthermore, the initial methodology included document analysis for data collection; however, participating companies raised confidentiality concerns, and therefore, document analysis was replaced with focus groups.

Ethical considerations

Ethical considerations were guided by the University's research guidelines to ensure compliance with principles such as informed consent, confidentiality and secure storage of data. This study was granted ethical clearance by the Department of Applied Management Ethics Review Committee, with the ethics clearance reference number: 2023_CEMS_DAM 007 (2023-1757-2073).

This study involved human participants who took part in interviews and focus groups. Informed consent was obtained from the participants in writing, through signed approval letters, before the interviews. For virtual interviews, consent forms were signed via email. Anonymity and confidentiality were maintained by using pseudonyms and removing any identifiable information. All the data were securely stored; documents stored in the computer were protected by

encrypting them with a password, and only the researcher had access to the passwords. Paper documents were secured in the researcher's office under lock and key. In accordance with the university's ethics policy, data will be retained for a period of 15 years; after 15 years, the researcher will safely discard the hard copies (shredding), and the soft copies will be deleted.

Gatekeeper permission letters were granted by each FMCG company to access participants. The study also complied with the *Protection of Personal Information Act*, ensuring that personal data is securely protected.

Results

The study identified three themes and nine subthemes that highlight challenges in achieving food traceability in the South African FMCG industry: limited information sharing across the supply chain, limitations of current traceability technologies and unintegrated traceability systems. Interview and focus group participants highlighted that important supply chain information is not shared with external role-players, and FMCG companies rely on manual methods such as emails, spreadsheets and paper-based records. These manual methods hinder transparency and increase the risk of food recalls.

Current traceability technologies, such as ERP systems, barcodes and QR codes, do not support item-level tracking and storing important information such as temperature and storage conditions. The lack of integration creates data silos and limited end-to-end traceability. Table 2 highlights the key themes and subthemes that were identified from the data.

Company A, Company B and Company C present gaps in how information is shared in the food supply chain. Enterprise resource planning systems that are currently used by FMCGs are insufficient in the context of information sharing. Company A, Company B and Company C's dependence on manual processes, barcodes, QR codes, RFIDs and ERP systems for basic operations (invoices and inventory control) does not aid comprehensive information sharing because they do not provide information about how a product was produced, how it travels through the supply chain, food temperatures and storage conditions.

Information used by Company A, Company B and Company C is not shared with external supply chain participants, which leads to the reliance on methods such as Excel spreadsheets and emails to communicate important information. These manual methods are not only time-consuming but also prone to human errors and are viewed as unreliable by stakeholders in the supply chain. All three companies demonstrated that information is not easily available and shared amongst supply chain participants and that it is subject to strict access control. Participant 3 from Company A noted how information sharing between supply chain partners is influenced by confidentiality concerns, resulting in limited access to vital information sharing:

> 'There is a portal, certain people have access to between us as the manufacturer and [*retailer A*]. But then, I am sure there's also restrictions within that portal.' (P3, Company A)

According to Participant 2 from Company A, there is a disconnect between real-time data capture and its integration into the system which can result in delays and inaccuracies in accessing information:

> 'But the data that has been done today and this week, in terms of receiving and recording the temperatures, I can't find it on the system.' (P2, Company A)

This need for accessible, real-time information is supported by Gottschald (2024), who argues that real-time traceability provides significant benefits, including better quality assurance and the ability to quickly identify and resolve issues. The lack of such capabilities in manual systems, where data retrieval can be slow and prone to errors, represents a significant challenge in maintaining food safety and quality standards.

Company B demonstrated that, while information is shared internally, it is not always accessible to customers. Participant 8 from Company B stated:

> 'So, different customers, yes, there's access to information … information is available at the request between us and the customers.' (P8, Company B)

The limited information sharing slows down information flow and has an impact on coordination between partners, as it affects the real-time exchange of information that could assist the food recall process. According to Charlebois and Haratifar (2015), traceability at every point of the supply chain improves consumer confidence and product integrity. However, maintaining visibility across all stages of the supply chain becomes difficult when data are kept in non-integrated systems (Agrawal et al. 2021; Ahmed et al. 2021). The effectiveness of traceability is compromised by this reliance on manual processes, which leads to poor coordination and delayed communication across various supply chain stages.

Despite Company A being less technologically advanced than Company C, both companies experience challenges with barcodes. Participant 1 from Company A highlighted an issue whereby the information that is stored in barcodes results in the printing of incorrect use-by dates on food product packaging, which then compromises the quality and safety of food.

TABLE 2: Themes and subthemes.

Themes	Subthemes
Limited information sharing across the supply chain	Limited access to external information
	Over-reliance on manual communication
	Limited real-time data sharing
Limitations of current traceability technologies	Inadequate ERP systems
	Lack of item-level tracking
	Data loss
Unintegrated traceability systems	Manual and digital technologies operating in silos
	Limited end-to-end traceability
	Integration challenges in multi-tech companies

ERP, enterprise resource planning.

Printing of the wrong dates hampers accurate information sharing on food products, such as product handling and storage, affecting product quality and safety throughout the supply chain. Furthermore, Participant 11 from Company C highlighted the challenge faced with QR codes and linear barcodes in maintaining master site data because of product changes and explained that outdated master data leads to barcodes not matching with the actual products. Participant 11 stated:

> 'New products that come into the system, the master data has to be updated. Sometimes, you might find that the barcodes do not correspond to the actual products, so that needs to be updated.' (P11, Company C)

This results in the wrong products being delivered.

Participant 5 from Company B states that, while barcodes or finished goods on pallets provide the batch number, additional steps are required for traceability, to access detailed product information such as temperature, production time and ingredients:

> 'So, we will use the batch details in order to facilitate looking at what material was used for that particular batch and then track upstream from the batch number.' (P5, Company B)

Therefore, scanning the barcode will only provide the batch number and will not provide comprehensive information about the product for traceability, which increases the risk of errors and delays.

Traceability is not just about responding to food crises through recalls but also about ensuring the continuous safety and quality of products through comprehensive data management. However, when critical information is scattered across paper records or unintegrated systems, it becomes difficult to guarantee the integrity of the food supply chain. By implementing blockchain technology, all supply chain partners will have access to accurate information, therefore enhancing transparency and the ability to trace products throughout the supply chain. Finding 1: The lack of information sharing reduces traceability and food safety in the South African FMCG companies.

Technology 1 and Technology 2 used by Company A, Company B and Company C are ERP systems that contribute to challenges in tracking and tracing food products in food recalls and mock recalls in the FMCG industry. According to Wisner, Tan and Leong (2019), ERP systems are systems that allow companies to integrate business processes and share information. Furthermore, ERP systems manage operational data such as invoicing, inventory levels, sales, production dates and batch details and are not necessarily a traceability system (Katuu 2020). This statement is supported by Participant 1 from Company A, regarding the use of ERP system, states:

> 'So, Technology 1 is for invoicing, making sure that we've got need not negative stock and if we got paid positive stock, we can trace that between your different transactions.' (P1, Company A)

Participant 2 from Company B discusses Technology 2, which is an ERP system that does not necessarily enable food traceability but is used for invoicing. Participant 6 states:

> 'Technology 2 in the system, it's not, it's not really used for traceability … the financial reasons because all of the costing and accounting, et cetera, is done via the Technology 2 system. There isn't batch coding that's recorded into Technology 2 …' (P6, Company B)

Company A and Company C mentioned that they use linear barcodes, which are made up of digits to manage inventory, which are implemented for scanning during warehousing processes such as receiving, picking and delivery. Company A uses basic one-dimensional barcodes to store basic information such as product codes and production dates to manage inventory; however, they also rely on manual processes by using traceability tags that are printed and attached to product batches. Participant 1 from Company A states:

> 'So, from batch one, after cooking then you've got the traceability tag … It states the date, code, product code and so on.' (P1, Company A)

Participant 7 from Company B stated that the manual traceability system experiences storage constraints as a result of years of accumulated paperwork, which overwhelms physical storage spaces and also makes data retrieval time-consuming. This was stated by Participant 7 from Company B:

> 'No, it's not just the timekeeping. It's the space … firstly, if the system is manual and the amount of paperwork that the attached. Now imagine you're keeping a two [*years*] or three years' worth of paperwork for such a long time. We've got two big rooms full of shelving and storage where documentation is currently kept, and it's still not enough.' (P7, Company B)

To manage the overflow of information, Company A, Company B and Company C store extra information in external repositories or storage facilities. Although this reduces storage limitations, it risks losing historical data, which is vital for product recalls and audits. Participant 6 from Company B states:

> 'Then it goes for destruction [*manual information not needed*] at the factory, gets shredded at the factory and gets sent for the paperwork, gets sent for recycling.' (P6, Company B)

Information stored manually on paper across Company A, Company B and Company C is usually stored for a period of 3 years – 5 years and it is then discarded (Mekki et al. 2019).

Although digital technologies such as barcodes, QR Codes and RFID are used by FMCG companies, their integration into ERP systems is limited. Company B utilises scanners and licence plate number (LPN) labels, which are QR codes to track and trace inventory through an ERP system. Participant 8 from Company B states:

> 'We use scanners, we track it. So, stock would have LPN labels when it's produced and moved from the plant to the DC …' (P8, Company B)

Participant 11 from Company C mentions that QR codes are used for the following:

> 'Batch codes identification when receiving, product identification for traceability, product information at the storage level, QR codes are used at the storage level when delivering products and when conducting product recall for easy traceability.' (P11, Company C)

Company C, which is more technologically advanced than Company A and Company B, uses RFID for operational efficiency, quality control, verification of delivery and reverse logistics. Participant 11 from Company C states:

> 'Quality checking uses an RFD hand-held scanner, which reads the barcode for verification that the correct stock is picked for the customer order, by scanning at the delivery point. Scan at returns [*reverse logistics*] for verification of stock and location where stock is to be returned.' (P11, Company C)

Fast-moving consumer goods companies use standard ERP systems that do not support functionalities that are important for the industry, such as the real-time tracking of cold food. Information such as temperature and storage conditions is stored manually on Excel spreadsheets, only accessible to employees who require the information. This was stated by Participant 8 from Company B:

> 'I think it's manually captured in Excel [*storing information such as time of production, storage conditions, ingredients etc.*] … for example, sugar is kept 15 degrees, the room will be 15 degrees, however, the recording of the temperature will be kept on a manual spreadsheet because we don't have a system where we capture it and then it populates all the way across.' (P8, Company B)

Participant 2 from Company A, like Company B, uses an ERP system, Technology 1, which does not store detailed information on storage conditions, temperature and time of production. The absence of this capability in the ERP results in the manual recording and tracking of critical food information:

> 'They don't give you the data, what time was it produced, which line, the temperatures, storage, yeah.' (P2, Company A)

From a focus group perspective, farmers must often deal with manual record-keeping for important information such as harvest dates, production quantities and storage conditions. Manual record-keeping results in the risks of inaccuracy and documentation errors, as highlighted by Farmer 5, Focus Group 4:

> 'It's in the files and the book where you write when you planted, when you fertilised and when you do the weeding and then on which day is it supposed to be harvested …' (F5, Farmer 5, Focus Group 4)

The manual entry of data in the FMCG industry poses a danger as a result of human mistakes, which leads to compromised data entry, as highlighted by Ellahi, Wood and Bekhit (2023). Farm-to-fork traceability is not supported by ERP systems because FMCG companies find that the current ERP systems are insufficient when it comes to handling food traceability. Finding 2: ERP systems do not support farm-to-fork tracking and tracing of food because FMCG companies experience limitations with the existing ERP systems in managing food traceability.

Integration refers to the seamless coordination of supply chain activities and role-players such as suppliers, manufacturers, distributors, retailers and consumers (Tiwari 2021). The degree to which managers are connected by a supply chain network, coordinate their activities and communicate influences supply chain integration. An organisation is fully integrated if it establishes partnerships and leverages information technologies such as blockchain.

Fast-moving consumer goods companies experience a lack of integration because of the manual processes used with the ERP systems. For integration to take place, manual processes should be eliminated and systems should be integrated throughout. The integration of digital technologies in small and medium-sized organisations often lags as a result of high costs and complexity, resulting in a mix of manual and digital processes that can create data silos and inefficiencies. Digitalisation and 4IR in the supply chain frequently make it difficult to combine new digital tools with old systems, which might result in insufficient traceability.

Information silos result from Company B's employment of both manual and ERP (Technology 2) systems for information storage, making it challenging to track information from farm to fork. Information silos reduce the reliability of the quality of food provided by FMCG companies to the public. Company B uses manual documentation and a third-party system ('System A') as well as Technology 2, which is an ERP system. Despite being more advanced than Technology 1, Company B is still not able to achieve end-to-end traceability. The technology's reliance on manual entry and limited use for traceability are the causes of human errors and inefficiency.

It is clear that there is no end-to-end traceability, and Participant 6 from Company B says the following regarding Technology 2:

> 'Ok. So, when it comes to Technology 2 from the current setup of Technology 2 in the system, it's not, it's not really used for traceability, if I can put it that way.' (P6, Company B)

According to Farmer 3 from Focus Group 3, they use manual techniques like Excel spreadsheets or paper-based records in order to track data:

> 'So, currently there are, most of it is kept on Excel or kept on paper sheets, on clipboards, and in that case, it's filed or captured, and you don't really look at it until someone wants to do analysis or you have to provide a report back to a retailer.' (F3, Farmer 3, Focus Group 3)

This quote illustrates how manual processes continue to dominate data management, hence impeding traceability.

Furthermore, Farmer 6 from Focus Group 4 highlights the absence of integrated systems, which then delays the process of food recalls, especially when information is retrieved manually during recalls.

> 'The auditor will choose block B, which was harvested … on the 1st of June [*year not specified*] and then the question would be where, you know, what was the process for this product … before it reached out, who handled, who harvested it, who planted, who fertilised it, who delivered the seedlings and so it goes. So, that sort of process will be really about looking back into that recorded paperwork.' (F6, Farmer 6, Focus Group 4)

Farmer 6 further highlights the challenge of non-integrated systems when asked where information is stored, which is partially on paper and partially on the system:

> 'So, at the moment that information is kept on file on file, digitally on an Excel sheet and then printed for use in fields for record-keeping and then filed and kept until it's required.' (F6, Farmer 6, Focus Group 4)

Company C uses more advanced technologies such as Technology 2, RFID, scanners and voice recognition, but the company still faces challenges in achieving food traceability. Company C experiences complexity because of different technologies, which means that different technologies are used at different stages of production:

> '… [*D*]epending on the scale of production, there will be different technologies that are applied at different stages.' (P11, Company C)

The use of multiple technologies throughout the supply chain can create silos where data from different stages of production and technologies is not seamlessly integrated (Wisner et al. 2019).

The lack of integration and reliance on manual processes means that the company cannot efficiently capture and store traceability data. The company is then unable to effectively store and capture traceability data from farm-to-fork. Operational disruptions like food recalls may result from this inefficiency (Alfian et al. 2017). Furthermore, the data silos that are caused by a lack of cloud systems impede seamless information sharing throughout the end-to-end supply chain (Islam, Manning & Cullen 2022). Trienekens et al. (2017) emphasise the need for better-integrated systems to reduce gaps in achieving end-to-end traceability to reduce disruptions in the food supply chain.

Integration is important in the FMCG industry, where the perishability of food is important, not only for compliance but also for food safety (Buse 2020). The manual systems do not integrate with other systems, which also creates an additional standalone system that detracts from traceability efforts. Manual systems hinder integration, as Participant 2 from Company A stated:

> 'There's no integration because, for example, as I told you, if I will do traceability now for a product that is non-conforming, I would have to find the receiving documents on a file and I was supposed to find those receiving documents on the system so if there was integration, they were supposed to be on the system, so they still have to work on that.' (P2, Company A)

The degree of integration has a direct impact on the supply chain's resilience and efficiency. When companies use innovative information technology like blockchain to improve transparency and real-time data sharing, full integration is more likely to be achieved. Mkhonto and Zuva (2023) emphasise that the adoption of such technologies is a key indicator of an organisation's integration level. Improved technological adoption and integration will ensure that all parts of the supply chain are adequately connected and are capable of end-to-end traceability. Finding 3: The lack of integrated traceability systems results in inefficiencies in the tracking of food, which affects food recalls in the South African FMCG industry. Figure 2 is a representation of blockchain technology adoption in the South African FMCG industry based on network theory.

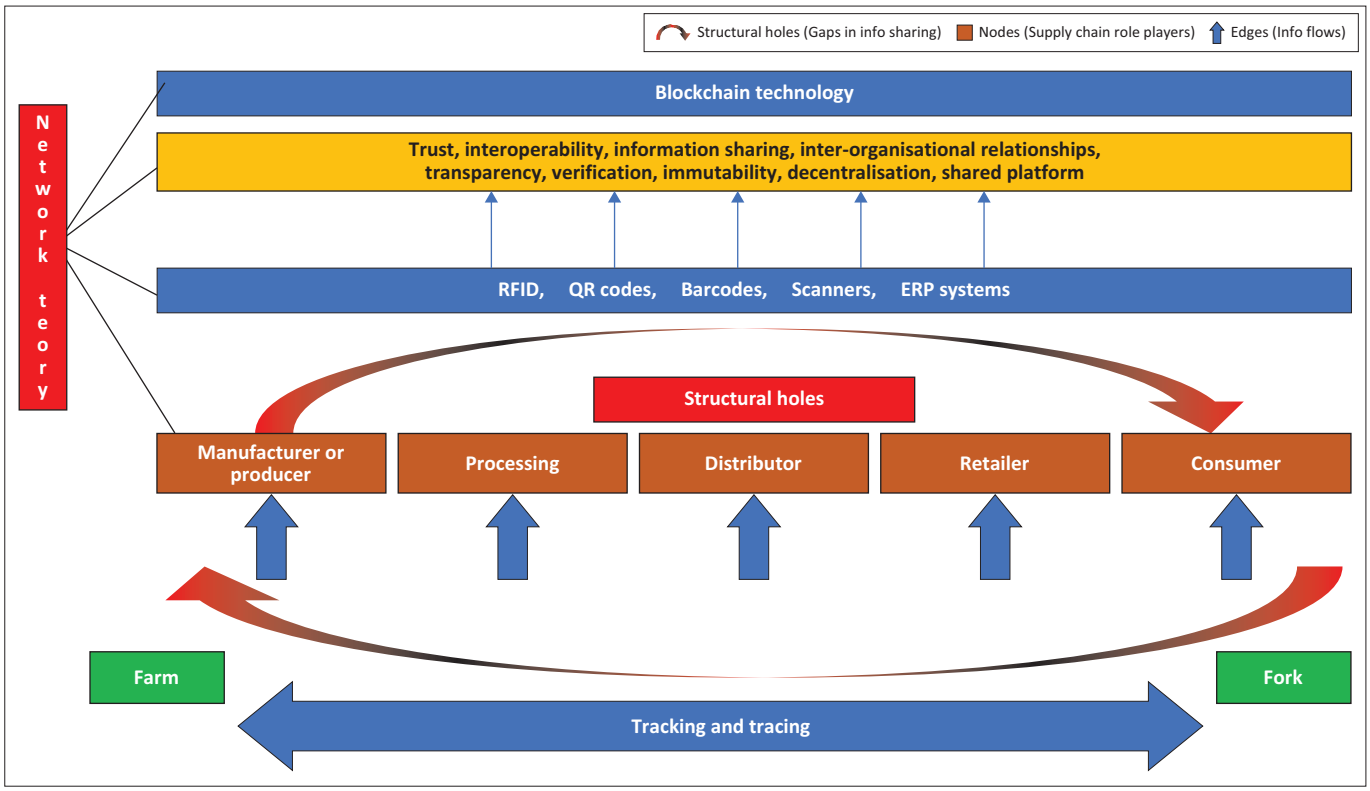
Discussion

The framework in Figure 2 incorporates the network theory, emphasising the nodes which are the supply chain role-players, the edges which are information flow and the structural holes which are the gaps in collaboration. Information sharing is vital for traceability in the food supply chain. Currently, manual processes and the lack of information sharing hinder communication between different nodes such as farmers, manufacturers, distributors and retailers. Blockchain technology, which is at the centre of Figure 1, is a decentralised platform that fosters collaboration by providing a shared immutable ledger accessible to all nodes in the food supply chain. The nodes are connected through the blockchain, and the strong ties are strengthened through transparent data sharing.

During production, RFID and QR codes capture agricultural details like farmer information, planting times and pesticide use (Kamilaris et al. 2019). While for livestock, RFID tracks movement, temperature and medical information and history (Tian 2016). Wireless sensor networks (WSN) supplement existing information with environmental data, such as the temperature under which crops were grown (Alshahrany, Abbod & Moualek 2015); with all information recorded on the blockchain through wireless networks (Tian 2016).

In processing, ingredients (the presence of pork and animal ingredients such as milk), colourants, additives, chemicals and allergens used to process the food products into final products are logged on the blockchain via RFID scans, reducing consumer reliance on certifications. Deoxyribonucleic acid (DNA) barcoding proactively identifies contaminants like undeclared pork in religiously sensitive foods, preventing fraud before recalls as consumers increasingly pay attention to food authenticity and safety.

The addition of meat in vegetarian food or the silent, undeclared inclusion of pork in Jewish and Muslim food,



RFID, radio-frequency identification; QR, quick response; ERP, enterprise resource planning.

FIGURE 2: A framework for the adoption of blockchain technology for food traceability in the South African fast-moving consumer goods industry.

which is prohibited, can be identified using DNA barcoding information in the processing stage of the supply chain, and not only during product recalls, preventing food fraud proactively.

Within warehouses, blockchain enables managers to trace farm origin data (the farm origin, batch numbers, soil quality, fertilisers and storage temperatures) (Kamath 2018), while RFID tags monitor inventory movement and storage conditions (the quantity, storage limit, storage conditions and receiving and delivery information). During distribution, sensors in trucks ensure safe transit (Kamath 2018).

In the final stage of the supply chain, retailers can integrate ERP and point of sale systems with the blockchain platform to trace every item sold (Kamath 2018). At the retail stage, ERP and point of sale systems integrated with blockchain enable item-level tracking, allowing contaminated products to be identified before sale (Kamath 2018). Finally, consumers access the full product history by scanning QR codes (Kamilaris et al. 2019), achieving complete farm-to-fork traceability.

Ultimately, this integrated framework redefines the managerial mandate from simple oversight to the active orchestration of a transparent and resilient supply chain network. By leveraging blockchain as the central collaborative platform, managers are empowered to close structural holes, automate information flow across all nodes, and transform raw data into auditable, strategic intelligence. Such capability provides managers with the unprecedented capability to proactively ensure food safety, execute precise recalls, verify authenticity for consumers and protect brand integrity, moving from reactive problem-solving to strategic, data-driven governance of the entire farm-to-fork journey.

Recommendations

This study recommends that blockchain technology should be integrated with other technologies such as RFID, QR codes, WSN, DNA barcoding and ERP to enable decentralised, tamper-proof, and real-time information sharing in the supply chain. Industry leaders and policymakers are urged to foster collaboration throughout the food supply chain, invest in integrated systems and promote education of new and innovative technology amongst supply chain role-players. These measures will help the South African FMCG industry to transition to a more secure, transparent and consumer-trusted traceability system. Future studies should examine how blockchain technology can be integrated with existing technologies in different FMCG companies across all South African provinces and assess implementation costs, fit with local regulations, ease of use, especially in areas where there is limited infrastructure. Future studies should investigate how traceability can be enhanced with blockchain technology at the retail level, as retailers play an important role as the final node in the food supply chain before food gets to consumers.

Conclusion

Limited information sharing, ineffective traceability technologies and a lack of integrated traceability systems

were identified as the key challenges in achieving food traceability in the South African FMCG industry. These challenges result in issues such as limited food safety, delays in recalls and reduced customer trust. This study concludes that traceability gaps in the FMCG industry will continue to exist if there is no technological integration and inter-organisational collaboration. By proposing a blockchain-based framework customised for the South African FMCG environment, this study advances current knowledge by providing an interoperable solution which bridges the gaps between legacy traceability systems and modern technologies, incorporating both supply chain role-players and technological infrastructure through the network theory. Consequently, closing these traceability gaps requires management to champion both the technological integration and foster the inter-organisational collaboration necessary for a seamless supply chain.

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Competing interests

The authors, Malente M. Modungwa and Anthea P. Amadi-Echendu, declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

CRediT authorship contribution

Malente M. Modungwa: Conceptualisation, Data curation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft. Anthea P. Amadi-Echendu: Conceptualisation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Visualisation, Writing – original draft, Writing – review & editing. All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication, and take responsibility for the integrity of its findings.

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Data availability

The data that support the findings of this study are not openly available and are available from the corresponding author, Malente M. Modungwa, upon reasonable request.

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