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Blockchain-Enabled Traceability for Food Supply Chains in West Africa

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Abstract- Food supply chains in West Africa face persistent challenges related to traceability, food safety, fraud, and weak regulatory enforcement. Fragmented supply networks, informal market structures, and limited data transparency reduce the ability of regulators, producers, and consumers to track food products across production, processing, and distribution stages. These conditions increase the risk of contamination, mislabeling, and post-harvest losses, while limiting access to higher-value markets. This paper presents a structured critical review of peer-reviewed studies that examine blockchain-enabled traceability in food supply chains, with relevance to West Africa. Drawing on journal articles and selected technical reports from international organizations, the review evaluates system design choices, traceability objectives, governance arrangements, and implementation constraints. The analysis focuses on reported benefits, data requirements, and contextual limitations. The reviewed evidence indicates that blockchain-based traceability systems can improve data integrity and auditability under specific conditions. However, their applicability in West African food systems remains constrained by infrastructural gaps, weak institutional coordination, high implementation costs, and limited stakeholder readiness. Many studies emphasize technical feasibility while giving insufficient attention to governance and adoption barriers. The paper focused approaches to traceability that align with the operational realities of food supply chains in West Africa.

I. INTRODUCTION

Food supply chains in West Africa are central to regional food security, employment, and economic activity, yet they are widely characterized by fragmentation, informality, and weak coordination across production, processing, and distribution stages. A large proportion of food products move through multiple intermediaries, often without standardized documentation or consistent oversight, which limits transparency and accountability within the supply chain (Aung and Chang, 2014; FAO, 2019). These conditions contribute to persistent challenges related to food safety, fraud, post-harvest losses, and limited access to premium domestic and export markets.

Traceability is widely recognized as a key mechanism for improving food safety management and supply chain governance. It enables the tracking of food products and associated information across supply chain stages, supporting recall systems, regulatory compliance, and consumer trust (Bosona and Gebresenbet, 2013). In developing regions, however, traceability systems often rely on paper-based records or isolated digital databases that are prone to data loss, manipulation, and delays (FAO, 2019). In West Africa, these limitations are compounded by weak enforcement capacity, limited digitization, and the dominance of informal markets, where traceability requirements are difficult to implement and monitor (World Bank, 2020).

In response to these challenges, digital technologies have increasingly been proposed as tools to improve traceability and information sharing in food supply chains. Among these technologies, blockchain has attracted growing attention due to its ability to store transaction records in a distributed ledger that is resistant to tampering and accessible to multiple stakeholders (Kouhizadeh et al., 2021). Blockchain-based traceability systems typically aim to improve data integrity, enhance transparency, and reduce information asymmetries between supply chain actors, including producers, processors, regulators, and consumers (Kamilaris et al., 2019).

A growing body of academic literature examines blockchain applications in food supply chains, with reported use cases spanning product provenance verification, food safety monitoring, and certification processes. Empirical and conceptual studies suggest that blockchain can support traceability by providing immutable records of transactions and facilitating auditability across complex supply networks (Tian, 2017; Kamilaris et al., 2019). However, many of these studies are based on pilot projects or conceptual frameworks developed in high-income countries with relatively formalized supply chains and advanced digital infrastructure.

The applicability of blockchain-enabled traceability in West Africa remains uncertain due to contextual constraints that are often underexplored in the literature. Food supply chains in the region face infrastructural limitations, including unreliable electricity, limited internet connectivity, and low levels of digital literacy among small-scale actors (World Bank, 2020). In addition, governance challenges such as unclear regulatory frameworks, weak institutional coordination, and limited incentives for data sharing shape how traceability systems are adopted and sustained (FAO, 2019). These factors raise important questions about whether blockchain-based systems can move beyond experimental deployments to support traceability in practice.

Recent review studies highlight that many blockchain traceability papers emphasize technical architecture and potential benefits while giving less attention to adoption barriers, governance arrangements, and cost implications in developing country contexts (Kouhizadeh et al., 2021). As a result, there is a need for critical synthesis that evaluates blockchain-enabled traceability not only in terms of technical feasibility, but also in relation to institutional capacity, supply chain structure, and regional realities.

This paper addresses this need by presenting a structured critical review of blockchain-enabled traceability research relevant to food supply chains in West Africa. Focusing on peer-reviewed studies, the review examines how blockchain-based traceability systems are designed, the traceability problems they seek to address, and the conditions under which they are reported to function effectively. The analysis is guided by three questions. First, how blockchain has been applied to food supply chain traceability in recent literature. Second, what benefits and limitations are reported in relation to traceability outcomes. Third, what institutional, infrastructural, and governance constraints affect the relevance of blockchain-enabled traceability in West African food systems.

By synthesizing existing studies through a regional and governance-oriented lens, this paper aims to clarify the realistic role of blockchain in improving food supply chain traceability in West Africa. Rather than treating blockchain as a universal solution, the review emphasizes alignment with local supply chain practices, regulatory capacity, and operational constraints.

II. LITERATURE REVIEW

This section reviews existing literature on food supply chain traceability and blockchain-enabled traceability systems, with particular attention to studies relevant to West African contexts. The review synthesizes findings from peer-reviewed journals and selected institutional reports to examine traceability challenges, limitations of conventional traceability approaches, and the proposed role of blockchain technologies in food supply chains.

2.1 Food Supply Chain Traceability Challenges in West Africa

Food supply chains in West Africa operate within complex social, economic, and institutional settings that create persistent barriers to effective traceability. The region's food systems are dominated by small-scale producers, informal traders, and open markets, where transactions often occur without standardized documentation or consistent regulatory oversight. These characteristics limit the ability to track food products across production, aggregation, processing, and retail stages, increasing exposure to food safety risks and supply chain inefficiencies (Aung and Chang, 2014; FAO, 2019).

One of the most significant challenges to traceability in West Africa is the high level of informality across food supply chains. Informal markets play a central role in food distribution, particularly for staple crops, fresh produce, and animal products. While these markets support affordability and access, they typically lack formal record-keeping systems that enable product identification and movement tracking (World Bank, 2020). As a result, information about product origin, handling practices, and transaction history is often fragmented or unavailable, making traceability difficult to implement and enforce.

Weak institutional and regulatory capacity further constrains traceability efforts. Many West African countries have food safety regulations and quality standards in place, but enforcement is uneven due to limited resources, overlapping institutional mandates, and gaps in coordination between agencies (Grace, 2015). Traceability systems depend on consistent monitoring, inspection, and data verification, which are difficult to sustain in settings where regulatory agencies face staffing and funding constraints. These weaknesses reduce incentives for compliance and limit the effectiveness of traceability requirements.

Infrastructure limitations also play a critical role. Reliable electricity, internet connectivity, and digital data systems are unevenly distributed across the region, particularly in rural production areas. These constraints restrict the adoption of electronic traceability systems that rely on real-time data capture and transmission (World Bank, 2020). In many supply chains, information is recorded manually at some stages and digitally at others, resulting in data discontinuities that undermine end-to-end traceability. Post-harvest handling and logistics conditions present additional challenges. Inadequate storage facilities, limited cold chain infrastructure, and poor transport conditions increase the risk of contamination and quality deterioration during distribution. Studies have shown that post-harvest losses for perishable foods in West Africa remain high, reflecting both infrastructural gaps and weak monitoring along supply chains (FAO, 2019). Without reliable traceability, it is difficult to identify where losses or contamination occur, limiting the effectiveness of targeted interventions.

Trust and information-sharing dynamics among supply chain actors further complicate traceability implementation. Small-scale producers and traders may be reluctant to share production or transaction data due to concerns about taxation, regulation, or exclusion from informal markets. In the absence of clear incentives and governance mechanisms, traceability systems may be perceived as tools for control rather than value creation (Kouhizadeh et al., 2021). These perceptions affect adoption and sustainability, particularly in contexts where supply chain relationships are built on informal agreements. Existing traceability initiatives in West Africa often focus on export-oriented value chains, such as cocoa, coffee, and horticultural products, where compliance with international standards is required. While these initiatives demonstrate that traceability can be implemented under specific conditions, their applicability to domestic food markets is limited (Grace, 2015). Domestic supply chains typically involve a larger number of actors, lower margins, and weaker regulatory pressure, making comprehensive traceability more difficult to achieve.

Taken together, the literature indicates that traceability challenges in West Africa are not solely technical in nature. They are shaped by informality, institutional capacity, infrastructure constraints, and governance arrangements that influence how information is generated, shared, and enforced across food supply chains. Understanding these challenges is essential for evaluating the relevance of blockchain-enabled traceability systems, which are often proposed as technical solutions without sufficient consideration of the broader supply chain context.

2.2 Traditional Traceability Systems and Their Limitations

Traditional traceability systems in food supply chains rely largely on paper-based records, centralized databases, and manual reporting procedures. These systems are designed to document product origin, movement, and handling at different stages of the supply chain. In principle, such approaches support food safety management and regulatory compliance. In practice, their effectiveness in West African food supply chains has been limited by structural, institutional, and operational constraints (Bosona and Gebresenbet, 2013; FAO, 2019).

Paper-based traceability remains common across domestic food markets in West Africa. Producers, traders, and transporters often record transactions manually, if at all, using delivery notes, receipts, or informal logs. These records are vulnerable to loss, damage, and deliberate alteration, and they are rarely standardized across actors or jurisdictions. As food products move through multiple intermediaries, the continuity of information breaks down, making it difficult to reconstruct product histories during food safety incidents or quality disputes (Aung and Chang, 2014).

Centralized digital databases have been introduced in some value chains to address these weaknesses. Such systems typically store traceability data within a single organizational or governmental platform, managed by a lead firm or regulatory authority. While centralized databases can improve data accessibility compared to paper records, they introduce new challenges related to trust, data integrity, and governance. Supply chain actors may question the accuracy of centrally managed records or fear data manipulation, particularly in contexts where institutional trust is low (Casino et al., 2019).

Data interoperability represents another significant limitation of traditional traceability systems. Different actors often use incompatible record-keeping formats or information systems, preventing seamless data exchange across the supply chain. This problem is especially pronounced in West Africa, where small-scale actors operate with limited technical capacity and where traceability initiatives are often implemented as isolated projects rather than integrated systems (FAO, 2019). As a result, traceability information may exist at individual stages without supporting end-to-end visibility.

Enforcement and verification challenges further reduce the effectiveness of conventional traceability approaches. Traceability systems depend on accurate data entry and regular verification to function properly. In many West African countries, regulatory agencies face resource constraints that limit their ability to inspect facilities, audit records, and verify compliance consistently (Grace, 2015). Weak enforcement reduces incentives for accurate reporting and allows non-compliant practices to persist without consequence.

Cost considerations also affect adoption. Implementing and maintaining traditional traceability systems requires investments in record-keeping infrastructure, training, and monitoring. For small-scale producers and traders operating on thin margins, these costs can outweigh perceived benefits, particularly when traceability does not directly translate into higher prices or improved market access (World Bank, 2020). As a result, participation in traceability schemes is often limited to export-oriented value chains where compliance is mandatory.

Finally, traditional traceability systems struggle to address deliberate fraud and data falsification. Centralized systems and paper records can be altered retrospectively, undermining confidence in traceability data. Studies have shown that food fraud related to mislabeling, adulteration, and origin misrepresentation remains a concern in supply chains with weak oversight mechanisms (Aung and Chang, 2014). These vulnerabilities have contributed to growing interest in alternative traceability approaches that emphasize data integrity and shared accountability.

Overall, the literature indicates that traditional traceability systems in West Africa face persistent limitations related to data reliability, interoperability, enforcement, cost, and trust. While these systems provide a foundation for traceability, they often fail to deliver continuous, verifiable, and trusted information across complex food supply chains. These shortcomings have created space for digital technologies, including blockchain, to be proposed as potential tools for strengthening traceability, particularly in environments where institutional trust and coordination are weak.

2.3 Blockchain Applications in Food Supply Chains

Blockchain technology has been proposed as a tool for improving traceability and information integrity in food supply chains by enabling shared, tamper-resistant records of transactions across multiple actors. In food systems, blockchain applications typically focus on recording product movements, processing events, and certification data in a distributed ledger that can be accessed by authorized participants. These systems aim to address weaknesses in traditional traceability approaches related to data manipulation, limited transparency, and low trust among supply chain actors (Kamilaris et al., 2019; Casino et al., 2019).

A growing body of literature examined blockchain-based traceability systems across a range of food supply chains, including fresh produce, meat, dairy, and processed foods. Many studies describe permissioned blockchain architectures, where access is restricted to verified participants such as producers, processors, retailers, and regulators. Permissioned systems are often favored in food supply chains due to data privacy requirements, regulatory considerations, and the need for governance mechanisms that define roles and responsibilities (Kouhizadeh et al., 2021).

Several empirical and pilot studies report that blockchain can improve data integrity by reducing the ability to alter records after they are created. By linking transaction data across supply chain stages, blockchain-based systems can support more reliable provenance verification and faster trace-back during food safety incidents. Studies conducted in Asia and Europe report reductions in trace-back time when blockchain is integrated with digital data capture tools such as barcodes, QR codes, or radio-frequency identification technologies (Tian, 2017; Kamilaris et al., 2019). These findings have contributed to interest in blockchain as a traceability tool for complex food supply chains.

In addition to traceability, some studies highlight the potential of blockchain to support certification and compliance processes. Smart contracts are often proposed as mechanisms for automating compliance checks, payments, or certification verification once predefined conditions are met. In theory, such features can reduce administrative burdens and improve coordination among supply chain actors (Kouhizadeh et al., 2021). However, the literature also notes that smart contract effectiveness depends on the reliability of off-chain data inputs, which remain vulnerable to error or manipulation.

Despite reported benefits, the literature identifies several limitations in existing blockchain traceability applications. Many studies are based on conceptual frameworks or small-scale pilots rather than large, operational deployments. As a result, evidence on long-term performance, cost, and scalability remains limited (Casino et al., 2019). In addition, blockchain systems do not inherently guarantee data accuracy, as incorrect or fraudulent data can still be recorded at the point of entry. This limitation is particularly relevant in food supply chains where data capture relies on manual input or informal practices.

Research focusing on developing regions emphasizes that blockchain adoption in food supply chains is shaped by infrastructural readiness, stakeholder capacity, and governance arrangements. Studies note that blockchain systems often require complementary digital infrastructure, such as reliable internet connectivity and digital identification tools, to function effectively (Kamilaris et al., 2019). Without these supporting conditions, blockchain-based traceability systems may increase complexity without delivering proportional benefits.

While relatively few studies focus explicitly on West Africa, the broader literature suggests that blockchain applications designed for formalized supply chains may face challenges when transferred to contexts characterized by informality and limited regulatory enforcement. Reviews of blockchain adoption barriers highlight issues related to cost, technical skills, and organizational readiness, which are particularly pronounced in small-scale and informal food systems (Kouhizadeh et al., 2021).

Overall, the literature indicates that blockchain has been applied to food supply chain traceability primarily as a tool for improving data integrity and transparency. However, most documented applications remain experimental and context-specific. The extent to which these approaches can be adapted to West African food supply chains depends on their alignment with local supply chain structures, governance frameworks, and data collection practices. This underscores the need for critical evaluation of blockchain traceability claims within the specific institutional and infrastructural conditions of the region.

2.4 Institutional, Infrastructural, and Governance Constraints

The adoption of blockchain-enabled traceability in West African food supply chains is shaped less by technical feasibility and more by institutional, infrastructural, and governance conditions. These factors influence whether traceability systems can be implemented, sustained, and trusted by supply chain actors over time. The literature consistently shows that digital traceability initiatives in developing regions face systemic constraints that limit their effectiveness, regardless of the underlying technology used (FAO, 2019; World Bank, 2020).

Institutional capacity is a central constraint. Effective traceability depends on clear regulatory mandates, coordination among public agencies, and consistent enforcement of food safety and quality standards. In many West African countries, food safety governance involves multiple institutions with overlapping responsibilities, limited resources, and weak coordination mechanisms (Grace, 2015). These conditions create uncertainty around data ownership, reporting obligations, and accountability, which complicates the implementation of shared traceability platforms such as blockchain-based systems.

Regulatory frameworks for digital traceability are also underdeveloped. While some countries have adopted food safety laws and standards, specific guidance on digital records, data sharing, and electronic verification is often lacking. Studies note that uncertainty around legal recognition of digital records and smart contracts reduces incentives for private actors to invest in advanced traceability systems (Kouhizadeh et al., 2021). Without clear regulatory support, blockchain initiatives risk operating as isolated projects rather than integrated components of national food control systems.

Infrastructural limitations present additional barriers. Reliable electricity and internet connectivity are uneven across West Africa, particularly in rural production areas where many food supply chains originate. Blockchain-based systems require stable digital infrastructure for data entry, validation, and access. Where connectivity is unreliable, data capture may be delayed or incomplete, undermining the continuity of traceability records (World Bank, 2020). These constraints increase operational costs and reduce system reliability.

Human capacity constraints further affect adoption. Many supply chain actors, including small-scale farmers and informal traders, have limited experience with digital tools and record-keeping systems. Training requirements for blockchain-based traceability systems can be substantial, especially when users must interact with mobile applications, digital identifiers, or scanning technologies. Studies on digital agriculture adoption indicate that low digital literacy reduces user participation and data quality, limiting the value of traceability systems (FAO, 2019). Governance arrangements within supply chains also shape blockchain adoption outcomes. Blockchain-based traceability systems rely on agreed rules for data entry, access, and validation. In food supply chains characterized by low trust and informal relationships, reaching agreement on governance rules can be difficult. Kouhizadeh et al. (2021) highlight that concerns about data misuse, surveillance, and unequal power relations discourage participation by smaller actors. These concerns are particularly relevant in West African contexts, where informal practices serve as coping mechanisms within weak regulatory environments.

Cost and sustainability considerations further constrain implementation. Blockchain systems involve costs related to software development, hardware, data storage, and ongoing maintenance. While pilot projects are often supported by external funding, long-term sustainability requires clear value propositions for participating actors. Evidence from traceability initiatives suggests that when benefits are not directly linked to higher prices, reduced losses, or improved market access, adoption rates remain low (World Bank, 2020).

Overall, the literature indicates that institutional readiness, infrastructure quality, and governance capacity are decisive factors in determining the success of blockchain-enabled traceability systems. Technical solutions that do not address these constraints risk reinforcing existing inequalities within food supply chains or failing to scale beyond pilot stages. These findings underscore the importance of evaluating blockchain traceability initiatives within their broader institutional and governance contexts, rather than focusing solely on system design.

2.5 Gaps in Existing Blockchain Traceability Literature

Although the literature on blockchain-enabled traceability in food supply chains has expanded in recent years, several important gaps limit its relevance for West African contexts. These gaps are not primarily technical, but relate to how blockchain is framed, evaluated, and situated within real supply chain environments. A recurring issue across studies is the tendency to emphasize technological capabilities while underexamining institutional, economic, and governance conditions that shape adoption and long-term use (Casino et al., 2019; Kouhizadeh et al., 2021). One major gap concerns the limited regional focus on West Africa. Most blockchain traceability studies are conducted in high-income countries or emerging economies with relatively formalized supply chains. While some papers claim applicability to developing regions, few provide empirical evidence drawn from West African food systems or comparable informal market settings (Kamilaris et al., 2019). As a result, assumptions about infrastructure availability, regulatory enforcement, and stakeholder behavior are often transferred without sufficient contextual validation. A second gap relates to the scale of analysis. Many studies evaluate blockchain traceability at the level of individual firms, pilot projects, or export-oriented value chains. These settings differ substantially from domestic food markets in West Africa, where supply chains involve numerous small-scale actors, low margins, and weak coordination. The literature provides limited insight into how blockchain systems perform when scaled across fragmented networks or integrated into national food control systems (FAO, 2019). The cost and economic feasibility of blockchain-based traceability is another underexplored area. While technical feasibility is frequently demonstrated, few studies provide detailed assessments of implementation costs, maintenance requirements, or cost-sharing mechanisms among supply chain actors. This omission is particularly significant in West African contexts, where financial constraints strongly influence technology adoption decisions (World Bank, 2020). Without clear evidence of economic viability, blockchain traceability risks remaining confined to donor-funded pilots. A further gap concerns data quality and data governance. Blockchain systems are often presented as solutions to data integrity problems, yet the literature acknowledges that blockchain does not prevent inaccurate or fraudulent data entry at the source. Few studies critically examine how data validation, verification, and accountability are managed in environments where record-keeping practices are weak and regulatory oversight is limited (Casino et al., 2019). This gap raises questions about the extent to which blockchain can improve traceability outcomes without parallel investments in data governance. The literature also shows limited engagement with stakeholder incentives and power dynamics. Small-scale producers and informal traders are frequently portrayed as passive data providers rather than active participants in traceability systems. Studies rarely examine how incentives are structured, how benefits are distributed, or how power asymmetries affect participation and compliance (Kouhizadeh et al., 2021). In West African food systems, where trust and informal relationships play a central role, these factors are critical to system sustainability.

Finally, there is a lack of longitudinal and outcome-based evaluation. Many blockchain traceability studies rely on conceptual models or short-term pilots, with limited evidence on long-term performance, adoption trajectories, or impacts on food safety and market access. Few studies assess whether blockchain-based traceability leads to measurable improvements in recall effectiveness, reduction in food fraud, or enhanced consumer trust over time (FAO, 2019). Taken together, these gaps suggest that existing blockchain traceability literature provides an incomplete basis for assessing the technology's relevance to West African food supply chains. Addressing these shortcomings requires research that moves beyond technical demonstrations to examine governance structures, economic feasibility, stakeholder incentives, and real-world outcomes. Identifying and synthesizing these gaps provides the foundation for the analytical focus of this review and frames the criteria used to evaluate blockchain-enabled traceability systems in subsequent sections.

Table 1. Key gaps in blockchain-enabled traceability literature relevant to West African food supply chains

Identified Gap	Evidence from Existing Literature	Implications for West African Food Supply Chains
Limited regional focus on West Africa	Most studies are conducted in high-income or formalized supply chains, with few empirical cases from	Limited transferability of findings to informal and fragmented markets

Identified Gap	Evidence from Existing Literature	Implications for West African Food Supply Chains
	West Africa (Kamilaris et al., 2019; Casino et al., 2019)	
Emphasis on technical design over governance	Many studies prioritize system architecture while underexamining regulatory and institutional arrangements (Kouhizadeh et al., 2021)	Weak governance may undermine traceability outcomes
Lack of economic feasibility analysis	Few studies assess implementation and maintenance costs for small-scale actors (World Bank, 2020)	Adoption is unlikely where costs exceed perceived benefits
Weak treatment of data quality and verification	Blockchain does not prevent inaccurate data entry, yet this limitation is often insufficiently examined (Casino et al., 2019)	Traceability reliability depends on complementary verification systems
Limited analysis of stakeholder incentives	Small-scale producers and informal traders are rarely examined as active decision-makers (Kouhizadeh et al., 2021)	Low participation may reduce system effectiveness
Scarcity of long-term evaluations	Most evidence is based on pilots or conceptual studies (FAO, 2019)	Long-term impacts on food safety and trust remain unclear

III. METHODOLOGY

3.1 Review Design

This study adopts a structured critical review approach to synthesize recent research on blockchain-enabled traceability in food supply chains, with relevance to West Africa. The approach emphasizes analytical comparison and contextual evaluation rather than quantitative aggregation. This design is appropriate given the heterogeneity of study designs, data sources, and outcome measures reported in the literature on blockchain traceability (Casino et al., 2019). The review focuses on how blockchain systems are applied, the traceability problems they address, and the conditions under which they are reported to function effectively. This study does not employ meta-analysis techniques, as the reviewed studies vary widely in design, data sources, and outcome measures, making quantitative aggregation inappropriate.

3.2 Data Sources and Search Strategy

The literature search was conducted using Scopus, Web of Science, and Google Scholar, which collectively cover a broad range of peer-reviewed journals in supply chain management, food systems, and information systems. Searches were performed using combinations of keywords including “blockchain,” “traceability,” “food supply chain,” “agriculture,” and “food safety.” In addition to journal articles, selected technical reports from international organizations were consulted to provide contextual insight into food supply chains and traceability in developing regions. These sources were used for background framing and interpretation, not for comparative evaluation.

3.3 Inclusion and Exclusion Criteria

Studies were included in the review if they met the following criteria. First, the study examined blockchain applications related to food supply chain traceability, rather than general blockchain architecture or cryptocurrency use. Second, the study was published in a peer-reviewed journal or refereed conference proceedings. Third, the study provided substantive discussion of traceability design, implementation, or evaluation, rather than purely conceptual commentary.

Studies were excluded if they focused solely on non-food supply chains, addressed blockchain without reference to traceability outcomes, or lacked sufficient methodological detail to support comparative analysis. Publications centered on financial applications of blockchain or speculative technology assessments were also excluded.

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3.4 Study Selection and Scope

These studies represent a mix of empirical case studies, pilot implementations, and analytical reviews focused on blockchain-enabled traceability in food supply chains. While relatively few studies focus explicitly on West Africa, selected studies addressing comparable developing contexts were included to inform regional analysis. Following title screening, abstract review, and full-text assessment, a distinct number of peer-reviewed studies met the predefined inclusion criteria and formed the analytical basis of this review.

3.5 Analytical Approach

The selected studies were analyzed using a qualitative comparative approach. Each study was examined along four dimensions. First, the traceability objective, including food safety, provenance verification, or compliance monitoring. Second, the system design, including blockchain type, data inputs, and governance arrangements. Third, the reported benefits, such as transparency or auditability improvements. Fourth, the limitations and constraints, particularly those related to infrastructure, governance, and adoption.

This approach allows for identification of patterns and divergences across studies, while maintaining sensitivity to contextual differences in supply chain structure and institutional capacity. Emphasis was placed on evaluating claims in relation to reported evidence and implementation conditions. This comparative structure ensured consistent evaluation across studies while allowing contextual differences in supply chain structure and governance to be explicitly considered.

3.6 Conceptual Review Workflow

To enhance transparency, the review process is summarized through a conceptual workflow that links literature selection, analytical dimensions, and synthesis outcomes. This workflow illustrates how studies were identified, screened, analyzed, and compared, and how findings were interpreted in relation to West African food supply chain contexts.

Figure 1 illustrates the conceptual workflow guiding the review process. It shows the sequence of literature identification, screening, and selection, followed by the analytical dimensions used to evaluate blockchain-enabled traceability systems. The figure clarifies how evidence from selected studies is synthesized to assess system design, reported benefits, and contextual constraints relevant to West African food supply chains.

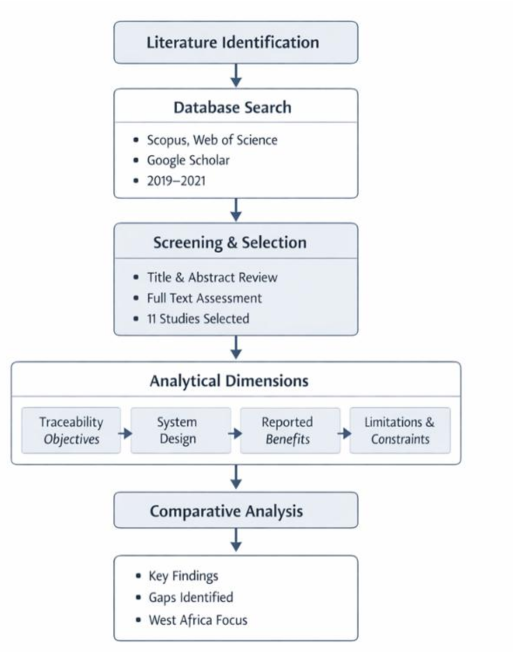

Fig 1: *Conceptual workflow for literature selection and analytical evaluation of blockchain-enabled traceability systems.*

3.7 Methodological Limitations

Several limitations should be noted. The review is constrained by the limited number of peer-reviewed studies focusing explicitly on West Africa. As a result, findings are informed partly by studies conducted in other developing regions. In addition, variation in study design and reporting limits direct comparison of outcomes. These limitations reflect both the current state of published evidence and the scope deliberately defined for this review.

IV. RESULTS AND EVALUATION

This section presents a comparative synthesis of the studies reviewed, focusing on how blockchain-enabled traceability systems have been applied in food supply chains and what outcomes have been reported. The analysis draws on peer-reviewed studies that met the inclusion criteria outlined in Section 3. The results are organized around traceability objectives, system design characteristics, reported benefits, and documented limitations.

4.1 Traceability Objectives and Use Cases

Across the reviewed studies, blockchain-based traceability systems are primarily designed to address food safety monitoring, product provenance verification, and compliance with quality or certification standards. Most applications focus on recording product movement and transformation events across supply chain stages, including production, processing, transport, and retail. Studies report that blockchain is commonly used to improve the visibility of product histories and to support faster trace-back during food safety incidents (Kamilaris et al., 2019; Tian, 2017).

Several studies emphasize export-oriented food value chains, such as fresh produce, meat, and specialty crops, where traceability requirements are driven by international market standards. In these cases, blockchain systems are often implemented alongside existing certification or quality assurance schemes to enhance data integrity and auditability (Casino et al., 2019). Fewer studies address domestic food supply chains or informal markets, which are more representative of food distribution in West Africa.

4.2 System Design and Data Architecture

The reviewed literature shows a clear preference for permissioned blockchain architectures in food supply chain traceability. Permissioned systems restrict participation to verified actors and allow governance rules to be defined by a consortium or lead organization. This design choice reflects concerns about data privacy, regulatory compliance, and system control within food supply chains (Kouhizadeh et al., 2021).

Data inputs typically include production records, batch identifiers, processing events, transport logs, and certification data. Many systems rely on external data capture technologies, such as QR codes or RFID tags, to link physical products to digital records stored on the blockchain. Studies consistently note that blockchain functions as a data storage and verification layer rather than a data generation tool, meaning that data accuracy depends on upstream capture processes (Casino et al., 2019).

Integration with Internet of Things devices is frequently proposed, particularly for monitoring temperature, humidity, or location during transport. However, empirical evidence of large-scale IoT-blockchain integration in food supply chains remains limited, with most studies reporting conceptual designs or small-scale pilots (Kamilaris et al., 2019).

4.3 Reported Benefits

The reviewed studies report several potential benefits associated with blockchain-enabled traceability systems. Improved data integrity and resistance to record alteration are among the most frequently cited outcomes. By storing records in an append-only ledger shared among participants, blockchain systems are reported to reduce opportunities for retrospective data manipulation (Tian, 2017).

Improved transparency and auditability are also commonly reported. Studies suggest that shared access to traceability records can enhance coordination among supply chain actors and support regulatory oversight by providing a single source of information (Casino et al., 2019). Some studies report reductions in trace-back time during simulated food safety incidents, although these findings are often based on controlled pilot settings rather than operational supply chains.

A smaller subset of studies highlights potential efficiency gains through automation, such as reduced paperwork or faster verification of compliance. These benefits are typically associated with the use of smart contracts, although empirical evidence of cost savings or performance improvements remains limited (Kouhizadeh et al., 2021).

4.4 Reported Limitations and Constraints

Despite reported benefits, the reviewed literature documents several limitations. High implementation and maintenance costs are frequently cited, particularly in relation to system development, hardware requirements, and ongoing technical support. These costs present barriers to adoption for small-scale actors operating with limited financial resources (World Bank, 2020).

Data quality remains a critical constraint. Studies consistently acknowledge that blockchain does not

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prevent inaccurate or fraudulent data entry at the point of capture. Without reliable verification mechanisms, blockchain-based systems may record incorrect information in an immutable form, undermining traceability objectives (Casino et al., 2019).

Scalability and sustainability challenges are also noted. Many blockchain traceability initiatives remain at the pilot stage, with limited evidence of long-term operation or expansion across complex supply chains. Factors such as stakeholder coordination, governance arrangements, and regulatory support are identified as critical determinants of system sustainability (Kouhizadeh et al., 2021).

4.5 Comparative Summary

Taken together, the reviewed studies indicate that blockchain-enabled traceability systems are most effective when applied to well-defined, formalized food supply chains with clear governance structures and supporting digital infrastructure. Evidence from informal or resource-constrained supply chains remains limited. While the literature reports potential improvements in transparency and auditability, these outcomes are often demonstrated under controlled conditions and may not translate directly to West African food systems without significant adaptation.

To support structured comparison across studies, a summary of reviewed blockchain traceability applications, including system characteristics, reported benefits, and limitations, is presented in Table 2.

Table 1. Summary of blockchain-enabled traceability studies in food supply chains

Author(s) and Year	Supply Chain Context	Blockchain Architecture	Traceability Focus	Data Inputs	Main Findings	Reported Limitations
Tian (2017)	Food safety supply chain	Permissioned blockchain	Product provenance, safety monitoring	Production records, logistics data, IoT inputs	Improved trace-back efficiency and immutability in pilot settings	Dependent on accurate off-chain data, limited real-world scale
Kamilaris et al. (2019)	Agriculture and food supply chains	Permissioned and hybrid	End-to-end traceability	Transaction records, certification data	Identified transparency and auditability benefits	Most applications conceptual or pilot-based
Casino et al. (2019)	Multiple food supply chains	Mixed architectures	Data integrity and traceability	Supply chain transaction data	Reduced risks of data tampering	High system complexity, limited cost evidence
Kouhizadeh et al. (2021)	Sustainable food supply chains	Permissioned blockchain	Traceability and compliance	Certification and logistics data	Governance and adoption conditions shape outcomes	High cost, low readiness among small actors
Galvez et al. (2018)	Food safety and quality chains	Permissioned blockchain	Fraud prevention and traceability	Batch and processing data	Enhanced auditability in controlled environments	Limited empirical validation
Lin et al. (2020)	Agricultural product traceability	Consortium blockchain	Provenance tracking	QR code-linked records	Improved consumer trust in pilot deployments	Infrastructure dependence

V. DISCUSSION

The synthesis of studies reviewed indicates that blockchain-enabled traceability has been primarily explored as a technical response to weaknesses in food supply chain transparency and data integrity. The reported benefits, including improved auditability and faster trace-back, are consistent across multiple studies. However, the discussion of results highlights a clear gap between technical feasibility and practical applicability in West African food systems.

One central issue is the mismatch between the design assumptions of many blockchain traceability systems and the operational realities of West African supply chains. Most reviewed studies are grounded in settings where supply chains are relatively formalized and where actors have the capacity to comply with digital record-keeping requirements. In contrast, food supply chains in West Africa are characterized by informality, fragmented governance, and limited documentation practices. Under these conditions, blockchain systems may reinforce existing information asymmetries rather than resolve them, particularly if participation is uneven across supply chain actors (FAO, 2019; World Bank, 2020).

The findings also suggest that claims about improved trust and transparency should be interpreted with caution. While blockchain can increase confidence in the integrity of recorded data, it does not address challenges related to data accuracy at the point of entry. In environments where verification mechanisms are weak, incorrect or misleading information can still be recorded in an immutable ledger. This limitation is particularly relevant for food safety and quality assurance, where traceability outcomes depend on reliable inspection and monitoring processes (Casino et al., 2019).

Governance emerges as a decisive factor shaping the effectiveness of blockchain-enabled traceability. The reviewed literature indicates that successful traceability systems require clear rules regarding data ownership, access rights, and responsibility for verification. In West African contexts, where regulatory authority is often fragmented across institutions, establishing such governance arrangements remains challenging. Studies emphasize that without institutional coordination and regulatory support, blockchain initiatives risk remaining isolated pilots with limited impact (Kouhizadeh et al., 2021).

Economic feasibility further constrains adoption. The costs associated with system development, infrastructure, and training present significant barriers for small-scale producers and traders. Several studies note that traceability systems are more likely to be adopted when they are linked to tangible economic benefits, such as access to premium markets or reduced compliance costs. In domestic food markets, where price sensitivity is high and margins are low, these incentives are often absent (World Bank, 2020). This raises questions about the sustainability of blockchain traceability initiatives that rely on external funding or donor support.

The discussion also highlights limitations in the existing evidence base. Most reviewed studies rely on short-term pilots or conceptual designs, with limited assessment of long-term adoption, system maintenance, or measurable impacts on food safety outcomes. Few studies examine how blockchain traceability affects recall effectiveness, fraud reduction, or consumer trust over extended periods. This lack of longitudinal evidence limits the ability to assess whether blockchain offers advantages over incremental improvements to existing traceability systems (FAO, 2019).

Taken together, the findings suggest that blockchain-enabled traceability should not be viewed as a standalone solution for traceability challenges in West Africa. Its potential value depends on complementary investments in regulatory capacity, infrastructure, and stakeholder engagement. Approaches that prioritize governance alignment, cost efficiency, and integration with existing practices are more likely to support meaningful improvements in traceability than technology-centered implementations.

VI. CONCLUSION

This paper examined blockchain-enabled traceability in food supply chains with specific relevance to West Africa through a structured critical review of peer-reviewed studies. The review focused on how blockchain has been applied to traceability, the benefits reported in the literature, and the institutional, infrastructural, and governance conditions that shape its applicability in the region.

The findings indicate that blockchain-based traceability systems have demonstrated potential to improve data integrity, transparency, and auditability in food supply chains under certain conditions. Studies report improved trace-back capabilities and enhanced visibility of product histories, particularly in formalized and export-oriented value chains. These outcomes suggest that blockchain can support traceability objectives where supporting digital infrastructure, governance mechanisms, and stakeholder coordination are in place.

At the same time, the review highlights significant limitations that constrain the relevance of blockchain-enabled traceability for West African food systems. High levels of informality, weak regulatory enforcement, limited digital infrastructure, and low stakeholder readiness reduce the feasibility of deploying blockchain systems at scale. The literature also shows that blockchain does not address fundamental challenges related to data accuracy at the point of capture, and that its effectiveness depends on complementary investments in inspection, verification, and data governance.

The analysis further suggests that many existing studies emphasize technical design and proof-of-concept implementations, with limited attention to long-term adoption, cost sustainability, and measurable impacts on food safety and market outcomes. Evidence from West Africa remains sparse, and findings from other regions cannot be transferred without careful adaptation to local institutional and supply chain contexts.

Overall, the review indicates that blockchain-enabled traceability should be viewed as a supporting tool rather than a standalone solution for traceability challenges in West Africa. Future research should prioritize empirical evaluation in domestic food markets, assess economic feasibility for small-scale actors, and examine governance arrangements that enable inclusive participation across supply chains. Meaningful improvements in traceability will depend on aligning digital systems with regulatory capacity, infrastructure, and existing supply chain practices.

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