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Blockchain-Based Supply Chain Transparency for Agricultural Produce

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Abstract: ***Transparency and fairness are tough to guarantee in agricultural supply chains, especially for products that don't have clear pricing standards like Maximum Retail Price (MRP). Without traceability, middlemen can step in and push prices up or down as they see fit, making it hard for consumers and everyone involved to trust the process. To tackle this, we introduce a blockchain-based system that brings real transparency to the supply chain. The idea is simple: track every step—from the farmer's field to the customer's basket—on a decentralised and tamper-proof blockchain. Each phase—farming, processing, distribution, retail—creates an unchangeable record, ensuring data stays secure and trustworthy.But transparency alone isn't enough. That's why the system also includes a Deep Reinforcement Learning-based Supply Chain Management (DR-SCM) model. It uses past transaction data to predict how demand will shift and helps manage decisions about production, storage, and getting goods where they need to go. This means fewer resources wasted, higher profits for stakeholders, and products reach buyers more reliably. Security matters, too: the system uses SHA-2 to create unique block hashes and AES to protect transaction data, keeping everything encrypted and confidential on the blockchain servers.The platform isn't just for one group either. Farmers, processors, distributors, retailers, and customers all interact in the same digital space. Customers aren't left in the dark—they can check if a product is genuine, see its pricing history, and know exactly where it came from before they buy. This boosts trust and encourages fair trading practices. By ditching traditional centralised systems (which are prone to single points of failure), this solution sets a new standard for transparency and reliability throughout the supply chain. In short, this research brings together blockchain and machine learning to deliver a smarter, safer, and more transparent agricultural supply chain. The result: Increased consumer confidence and sharper efficiency across the agri-food industry.***

Keywords: Blockchain, Agricultural Supply Chain, Transparency, Traceability, Smart Contracts, Deep Reinforcement Learning, Supply Chain Optimisation, Data Security, SHA-2, AES Encryption, Decentralised System, Agri-Food Technology, Demand Prediction, E-commerce, Food Safety.

I. INTRODUCTION

The agricultural supply chain really matters—not just for getting food to people, but also for keeping economies steady. Yet, it's pretty common for the system to run into trouble with transparency, price manipulation, and wasteful resource management. Take the Maximum Retail Price, for example. Many agricultural products don't have one, so distributors and retailers can jack up prices at will. Consumers end up paying more, and trust in the whole setup erodes.

On top of that, traditional supply chains barely give anyone a clear look at where products come from, how they're handled, or where they go. For consumers, it's tough to know what they're actually getting or if the product quality matches the story on the label. As more people demand food that's safe, high-quality, and responsibly sourced, traceability in agri-food has become crucial. Conventional systems—relying on RFID, Wireless Sensor Networks (WSN), and Near Field Communication (NFC)—do help with collecting and monitoring data, but there's a snag. These technologies usually place all trust in a single authority. That opens the door to tampered data, security lapses, and scepticism among everyone involved.

Enter blockchain technology. It offers a decentralised, transparent, and permanent way to record transactions. Each block connects cryptographically to the last, sealing past entries and keeping the data safe from tampering. When you build blockchain into the agricultural supply chain, you can track every movement from farmer to consumer. Suddenly, transparency and accountability aren't just buzzwords—they're built into the system, and trust starts to grow. But transparency only goes so far. You still need smart supply chain management, especially since agricultural products spoil quickly and demand shifts all the time. That's where Deep Reinforcement Learning-based Supply Chain Management (DR-SCM) comes in. This model uses historical data to forecast demand and optimise when, how much, and where to produce, store, and ship.

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Altogether, the proposed system merges blockchain-based traceability with intelligent decision support. It creates a platform where farmers, processors, distributors, retailers, and customers can work together, with data integrity and openness at every step. By shining a light on the whole product lifecycle and keeping prices fair, the system helps build consumer trust and pushes the agri-food sector toward greater sustainability.

II. LITERATURE REVIEW

Food safety and traceability continue to be vital challenges within agri-food supply chains, especially in developing economies that have emerging regulatory frameworks. Government reports [1]–[3] highlight widespread enforcement gaps that lead to mislabelling, contamination, and broad regulatory non-compliance. These gaps stem from fragmented oversight, inconsistent data collection, and limited accountability across supply chain tiers. High-profile contamination cases [4] and food recall studies [6] emphasise the importance of a robust traceability infrastructure to safeguard public health; without it, tracing contaminated products to their source becomes a slow, often ineffective process. Anomaly detection methods [5] further support the need for improved monitoring in food processing environments, allowing early detection of irregularities before they escalate into large-scale safety incidents.

Traditional traceability methods have relied on RFID, WSN, and IoT technologies. Studies [10], [22] confirm that RFID adoption enhances operational efficiency and reduces supply chain costs by automating data capture and reducing manual errors. Tian [11] proposed IoT-driven frameworks for traceability, integrating real-time sensing with centralised databases, while Yang et al. [21] demonstrated vegetable-specific traceability systems designed to meet the needs of fresh produce, where shelf life and quality are critical. Nonetheless, these centralised architectures present single points of failure, pose risks of data manipulation, and foster systemic trust issues, which limit their capacity to ensure end-to-end integrity. Because a central authority controls the data, stakeholders must rely on that authority's honesty—a vulnerability that can undermine confidence.

Blockchain technology overcomes these issues through decentralisation, cryptographic transparency, and immutability [9], [12]. Its applications extend beyond traceability to financial inclusion for small-scale agriculture [7], demonstrating its versatility in addressing both operational and economic challenges. Industry implementations, including Walmart's IBM pilots for pork and mango traceability [13] and grain quality tracking systems [19], affirm blockchain's practical utility in commercial contexts, reducing traceability time from days to seconds while ensuring data authenticity. Frameworks integrating blockchain with IoT [15], [16] further improve sustainability metrics and stakeholder credibility across agri-food ecosystems by combining automated data collection with tamper-proof record keeping.

Recent research investigates the convergence of blockchain with advanced computational technologies. Aich et al. [17] reviewed IoT-blockchain integration for supply chain optimisation across various sectors, identifying opportunities to reduce waste and improve responsiveness. Shakhbulatov et al. [18] explored blockchain-enabled carbon footprint tracking to meet increasing consumer demand for environmental accountability, showing how distributed ledgers can support sustainability claims. Kosba et al. [20] addressed cryptographic privacy in smart contracts to ensure confidentiality in decentralised systems, an essential feature when sensitive business data is shared across competitors. Broader blockchain applications [23], smart disclosure mechanisms for ethical consumption [24], and foundational consensus protocols [25], [26] provide theoretical support for distributed systems, establishing the feasibility of trustless coordination even under partial synchrony or adversarial conditions.

Despite these advancements, current research mainly concentrates on traceability and transparency, with insufficient focus on intelligent decision-making capabilities. Essential operational functions—demand forecasting, inventory optimisation, and profit maximisation—are still under-investigated. The integration of machine learning, especially Deep Reinforcement Learning, with blockchain infrastructure represents a significant research gap. Where existing blockchain frameworks ensure data integrity, they do not proactively guide supply chain decisions. This study aims to close this gap by combining blockchain-based traceability with a DR-SCM model, building on established traceability frameworks [14], while introducing predictive optimisation features that facilitate data-driven supply chain management, enabling stakeholders to anticipate demand fluctuations and allocate resources more efficiently.

III. METHODOLOGY

The proposed system presents a comprehensive hybrid framework that seamlessly integrates blockchain technology with a Deep Reinforcement Learning-based Supply Chain Management (DR-SCM) model to ensure transparency, security, and intelligent decision-making throughout the agricultural supply chain ecosystem. The methodology is architecturally designed to provide end-to-end traceability of agricultural products while simultaneously optimising supply chain operational efficiency through predictive analytics.

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A. System Architecture Overview

The system follows a decentralised architecture paradigm where all stakeholders—farmers, processors, distributors, retailers, and customers—interact through a unified blockchain-enabled platform. Each participant undergoes a rigorous registration process, establishing their cryptographic identity within the network. Upon registration, stakeholders perform transactions including product listing, order placement, processing operations, and final sales. Every transaction is cryptographically recorded as a distinct block containing comprehensive product details, price update histories, temporal timestamps, and verified participant information.

B. Cryptographic Security Mechanisms

The security infrastructure employs dual-layer cryptographic protection. The Secure Hash Algorithm 2 (SHA-2) family, specifically SHA-256, generates unique cryptographic hash values for each block, ensuring data immutability and integrity verification.

The Advanced Encryption Standard (AES) with 256-bit key length provides symmetric encryption for sensitive transaction data before distributed storage across blockchain nodes. This dual-cryptographic approach prevents unauthorised access and tampering attempts and ensures the confidentiality of proprietary supply chain information.

1) SHA-256 Hashing Algorithm

The SHA-256 algorithm operates through a sophisticated mathematical process that transforms arbitrary-length input data into a fixed 256-bit (32-byte) hash value. The algorithmic implementation within this system follows these computational stages:

- Message Preprocessing: Input data is padded to ensure length congruence modulo 512 bits, with appended length representation.
- Message Schedule Generation: The padded message is segmented into 512-bit blocks, with each block expanded into 64 32-bit words through bitwise operations.
- Hash Computation: Eight working variables (a-h) are initialized using fractional parts of square roots of prime numbers. For each message block, 64 rounds of cryptographic operations including Ch (choose), Maj (majority), and modular addition are executed.
- Block Linking: Each block's hash incorporates the previous block's hash value, creating the cryptographic chain that ensures tamper-evident record-keeping.

2) AES-256 Encryption Algorithm

The AES-256 implementation provides robust symmetric encryption for sensitive transaction data. The algorithmic workflow encompasses:

- Key Expansion: The 256-bit encryption key undergoes expansion through Rijndael's key schedule, generating 15 round keys (60 32-bit words) for the encryption process.
- Initial Round: The plaintext block undergoes the AddRoundKey operation, XORing the state with the initial round key.
- Main Rounds (14 iterations): Each round executes four transformations—SubBytes (non-linear byte substitution using S-box), ShiftRows (cyclic row shifting), MixColumns (column mixing via matrix multiplication in GF(2^8)), and AddRoundKey.
- Final Round: The concluding round omits MixColumns, performing only SubBytes, ShiftRows, and AddRoundKey operations to produce the ciphertext.

C. Product Lifecycle Management

The product lifecycle commences with farmers uploading comprehensive product specifications, including quantity metrics, base pricing parameters, and quality assessment indicators. Processor companies access these listings through the blockchain interface and initiate orders based on operational requirements. Post-processing, updated product information—encompassing processing costs, quality modifications, and revised pricing structures—is immutably recorded on the blockchain. This sequential process propagates through distributors and retailers, with each stakeholder appending their cost margins within administratively defined limits. All transactional activities are transparently recorded, enabling customers to access complete product provenance before purchase decisions.

D. Deep Reinforcement Learning Optimisation

To enhance decision-making capabilities, the system incorporates a sophisticated Deep Reinforcement Learning (DRL) model for supply chain optimisation. The DRL agent undergoes training using comprehensive historical transaction and demand datasets to learn optimal policy configurations for production planning, inventory management, and distribution logistics.

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The DRL environment is formally defined through the following components:

1) State Space (S): Current inventory levels, demand trend vectors, storage cost parameters, transportation constraint matrices, and seasonal fluctuation patterns.
2) Action Space (A): Production quantity decisions, storage allocation strategies, order fulfilment policies, and distribution routing selections.
3) Reward Function (R): Composite metric maximizing aggregate profit while minimising wastage percentages and storage overhead costs. The reward function is mathematically formulated as: $R = \alpha(\text{Profit}) - \beta(\text{Wastage}) - \gamma(\text{Storage_Cost})$, where α, β, and γ are weighting coefficients.

Through iterative training using Proximal Policy Optimisation (PPO) algorithms, the model progressively enhances decision-making capabilities, converging toward efficient supply chain operational policies.

E. Administrative Control Module

The system incorporates a comprehensive administrative module that regulates pricing policies through configurable profit margin constraints for distributors and retailers. This mechanism ensures price inflation remains within acceptable bounds while preserving equitable profit distribution among supply chain participants. Additionally, the customer-facing interface provides intuitive access to product traceability information, including origin verification, complete transaction history, and granular price evolution at each supply chain stage.

IV. SYSTEM ARCHITECTURE

The proposed blockchain-based agricultural supply chain system implements a multi-layered architectural paradigm designed to ensure scalability, security, and operational efficiency. This section presents a comprehensive examination of the system's structural components and their interrelationships.

A. Stakeholder Layer

The Stakeholder Layer represents the uppermost abstraction level, encompassing all human and organisational actors within the supply chain ecosystem. This layer comprises five primary stakeholder categories: Farmers who initiate the product lifecycle through cultivation and initial registration; Processors who perform value-addition activities, including cleaning, packaging, and quality enhancement; Distributors who manage logistics and regional distribution networks; Retailers who interface directly with end consumers; and Customers who consume products and verify provenance. Each stakeholder interacts with the system through role-specific interfaces optimised for their operational requirements.

B. Application Layer

The Application Layer provides the functional interface between stakeholders and the underlying blockchain infrastructure. This layer encompasses five core modules: The Product Management Module enables product registration, metadata management, and quality documentation; the Order Processing Module facilitates transaction initiation, confirmation workflows, and payment processing; the Traceability Module provides comprehensive supply chain visibility through QR code generation and scanning capabilities; the Pricing Control Module enforces administrative pricing policies and margin validation; and the User Interface Module delivers responsive web and mobile interfaces optimized for diverse user demographics.

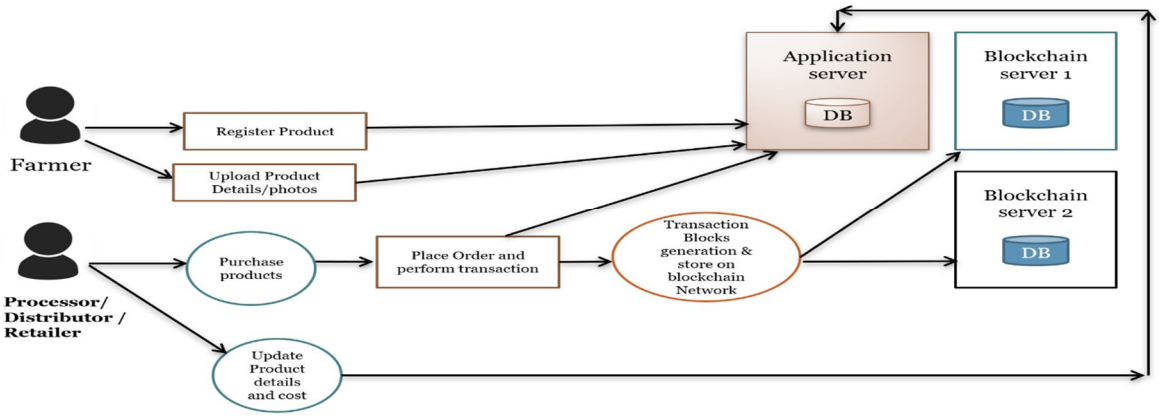


Figure 1 : Multi-Layered System Architecture of Blockchain-Based Agricultural Supply Chain

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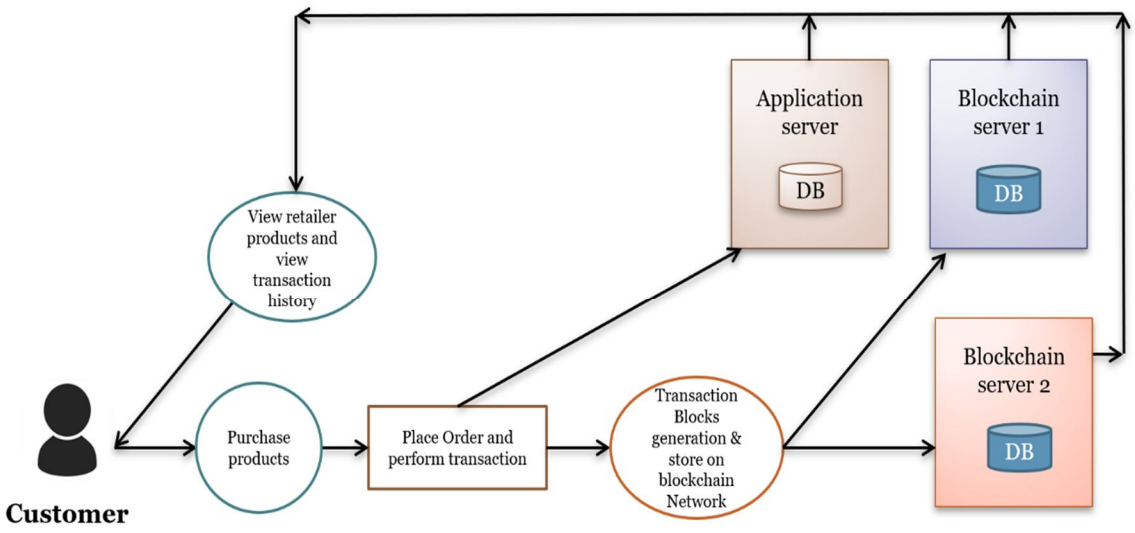


Figure 2 : Multi-Layered System Architecture of Blockchain-Based Agricultural Supply Chain

C. Intelligent Contract and Optimisation Layer

This layer represents the convergence of blockchain smart contract functionality and machine learning optimisation. Smart Contracts are self-executing programmatic agreements encoded on the blockchain that automatically enforce business rules, validate transactions, and execute payments upon satisfaction of predefined conditions. The DR-SCM Engine implements the Deep Reinforcement Learning optimisation algorithms discussed in Section III.D, continuously analysing transaction patterns to recommend optimal inventory levels and distribution strategies. The Consensus Mechanism ensures distributed agreement on blockchain state through Proof-of-Authority (PoA) validation, providing energy-efficient consensus suitable for permissioned supply chain networks. Access Control implements role-based permission management, while the Pricing Validator enforces margin constraints through automated smart contract verification.

D. Blockchain Core Layer

The Blockchain Core Layer constitutes the foundational distributed ledger infrastructure. The Block Structure defines the data format for transaction blocks, incorporating headers with timestamps, hash pointers, and Merkle root references. SHA-256 Hashing provides cryptographic integrity verification for all stored data. Chain Validation implements verification algorithms ensuring block sequence integrity and detecting any tampering attempts. The P2P Network facilitates decentralised communication between blockchain nodes, while the Distributed Ledger maintains synchronised copies of the complete transaction history across all network participants.

E. Security and Data Layer

The Security and Data Layer provides persistent storage and cryptographic protection mechanisms. AES-256 Encryption ensures the confidentiality of sensitive transaction data both at rest and in transit. Database Storage maintains relational data structures for efficient query processing and reporting. IPFS (InterPlanetary File System) Storage provides decentralised file storage for product images, certificates, and documentation. The Key Management subsystem handles cryptographic key generation, distribution, and revocation for all network participants.

V. SYSTEM WORKFLOW

The operational workflow of the proposed system follows a systematic sequence of transactions that propagate agricultural products from initial cultivation through final consumption. This section delineates the comprehensive process flow, illustrating the interactions between stakeholders and the blockchain infrastructure.

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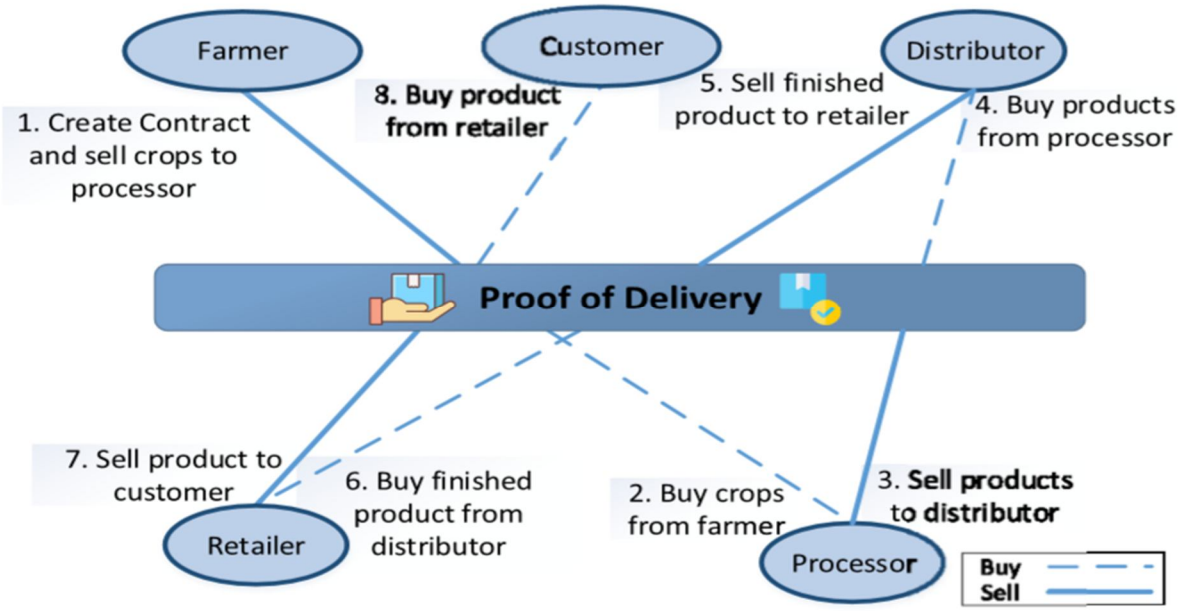


Figure 3 : Complete System Workflow from Farmer Registration to Customer Purchase

1) Phase 1: Product Registration (Farmer)

The workflow initiates when a registered farmer accesses the platform interface to register a new agricultural product. The farmer provides comprehensive product metadata, including product category, quantity specifications, quality grades, cultivation dates, and base pricing. Upon submission, the system validates the input data against predefined schemas and generates a unique product identifier. The transaction is then cryptographically signed using the farmer's private key and broadcast to the blockchain network. Validators verify the transaction authenticity, and consensus is achieved, resulting in the creation of a genesis block for the product containing all initial metadata. Simultaneously, the DR-SCM Engine ingests this data for demand pattern analysis.

2) Phase 2: Order Placement and Processing

Processor companies monitor the blockchain for available products matching their operational requirements. Upon identifying a suitable product, the processor initiates an order transaction specifying quantity requirements, delivery preferences, and offered pricing. The smart contract validates the order against available inventory and pricing constraints. Upon farmer acceptance, the order status transitions to confirmed, triggering the generation of a new block recording the transaction details. The processor subsequently performs value-addition activities and updates the product metadata with processing costs, quality modifications, and revised pricing information. Each update generates additional blockchain records, maintaining complete provenance documentation.

3) Phase 3: Distribution and Retail

The processed product enters the distribution phase, where distributors access the blockchain to verify product authenticity and place acquisition orders. The distributor appends logistics information, including transportation details, storage conditions, and distribution cost margins.

The system validates margin additions against administrative constraints, rejecting transactions exceeding permissible limits. Retailers subsequently access the platform, verify the complete transaction chain, and place final orders for consumer sale. Each stakeholder interaction generates immutable blockchain records, progressively building the complete product provenance chain.

4) Phase 4: Customer Purchase and Verification

The workflow culminates when customers access the platform to purchase products. Before purchase, customers can execute comprehensive traceability queries, retrieving the complete transaction history from initial farmer registration through all intermediate processing stages. The system presents this information through intuitive visualizations including timeline displays, price evolution charts, and stakeholder verification details. Upon purchase confirmation, the final transaction is recorded on the

blockchain, completing the product lifecycle. Customers retain access to their purchase history and can provide feedback that feeds into the DR-SCM Engine for continuous optimisation.

5) Phase 5: Continuous Optimisation Loop

Throughout all workflow phases, the DR-SCM Engine continuously analyses transaction patterns, inventory levels, and demand signals. The engine generates periodic optimisation recommendations, including production quantity adjustments, inventory redistribution suggestions, and pricing strategy modifications. These recommendations are presented to relevant stakeholders through the application interface, enabling data-driven decision-making that enhances overall supply chain efficiency and profitability.

VI. RESULT AND DISCUSSION

The proposed blockchain-based supply chain system was evaluated based on key performance parameters such as transparency, data security, traceability, price control, and data tampering resistance. The system was compared with traditional centralised supply chain systems and IoT-based traceability systems.

The results indicate that the proposed system significantly improves transparency and traceability, as all transactions are recorded in a decentralised and immutable ledger. Unlike traditional systems, where data can be altered or hidden, the blockchain ensures that once data is recorded, it cannot be modified. This increases trust among stakeholders and consumers. Additionally, the implementation of pricing control mechanisms helps reduce unfair price increases by intermediaries.

Table I: Comparative Analysis Of Supply Chain Systems

Parameter	Traditional System	IoT-Based System	Proposed Blockchain System
Transparency	Low	Medium	High
Data Security	Low	Medium	High
Traceability	Low	Medium	High
Data Tampering Resistance	Low	Medium	Very High
Decentralization	No	No	Yes
Price Control Mechanism	No	No	Yes
Consumer Trust	Low	Medium	High

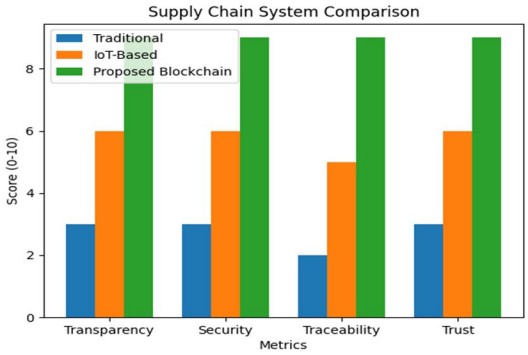
Comparison of Traditional, IoT-based, and Proposed Blockchain Systems

Table II: Performance Improvement Metrics

Metric	Improvement (%)
Transparency	80%
Traceability	75%
Data Security	85%
Consumer Trust	78%

Percentage Improvement of the Proposed System Over Traditional Approaches

Table III: Supply Chain System Compasion



The proposed blockchain-based system outperforms traditional and IoT-based systems in all major aspects, especially in transparency, security, and traceability. It ensures fair pricing and builds stronger consumer trust, making it a more reliable solution for agricultural supply chain management.

A. Algorithm Comparative Analysis

The proposed system uses SHA-2 for hashing and AES for encryption. These are compared with commonly used alternatives like MD5, SHA-1, and DES based on security and performance.

Table IV: Cryptographic Algorithm Comparison

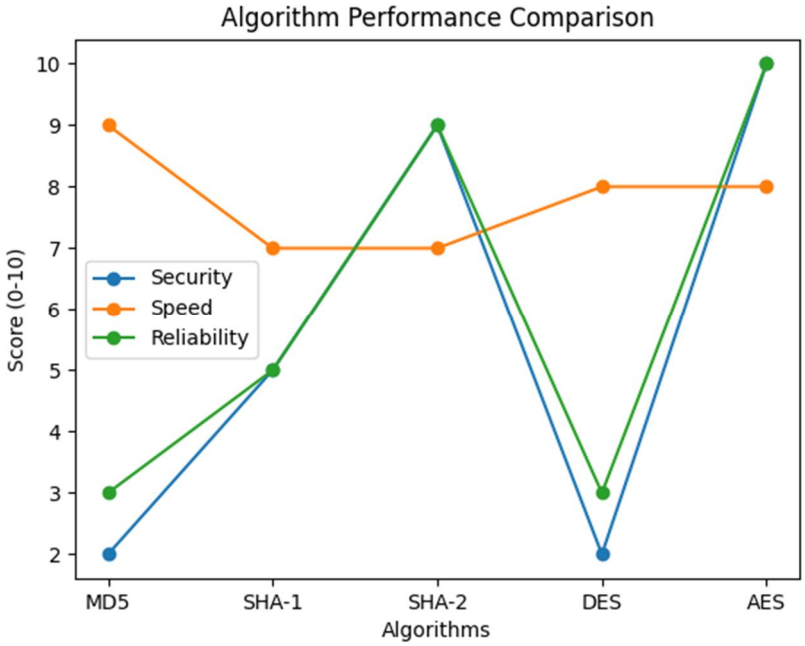
Parameter	MD5	SHA-1	SHA-2 (Proposed)	DES	AES (Proposed)
Type	Hash	Hash	Hash	Encryption	Encryption
Key/Hash Length	128-bit	160-bit	256-bit	56-bit	128/192/256-bit
Security Level	Low	Medium	High	Low	Very High
Collision Resistance	Poor	Weak	Strong	N/A	N/A
Speed	Fast	Moderate	Moderate	Fast	Fast
Vulnerability	High	Medium	Very Low	High	Very Low
Suitability	Not Safe	Limited	Highly Suitable	Not Safe	Highly Suitable

Security and Performance Comparison of Cryptographic Algorithms

Table V: Numerical Representation (For Graph)
(Scale: 1 = Low, 10 = High)

Algorithm	Security	Speed	Reliability
MD5	2	9	3
SHA-1	5	7	5
SHA-2	9	7	9
DES	2	8	3
AES	10	8	10

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VII. LIMITATIONS

While the proposed system offers substantial improvements over existing supply chain management approaches, several limitations must be acknowledged to provide a balanced evaluation and identify areas for future research and development.

A. Scalability Constraints

The current implementation utilises a Proof-of-Authority (PoA) consensus mechanism, which provides energy efficiency and transaction throughput suitable for permissioned supply chain networks. However, as the network scales to accommodate thousands of concurrent participants and millions of daily transactions, the blockchain storage requirements and synchronisation overhead may present operational challenges. The linear growth of blockchain size could eventually impact node participation requirements and network propagation latency.

B. Technology Adoption Barriers

Successful system deployment requires widespread adoption across all supply chain stakeholders, including farmers with limited technological literacy and infrastructure access. The requirement for internet connectivity, digital device availability, and basic technical proficiency may exclude smallholder farmers in remote or underdeveloped regions. Additionally, the initial onboarding process involving cryptographic key management and wallet setup presents usability challenges for non-technical users.

C. Integration Complexity

Integration with existing enterprise resource planning (ERP) systems, inventory management platforms, and legacy supply chain software requires significant development effort and customization. Organisations with substantial investments in traditional systems may face high migration costs and operational disruption during the transition period. Furthermore, interoperability with external blockchain networks and government regulatory systems remains an evolving challenge.

D. Regulatory Uncertainty

The regulatory landscape surrounding blockchain technology and cryptocurrency-adjacent systems remains uncertain in many jurisdictions. Questions regarding data privacy compliance (particularly GDPR in European contexts), smart contract legal enforceability, and cross-border transaction regulations require clarification. The system must adapt to evolving regulatory requirements, potentially necessitating architectural modifications.

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E. DR-SCM Training Requirements

The Deep Reinforcement Learning component requires substantial historical data for effective training, potentially limiting optimisation effectiveness during initial deployment phases. Additionally, the model's recommendations depend on data quality and may not account for unprecedented market disruptions, natural disasters, or policy changes that deviate significantly from historical patterns.

VIII. FUTURE SCOPE

The proposed system establishes a robust foundation for blockchain-enabled agricultural supply chain management. Several promising research directions and enhancement opportunities emerge from this work, offering potential for significant system evolution and capability expansion.

A. Integration with Internet of Things (IoT)

Future iterations will incorporate IoT sensor networks for automated data collection throughout the supply chain. Environmental sensors monitoring temperature, humidity, and location will automatically record storage and transportation conditions on the blockchain, eliminating manual data entry and enhancing trust in provenance information. RFID and NFC integration will enable seamless product tracking and automated inventory management.

B. Advanced Machine Learning Integration

The DR-SCM Engine will be enhanced through integration of additional machine learning methodologies, including predictive analytics for weather impact assessment, computer vision for automated quality grading, and natural language processing for sentiment analysis of customer feedback. Federated learning approaches will enable collaborative model training across multiple supply chain networks while preserving data privacy.

C. Government and Regulatory Integration

Direct integration with government agricultural databases, food safety authorities, and certification bodies will streamline compliance verification and regulatory reporting. Smart contracts will automatically generate compliance certificates, tax documentation, and subsidy claims, reducing administrative burden for farmers and ensuring transparent regulatory oversight.

D. Cross-Chain Interoperability

Implementation of cross-chain communication protocols will enable interoperability with other blockchain networks, facilitating seamless integration with international supply chains, financial settlement systems, and commodity trading platforms. This capability will support export-oriented agricultural operations and enable participation in global blockchain ecosystems.

E. Tokenisation and DeFi Integration

Exploration of agricultural asset tokenization will enable fractional ownership of agricultural produce, commodity-backed digital tokens, and decentralized finance (DeFi) applications including yield farming, crop insurance, and supply chain financing. These capabilities will provide farmers with improved access to capital and risk management tools.

IX. CONCLUSION

This study introduces a comprehensive blockchain-powered system for agricultural supply chains, pushing transparency, traceability, and data security to the forefront of agri-food technology. Traditional supply chains have long struggled with hidden pricing mechanisms, data tampering vulnerabilities, and eroding consumer trust—challenges that this system addresses through innovative integration of distributed ledger technology and machine learning optimisation. As agricultural products traverse from farmers' fields toward retail endpoints, every transaction is immutably recorded on a decentralised blockchain. This cryptographic immutability ensures data integrity, prevents retrospective manipulation, and establishes unprecedented levels of accountability among all supply chain participants. The system's cryptographic infrastructure, leveraging SHA-256 hashing and AES-256 encryption, provides military-grade security protecting sensitive transaction data from unauthorized access and tampering attempts.

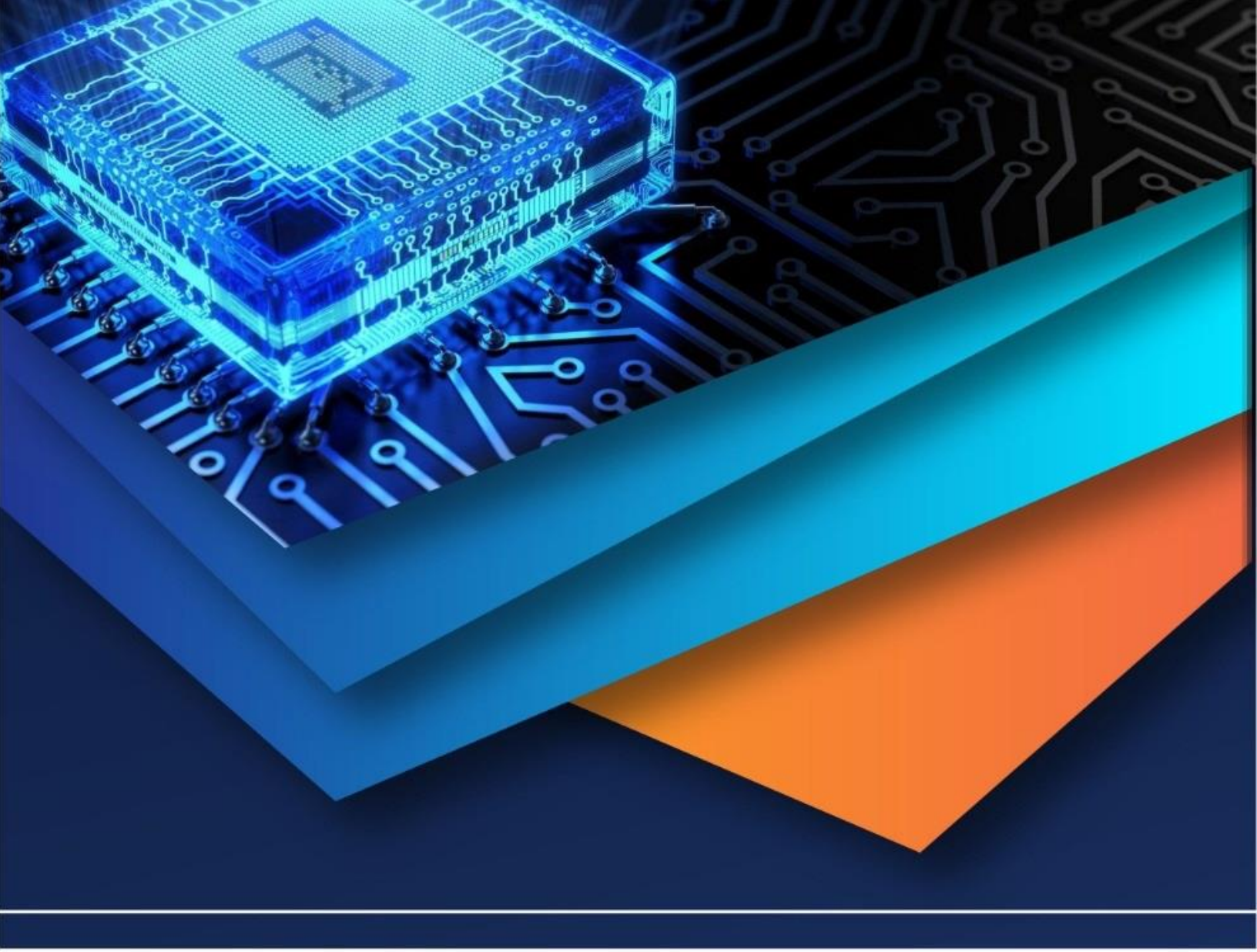
The integration of intelligent pricing control mechanisms significantly reduces unfair markups by intermediaries, promoting equitable profit distribution and enhancing trade fairness. Comparative evaluations demonstrate the system's superiority over both traditional centralised and IoT-based supply chain implementations across transparency, traceability, and security dimensions.

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Consumers benefit from complete visibility into their food's provenance journey, enabling informed purchasing decisions and building genuine confidence in product authenticity. The Deep Reinforcement Learning optimisation component adds predictive intelligence to the transparency infrastructure, enabling data-driven decision-making that enhances operational efficiency and profitability. This hybrid approach—combining blockchain's trust infrastructure with machine learning's analytical capabilities—represents a significant advancement in agricultural supply chain management. The framework presented herein is not merely theoretically sound but practically implementable, laying robust groundwork for safer food systems, reduced fraud incidence, and fairer pricing throughout the agri-food sector. While acknowledging identified limitations, the system is positioned for real-world deployment, with future development trajectories targeting scalability enhancement, government system integration, and expanded machine learning capabilities for widespread industry adoption.

REFERENCES

[1] Ministry of Health and Family Welfare Report No. 37 of 2017; Implementation of Food Safety and Standards Act 2006; Union Government, Govt. of India: Delhi, India, 2017; pp. 1–102.
[2] MLJ. FSSAI. Available online: https://fssai.gov.in/cms/food-safety-and-standards-act-2006.php (accessed on 10 April 2020).
[3] PTI. Swiggy, Zomato, Others Remove 10,500 Restaurants for Violating Food Safety Law. Press Trust of India, 2018. Available online: https://economictimes.indiatimes.com/small-biz/startups/newsbuzz/swiggy-zomatoothers-remove-10500-restaurants-for-violating-food-safety-law/articleshow/67093466.cms?from=mdr (accessed on 10 April 2020).
[4] Sardar, D.R.Maggi Stewsin Lead and MSGPot: Controversy Over India's Favourite Instant Noodles; Social Science Research Network: Rochester, NY, USA, 2018.
[5] Boukema,A.;Lahaye,R.AdvantagesofAnomalyDetectionBetweentheControllingUnitandtheProcessDevicesof an Industrial Control System; University of Amsterdam: Amsterdam, The Netherlands, 2017; pp. 1–14.
[6] Paramithiotis, S.; Drosinos, E.H.; Skandamis, P.N. Food recalls and warnings due to the presence of foodborne pathogens—A focus on fresh fruits, vegetables, dairy and eggs. Curr. Opin. Food Sci. 2017, 18, 71–75. [CrossRef]
[7] Chinaka, M. Blockchain Technology—Applications in Improving Financial Inclusion in Developing Economies: Case Study for Small Scale Agriculture in Africa. Ph.D. Thesis, Massachusetts Institute of Technology (MIT), Cambridge, MA, USA, 2016; p. 43.
[8] Afshin, A.; Sur, P.J.; Fay, K.A.; Cornaby, L.; Ferrara, G.; Salama, J.S.; Mullany, E.C.; Abate, K.H.; Abbafati, C.; Abebe, Z.; et al. Health effects of dietary risks in 195 countries, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017. Lancet 2019, 393, 1958–1972. [CrossRef]
[9] Dai, H.-N.; Zheng, Z.; Zhang, Y. Blockchain for Internet of Things: A Survey. IEEE Int. Things J. 2019, 6, 8076–8094. [CrossRef]
[10] Ustundaga, A.; Tanyasb, M. The impacts of Radio Frequency Identification (RFID) technology on supply chain costs. Transp. Res. Part E Logist. Transp. Rev. 2009, 45, 29–38. [CrossRef]
[11] Tian, F. A supply chain traceability system for food safety based on HACCP, blockchain & Internet of Things. In Proceedings of the 14th International Conference on Services Systems and Services Management, ICSSSM 2017, Dalian, China, 16–18 June 2017; pp. 1–6.
[12] Tripoli, M.; Schmidhuber, J. Emerging Opportunities for the Application of Blockchain in the Agri-food Industry; FAO: Geneva, Switzerland, 2018; pp. 1–29.
[13] Kamath, R. Food Traceability on Blockchain: Walmart's Pork and Mango Pilots with IBM. J. Br. Blockchain Assoc. 2018, 1, 47–53. [CrossRef]
[14] Aung, M.M.; Chang, Y.S. Traceability in a food supply chain: Safety and quality perspectives. Food Control 2014, 39, 172–184. [CrossRef]
[15] Mao, D.; Hao, Z.; Wang, F.; Li, H. Innovative blockchain-based approach for sustainable and credible environment in food trade: A case study in Shandong Province, China. Sustainability (Switzerland) 2018, 10, 3149. [CrossRef]
[16] Arena,A.;Bianchini,A.;Perazzo,P.;Vallati,C.;Dini,G.BRUSCHETTA: An IoT Blockchain-Based Framework for Certifying Extra Virgin Olive Oil Supply Chain. In Proceedings of the 2019 IEEE International Conference on Smart Computing (SMARTCOMP), Washington, DC, USA, 12–15 June 2019; pp. 173–179.
[17] Aich, S.; Chakraborty, S.; Sain, M.; Lee, H.; Kim, H.-C. A review on the benefits of IoT integrated Blockchain based supply chain management implementations across different sectors with casestudy. In Proceedings of the 2019 21st International Conference on Advanced Communication Technology (ICACT), PyeongChang, Korea, 17–20 February 2019; pp. 138–141.
[18] Shakhbulatov, D.; Arora, A.; Dong, Z.; Rojas-Cessa, R. Blockchain Implementation for Analysis of Carbon FootprintacrossFoodSupplyChain. In Proceedings of the 2019 IEEE International Conference on Blockchain (Blockchain), Atlanta, GA, USA, 14–17 July 2019; pp. 546–551.
[19] Lucena, P.; Binotto, A.P.; Momo, F.D.S.; Kim, H. A Case Study for Grain Quality Assurance Tracking based on a Blockchain Business Network. In Proceedings of the Symposium on Foundations and Applications of Blockchain (FAB '18), Los Angeles, CA, USA, 9 March 2018; pp. 31–36.
[20] Kosba, A.; Miller, A.; Shi, E.; Wen, Z.; Papamanthou, C. Hawk: The Blockchain Model of Cryptography and Privacy-Preserving Smart Contracts. In Proceedings of the 2016 IEEE Symposium on Security and Privacy, SP 2016, San Jose, CA, USA, 23–25 MAY 2016; pp. 839–858.
[21] Yang, X.T.; Qian, J.P.; Sun, C.H. Design and application of a safe production and quality traceability system for vegetables. Trans. Chin. Soc. Agric. Eng. 2008, 24, 162–166.
[22] Sari, K. Exploring the impacts of radio frequency identification (RFID) technology on supply chain performance. Eur. J. Oper. Res. 2010, 207, 174–183. [CrossRef]
[23] Foroglou, G.; Tsilidou, A.L. Further applications of the blockchain. In Proceedings of the Columbia University PhD in Sustainable Development 10th Anniversary Conference, Athens, Greece, 27 February 2014; Volume 1, pp. 1–8.
[24] Sayogo, D.S.; Zhang, J.; Pardo, T.A.; Tayi, G.K.; Hrdinova, J.; Andersen, D.F.; Luna-Reyes, L.F.Going Beyond OpenData: Challenges and Motivations for Smart Disclosure in Ethical Consumption. J.Theor. Appl. Electron. Commer. Res. 2014, 9, 1–16. [CrossRef]
[25] Fischer, M.J.; Lynch, N.A.; Paterson, M.S. Impossibility of distributed consensus with one faulty process. J. ACM 1985, 32, 374–382. [CrossRef]
[26] Dwork, C.; Lynch, N.; Stockmeyer, L. Consensus in the presence of partial synchrony. J. ACM 1988, 35, 288–323. [CrossRef]



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