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# Blockchain for Supply Chain Transparency in Agri-Trade

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**Abstract: -**

Blockchain technology has emerged as a transformative digital innovation capable of addressing long-standing transparency and trust issues within agricultural supply chains. Originating as the foundational technology behind Bitcoin, blockchain has evolved beyond cryptocurrency applications to support smart contracts and decentralized data management across diverse sectors, including agriculture. In agri-trade, blockchain enables secure, tamper-proof, and real-time recording of transactions across all stages of the supply chain—from production and harvesting to storage, transportation, processing, and marketing. By ensuring data immutability and traceability, blockchain enhances food safety, quality assurance, fair pricing, and regulatory compliance while reducing fraud, inefficiencies, and information asymmetry. This paper reviews the working mechanisms, types, and applications of blockchain technology in agri-trade and highlights its role in improving supply chain transparency, strengthening farmer confidence, and promoting sustainable and accountable agricultural marketing systems. The study also discusses real-world implementations and ongoing challenges, positioning blockchain as a critical enabler of resilient and trustworthy agri-trade ecosystems.

**Keywords:** Blockchain technology, Agri-trade, Supply chain transparency, Traceability, Digital ledger.

**Introduction:**

Blockchain technology originated in 2008 when Satoshi Nakamoto introduced it as the underlying technology for Bitcoin through the paper *"Bitcoin: A Peer-to-Peer Electronic Cash System."* Initially, blockchain was used only for cryptocurrency transactions, where it functioned as a decentralized and secure digital ledger. Over time, researchers and

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industries recognized its broader potential beyond finance. From around 2015 onwards, blockchain evolved into Blockchain 2.0, enabling smart contracts and applications in sectors such as supply chain management, healthcare, and agriculture. Today, blockchain is widely applied in agri-trade to improve transparency, traceability, trust, and efficiency across agricultural supply chains, supporting fair trade and sustainable development. Blockchain technology enhances transparency and trust in agri-trade by creating a secure, decentralized, and tamper-proof digital record of every transaction along the agricultural supply chain—from farm to consumer (Nakamoto, 2008; Kshetri, 2018). Each stage such as production, harvesting, storage, transportation, processing, and marketing is recorded in real time and cannot be altered, ensuring data authenticity and reliability (Swan, 2015). This system helps farmers receive fair prices, reduces the role of middlemen, minimizes fraud and adulteration, and improves traceability of food products, which is especially important for quality assurance, food safety, and export compliance (Tian, 2016). In agri-trade, blockchain supports transparent pricing, faster payments, efficient contract enforcement through smart contracts, and better access to global markets, thereby strengthening farmer confidence and promoting sustainable and accountable agricultural marketing systems (Casino et al., 2019). At its core, a blockchain is a distributed digital ledger that records transactions in a secure and transparent manner. Each transaction is packaged into a "block" and linked cryptographically to the prior block, forming an immutable chain. This design ensures that data, once added, cannot be altered without consensus from the network, eliminating the risk of manipulation or unauthorized changes. In agricultural supply chains, blockchain enables stakeholders to record key data points such as planting dates, harvest yields, storage conditions, transportation milestones, quality assessments, and pricing details at every stage from farm to fork.

**Types of Blockchain**

Businesses must comprehend blockchain technology's many forms before employing it. Because the variations can be so huge, businesses should select the solution that is most suited to their unique company model. (Thompson 2016).

The following discussion covers the three main types of Blockchain:

**Public Blockchain**: Anyone with even rudimentary means can participate in a public Blockchain, as it is fully decentralized. Public Blockchain facilitates peer-to-peer transactions by removing the need for a third party. Blockchain that are accessible to the general public are often used to illustrate publicly available cryptocurrencies like Bitcoin, Ethereum, and others. Each transaction is verified by the network before it is recorded, thus enhancing its security. Despite being more expensive and slower than private Blockchain, public Blockchain continues to surpass the systems now used for recording. It was found (Thompson, 2016).

**Private Blockchain**: Users of a private Blockchain, which is a permission variety, need to get consent from acentral authority before they can do anything. Because the middleman still has some say in the system, we cannot say it is decentralized. According to (Thompson, 2016). A regulatory agency must first approve every transaction before it can be officially documented. When compared to a public Blockchain, a private Blockchain is both faster and cheaper. Mainly applicable to corporate governance and business structures. Great potential exists for it to boost output while cutting expenses. Private Blockchain technology may find application in online voting systems. Consortium Blockchain is a special kind of private Blockchain that has the characteristics of private Blockchain but is managed by a consortium of companies instead of a single entity (Dragon chain 2019).

**Hybrid Blockchain**: Hybrid Blockchain, as the name suggests, incorporates the best features of both private and public Blockchain. It's a private network setup that doesn't rely on a single entity. The handling of data and adaptability are excellent. It will be most useful to organizations with rigorous regulations to follow. One such example is the Xin Fin hybrid Blockchain, which was produced by combining Quorum and Ethereum (public) (private). Companies gain because their supply chains are improved (Roshan Khadka, 2020).

**The Working Mechanism of Blockchain**

Blocks are linked in a chain, hence the name "Blockchain," which describes how it operates. The hash of the block before it, the hash of the subsequent block, and a list of all valid transactions are some of the interconnected pieces of data that make up a block. Hashes are a type of digital signature. The hash connects each block to the one before it. miking it easier to verify its authenticity. As a result, a Blockchain is created that cannot be altered. (Gupta 2018). To fully comprehend Blockchain, it is important to keep in mind five fundamental concepts: a network of nodes, currency, a structure, a consensus process, and rules. The first thing to know is that the individual computers that make up a network are its "nodes." The nodes engage in conversation and cross examination. the transactions' integrity. A more robust network is one in which more links exist between its nodes. The possession of tokens, often known as digital currency or cryptocurrency, represents value. It has the same fungibility as money and can be exchanged for other assets. The next piece of Blockchain architecture is a chronological list of transactions. A blockchain is made up of interconnected blocks. To wit: (Krause et al., 2016). To establish which version of the ledger is the most correct, each node in a network participates in the consensus mechanism, which functions as a group decision making process. The risk of double payments or other types of transaction manipulation is eliminated by nodes. The two choices are proof-of-stake and proof-of-work approaches. To add new blocks to the Blockchain, the proof-of-work network of nodes must solve challenging puzzles. It is difficult to alter the transactions since the third party would have to outperform the whole network. It is utilized by Bitcoin. Proof-of-stake relies on token ownership as its underlying mechanism. The network with the most token has the most block creation power. The guidelines for how the parties should communicate with one another have been established. It explains what makes accounting systems tick. To wit: (Krause et al., 2016).

**Why Transparency Matters in Agri-Trade**

Supply chain transparency is a critical determinant of sustainability and efficiency in the agricultural sector, influencing consumer trust, food safety, farmer remuneration, and trade performance. Growing consumer awareness has intensified the demand for verifiable information regarding the origin of agricultural products, including cultivation practices, certifications, and post-harvest handling conditions. Blockchain technology facilitates end-to-end traceability by enabling the tracking of produce back to the farm level, thereby reducing food fraud and adulteration, supporting the rapid identification of contamination or food safety incidents, and strengthening consumer confidence in labels

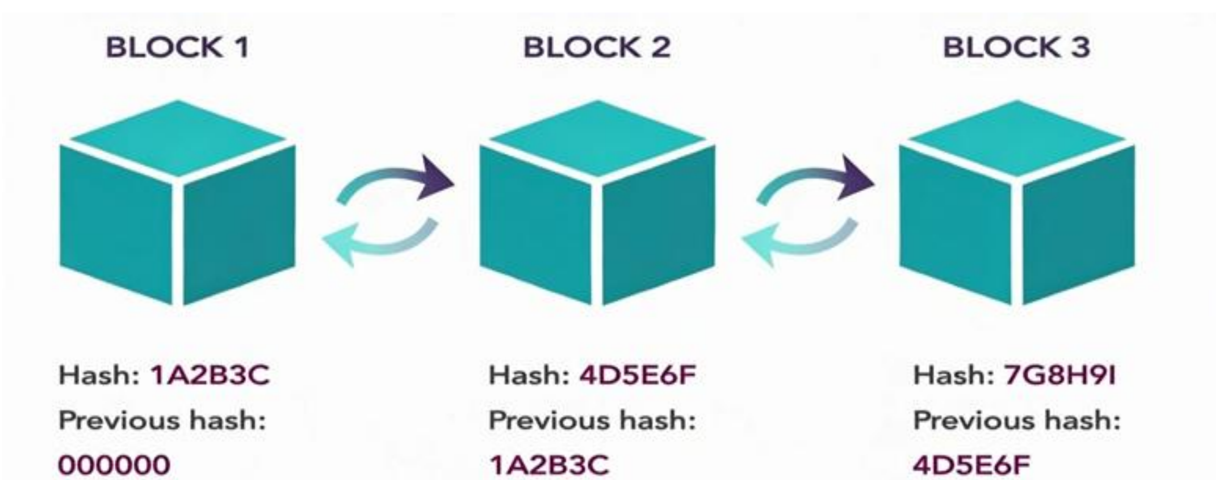


**Fig: Working Mechanism of Blockchain**

such as organic, fair trade, and sustainably sourced products. Moreover, enhanced transparency contributes to fairer pricing mechanisms for farmers by ensuring price visibility across transaction stages, maintaining immutable records of contractual agreements and payments, and minimizing malpractices related to weighing, grading, and settlement. In the context of agricultural trade and exports, blockchain further improves operational efficiency by streamlining documentation and regulatory compliance through automated verification of quality and phytosanitary certificates, facilitating faster settlements via smart contracts, and ensuring greater compliance with international trade regulations. Collectively, these features position blockchain-enabled transparency as a transformative mechanism for strengthening the integrity and resilience of agricultural supply chains.

**How Blockchain Improves Agri-Trade Processes**

In blockchain-enabled agri-trade supply chains, each participant is able to upload verified and time-stamped data to a shared and decentralized ledger. Farmers can record critical information such as the date and method of planting, while warehouses document storage conditions, including temperature and humidity levels. Logistics providers can further contribute by uploading real-time data related to cold-chain transportation, and retailers or exporters can access this consolidated information to substantiate product quality and compliance claims. Once recorded on the blockchain, such data cannot be altered or tampered with, thereby ensuring data integrity and fostering trust among all stakeholders in the supply chain.

Smart contracts further enhance efficiency by enabling automated, self-executing agreements on blockchain platforms. These contracts can trigger payments to farmers upon successful completion of quality inspections, authorize the release of goods once predefined shipment conditions are met, and apply penalties or incentives in accordance with contractual terms. By eliminating manual intervention and reducing paperwork, smart contracts facilitate faster settlements, minimize disputes, and improve overall operational efficiency.

Moreover, the inherent transparency of blockchain technology significantly reduces fraud and post-harvest losses in agri-trade systems. The visibility of transactions discourages unethical practices such as mislabelling of produce, manipulation of weights or grades, and concealment of product recalls or quality failures. In addition, real-time tracking and traceability enable timely interventions, thereby reducing waste associated with delayed, damaged, or lost shipments and contributing to more sustainable and resilient agricultural supply chains.

Blockchain technology has enormous potential to improve the agricultural supply chain's efficiency, traceability, and openness. Some potential applications of blockchain technology in agriculture are listed below. Provenance and traceability: From planting to harvesting to processing to packaging and distribution, the whole supply chain may be recorded on a blockchain that is both immutable and transparent. Therefore, customers, merchants, and authorities may verify the authenticity and quality of food items by tracking their entire supply chains back to their points of origin.

**Real-World Examples of Blockchain in Agri-Trade**

Across the globe, pilot projects and implementations are already underway:

- **Coffee and cocoa supply chains** use blockchain to trace bean origins and share this information with consumers to support ethical sourcing.
- **Seafood tracking systems** employ blockchain to track catch data, preventing illegal fishing and mislabelling.
- **Cold-chain vegetables and dairy products** use sensors linked to blockchain to monitor temperature and transport integrity.

These initiatives demonstrate blockchain's potential to boost market access and increase value returns for producers.

**Supply Chain Management (SCM) Challenges**

Contemporary global supply chains grapple with systemic vulnerabilities rooted in trust deficits, bureaucratic inefficiencies, and counterfeit proliferation. Trust erosion manifests as asymmetric information sharing: manufacturers withhold sourcing details to protect margins, while retailers doubt quality certifications. This opacity enables counterfeit networks, with the OECD attributing 3.3% ($509B) of global trade to falsified goods, notably pharmaceuticals (e.g., 267,000 annual deaths from fake antimalarials and luxury items (e.g., 30% of premium watches sold online are replicas, Paperwork bottlenecks compound these issues: cross-border shipments require 240+ documents, causing customs delays averaging 5.8 days and inflating logistics costs by 18%. Fragmented data architectures exacerbate risks, as evidenced by the 2022 baby formula crisis, where manual recordkeeping delayed contamination by 14 days. These challenges reflect a fundamental misalignment between SCM's physical complexity and its digital infrastructure.

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