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SQRBLOCK: QR-Driven Food Product Traceability Platform For Consumer Safety

Mr K Vikram Reddy[1],Shalmali Kadem[2],Sharvaani Kamlekar[3],Gayathri Mahadevoju[4]
[1]Associate Professor, Department Of IT, Matrusri Engineering College, Telangana, India.
[2,3,4]B.Tech Students;Department Of CME, Matrusri Engineering College, Telangana, India
Mail Id;shalmalikadem@gmail.com[2] , sharvaani213@gmail.com [3]
gayathrimahadevoju@gmail.com [4]

ABSTRACT

Food safety is a critical global concern, and traditional food supply chains often lack complete traceability, making it difficult to track products and quickly identify the source of contamination or food-borne outbreaks. These limitations delay response times and compromise consumer health. Although blockchain technology has shown potential in improving traceability, many existing solutions lack user-friendly interfaces, reducing accessibility for both producers and consumers. To address these challenges, the proposed SQRBlock framework introduces a blockchain-based food product traceability system that digitizes production and supply chain information, making it accessible, verifiable, and tamper-evident through QR codes. By recording key product details at every stage of the supply chain from production to retail, SQRBlock generates an immutable record for each food item. QR codes are generated for each batch, enabling consumers to instantly view product information and verify authenticity by scanning the QR code. The system uses SHA-256 hashing to secure each block of data, ensuring that any attempt to alter stored information breaks the chain and immediately reveals tampering. Integrated through a lightweight backend and scalable storage, SQRBlock supports efficient data retrieval, real-time validation, and reliable performance for both small-scale and large-scale operations. Experimental evaluation demonstrates that SQRBlock maintains data integrity, provides seamless traceability, and offers a practical verification mechanism for consumers, retailers, and regulatory authorities. With its transparent, secure, and user-friendly design, SQRBlock enhances trust in the food supply chain and contributes to improved global food safety standards.

KEYWORDS*— Blockchain, Food Supply Chain Security, QR Code Authentication, SHA-256 Hashing, Tamper Detection, Traceability System.*

INTRODUCTION

Food safety and supply chain transparency have become critical global challenges due to the increasing complexity of food distribution networks and the rise in counterfeit and contaminated food products. Traditional food traceability systems primarily rely on centralized databases, which are susceptible to data manipulation, delayed updates, and single points of failure. These limitations hinder rapid identification of contamination sources and reduce consumer trust in food product authenticity.Recent technological advancements have introduced various mechanisms to improve traceability in agri-food supply chains. Quick Response (QR) codes enable consumers to access product-related information through smartphone scanning, while Radio Frequency Identification (RFID) enhances automated tracking during logistics and distribution. Additionally, blockchain technology has emerged as a promising solution for secure and immutable record management due to its decentralized architecture and cryptographic integrity mechanisms. Several studies have explored blockchain-based food traceability systems integrated with IoT sensors, smart contracts, and hybrid RFID–QR models.Despite these advancements, existing systems present significant limitations. Centralized QR-based platforms lack tamper detection capabilities and remain vulnerable to unauthorized database modifications. RFID-based models require costly hardware and specialized readers, limiting their adoption among small-scale producers. Many blockchain-enabled solutions involve complex architectures, high storage requirements, and computational overhead, making them impractical for lightweight deployment. Furthermore, most implementations do not provide a consumer-friendly verification interface that allows real-time validation of product authenticity.To address these challenges, this paper proposes SQRBlock: a QR-Driven Food Product Traceability Platform for Consumer Safety. The proposed system integrates blockchain-based hashing with dynamic QR code generation to provide secure, scalable, and user-friendly traceability. Each food batch is registered with essential metadata, stored in a lightweight SQLite database, and cryptographically secured using SHA-256 hashing within a blockchain ledger structure. The generated QR code links to a backend verification service, enabling consumers to validate product authenticity in real time.Unlike conventional centralized systems, SQRBlock detects tampering by recalculating and validating blockchain hashes against stored records. Any alteration in product data breaks the chain integrity, immediately indicating inconsistency. The system architecture is designed to remain lightweight, reducing storage overhead while maintaining immutability and transparency. Additionally, the user-centric verification module enhances consumer confidence and promotes accountability among supply chain participants.

The primary contributions of this work are as follows:

1. A lightweight blockchain-integrated traceability framework suitable for small- and medium-scale producers.
2. A tamper-detection mechanism using SHA-256 hashing linked through a chained block structure.
3. A QR-based real-time verification interface for consumer authentication.
4. A scalable and practical implementation using Flask and SQLite for efficient deployment.

By combining blockchain integrity with QR-based accessibility, SQRBlock bridges the gap between secure backend traceability and consumer-level verification, thereby strengthening transparency, improving food safety monitoring, and enhancing trust within the food supply chain ecosystem.

LITERATURE SURVEY

Food supply chain traceability has attracted significant research attention in recent years, particularly with the integration of QR codes, RFID systems, and blockchain technologies.

Jose et al. (2024) proposed a QR-based food supply traceability system using a centralized database for dry-fish supply chains. The system enabled consumers to access product details such as source, freshness, and safety information through QR scanning. The study demonstrated improved transparency and cost-effectiveness for micro and small enterprises. However, since the system relied on centralized storage, it lacked mechanisms for tamper detection and remained vulnerable to unauthorized database modifications.

Černý (2023) introduced a hybrid RFID and QR-based tracking model aimed at improving operational efficiency across production and distribution stages. The combination of RFID for rapid scanning and QR for consumer-level lookup enhanced logistical performance. Despite its efficiency benefits, RFID infrastructure required specialized hardware and increased implementation costs. Moreover, the proposed model did not incorporate blockchain-based immutability, making it susceptible to cloning and interception risks.

Several IRJET and conference publications (2023–2024) proposed QR-based product authentication systems linked to centralized backend servers. These systems provided a low-cost anti-counterfeiting mechanism and allowed consumers to verify product authenticity through web interfaces. While practical and simple to deploy, such approaches suffered from a critical limitation: QR codes could be copied or reused on counterfeit products, and centralized databases lacked robust tamper-proof mechanisms.

The Internet Society (2020) presented a QR Code Security and Risk Framework focusing on secure scanning practices and IoT data handling. The framework identified common vulnerabilities such as phishing, QR cloning, and unauthorized redirection. Although it outlined security best practices, it did not provide a complete architectural solution integrating tamper detection or blockchain validation mechanisms.

From the reviewed literature, two primary research gaps are identified:

5. The absence of lightweight blockchain-integrated traceability systems suitable for small-scale deployment.
6. The lack of consumer-friendly verification mechanisms combined with strong tamper-detection capabilities.

The proposed SQRBlock framework addresses these limitations by integrating SHA-256-based blockchain hashing with dynamic QR verification, ensuring immutability, real-time validation, and enhanced transparency in food supply chains.

EXISTING SYSTEM

Existing agri-food traceability systems employ blockchain, RFID, IoT, and QR-based technologies to improve supply chain transparency and monitoring. However, these solutions often involve high storage and computational requirements, complex architectures, and costly infrastructure. Additionally, many lack consumer-friendly verification interfaces, emphasizing the need for scalable, lightweight, and accessible traceability mechanisms.

PROBLEM STATEMENT

Existing food traceability systems lack effective tamper-detection mechanisms, particularly in centralized QR and database-based models. As a result, stored product information remains vulnerable to unauthorized modification.

QR codes used in such systems can be easily copied or reused on counterfeit products, reducing the reliability of authentication. Similarly, RFID-based approaches require expensive hardware and specialized readers, limiting their feasibility for small-scale producers.

The absence of immutable data structures further increases the risk of server-side alterations. In addition, complex architectures make deployment and

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maintenance difficult, especially for small and medium enterprises.

Redundant QR generation across multiple supply chain stages often creates confusion and data inconsistency. Moreover, many existing systems provide limited support for real-time traceability and lack consumer-friendly verification interfaces.

These challenges highlight the need for a lightweight, secure, and scalable traceability framework that ensures data integrity and reliable product authentication.

PROPOSED SYSTEM

To address the limitations of existing traceability models, this paper proposes SQRBlock, a lightweight blockchain-integrated food product traceability system. The proposed framework combines QR-based verification with SHA-256 blockchain hashing to ensure data integrity and tamper detection.

In SQRBlock, producers register product batch details through a web interface, and the information is stored in a SQLite database. Each batch record is converted into a blockchain block containing a timestamp, previous hash, and current hash, thereby forming an immutable chain. A dynamic QR code is generated for each batch, linking to a backend verification page rather than storing static product information.

When a consumer scans the QR code, the system retrieves the stored data, recalculates the hash, and validates it against the blockchain ledger. Any mismatch indicates tampering. The proposed system ensures secure, scalable, and consumer-friendly real-time product authentication while maintaining a lightweight and cost-effective architecture.

METHODOLOGY

The proposed SQRBlock system follows a modular and lightweight architecture integrating database storage, blockchain hashing, and QR-based verification to ensure secure food product traceability.

Product Registration

Producers enter product details such as product name, batch ID, manufacturing date, expiry date, and description through a web interface. The data is validated and stored in a SQLite database. The registered batch information is then prepared for blockchain processing.

Blockchain Block Creation

Each batch record is converted into a blockchain block. The data is serialized into JSON format and hashed using SHA-256. Every block contains a timestamp, batch data, previous hash, and current hash, forming a linked chain. Any alteration in stored data results in a hash mismatch, enabling tamper detection.

QR Code Generation

After successful block creation, a QR code is generated using Python libraries. The QR encodes a verification URL rather than static product data. The generated QR is stored and attached to the product batch.

Verification and Integrity Check

When a consumer scans the QR code, the system retrieves batch details from the database and recalculates the hash. The recalculated hash is compared with the blockchain record. If both values match, the product is verified; otherwise, tampering is detected.

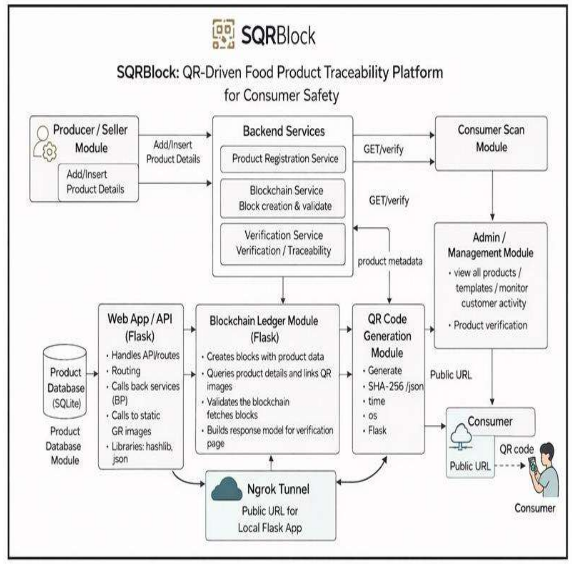

Figure 1: SQRBlock System Architecture Diagram

Implementation Environment

The system is implemented using Python, Flask, SQLite, SHA-256 hashing (hashlib), JSON-based blockchain storage, and QR generation libraries. Experimental testing confirmed successful detection of data modification and reliable traceability.

IMPLEMENTATION / DISCUSSION

The proposed SQRBlock system was implemented using Python 3.x with the Flask framework for backend development. SQLite was used as a lightweight database to store product batch information. Blockchain functionality was implemented using SHA-256 hashing through Python's hashlib library, with blocks structured in JSON format. QR codes were generated using the qrcode and Pillow libraries, encoding dynamic verification URLs.

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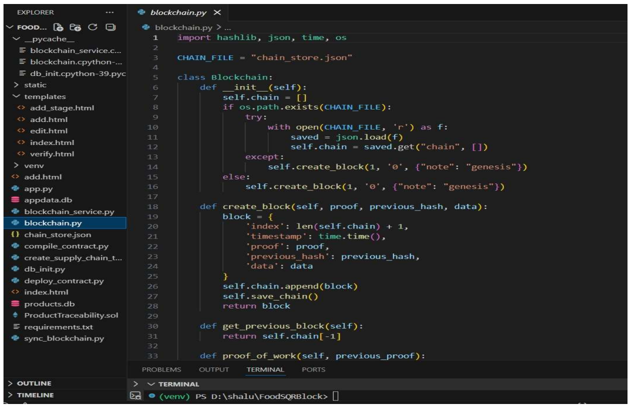

Figure 2 : blockchain.py — Blockchain Implementation Code in VS Code

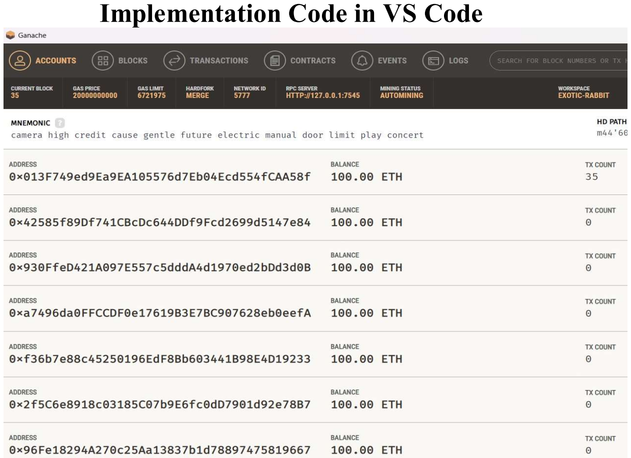

Figure 3: Ganache Accounts — Ethereum Test Accounts (100 ETH each)

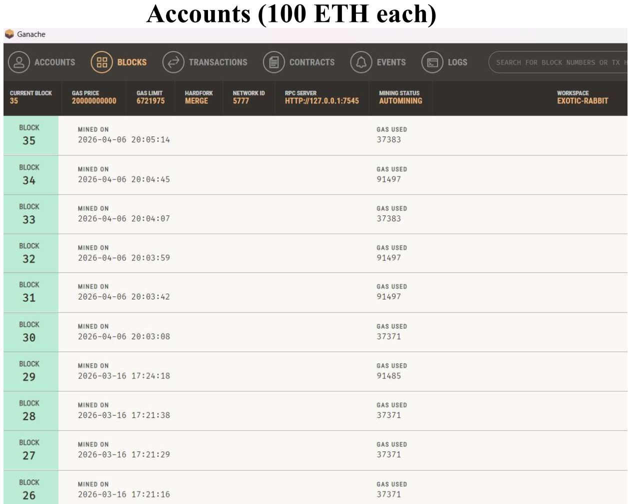

Figure 4: Ganache Blocks — Mined Blocks with Transaction Records

The system consists of modules for product registration, blockchain block creation, QR generation, consumer verification, and admin monitoring. The application was deployed on a local server environment and tested using standard web browsers.

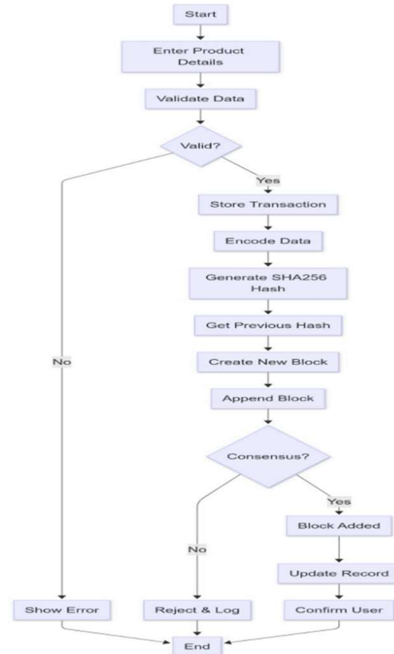

Figure 5: All Products Dashboard — Admin Management Interface

Experimental testing was conducted by registering multiple product batches and simulating data tampering within the database. The system successfully detected inconsistencies when stored data was altered, as recalculated hashes failed to match the blockchain records.

The results demonstrate that integrating blockchain hashing with QR-based verification provides effective tamper detection and real-time traceability. Compared to centralized QR systems, SQRBlock enhances data integrity while maintaining a lightweight and cost-efficient architecture suitable for small-scale deployment.

EXPERIMENTAL RESULTS

The proposed SQRBlock system was tested by registering multiple product batches and performing verification through generated QR codes. The system successfully retrieved batch information and validated blockchain integrity in real time.

When database records were intentionally modified, the recalculated SHA-256 hash did not match the stored blockchain hash, and the system correctly displayed a tampering alert.

Output

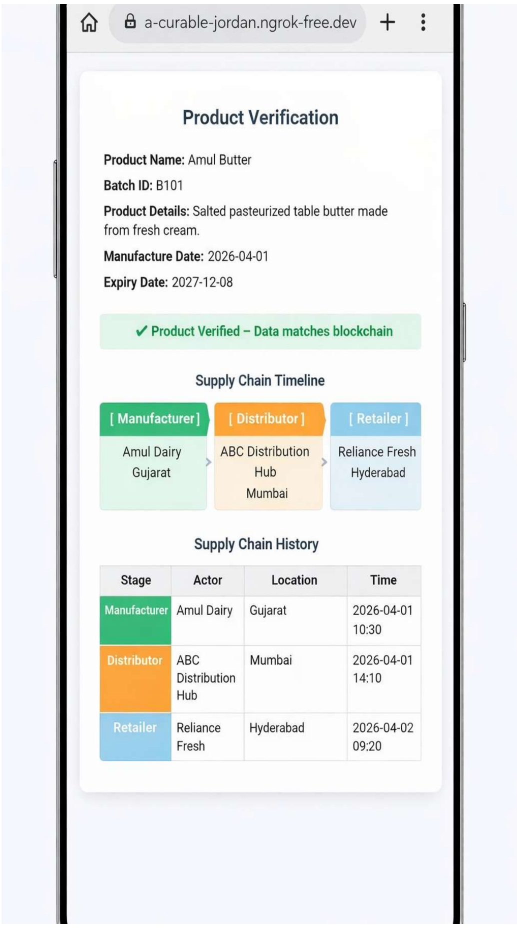

Figure 6: Product Verification — Verified Output on Mobile (Amul Butter, Batch B101)

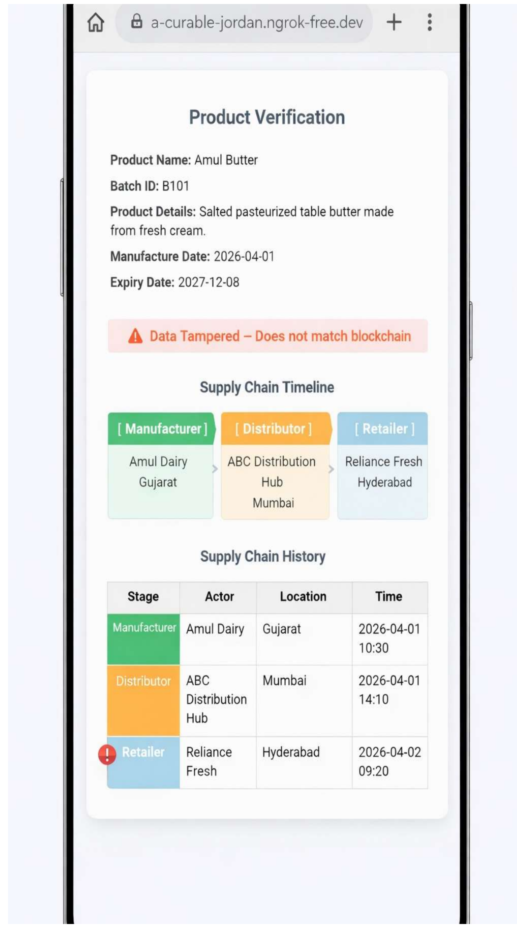

Figure 8: Product Verification — Tampered Data Alert on Mobile

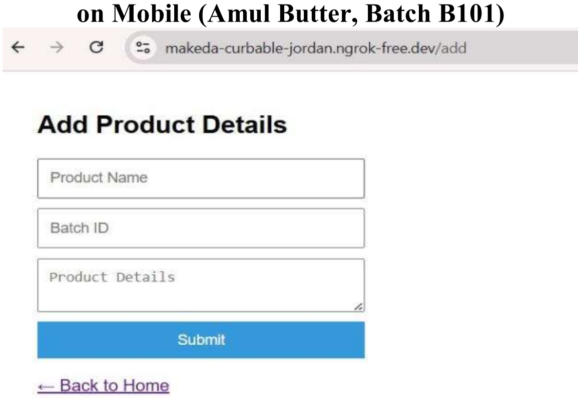

Figure 7: Supply Chain History — Tampering Detection Interface

Figure 9: Product Verification Result Page

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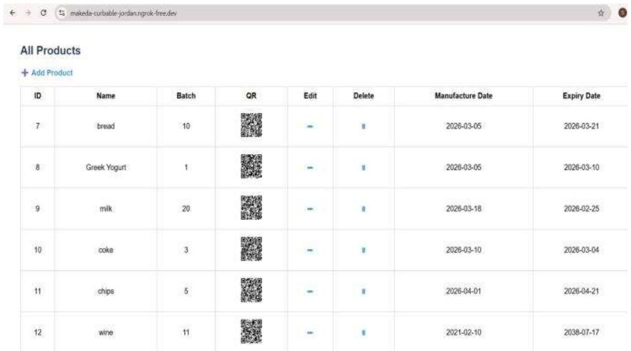

Figure 10: Additional Verification Output

CONCLUSION

This paper presented SQRBlock, a lightweight blockchain-integrated food traceability system that combines SHA-256 hashing with QR-based verification. The proposed framework ensures data immutability, real-time tamper-detection, and consumer-friendly authentication. Experimental evaluation demonstrated reliable integrity validation and effective detection of unauthorized modifications. By integrating secure backend mechanisms with accessible QR verification, SQRBlock enhances transparency, trust, and safety within the food supply chain while remaining scalable and suitable for small-scale deployment.

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