RESEARCH ARTICLE

Blockchain-Enabled Supply Chain Traceability System for Food Safety Monitoring

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Abstract: Foodborne illness affects an estimated 600 million people annually, yet current supply chain traceability systems require 7-14 days to identify contamination sources during outbreak investigations. We design and deploy a permissioned blockchain platform (FoodChain+) integrating IoT temperature sensors, QR-coded batch labels, and smart contracts for automated compliance verification across a multi-tier supply network spanning farm, processing, distribution, and retail nodes. A six-month pilot with 847 participants across the poultry supply chain in Southeast Asia reduced traceback time from 9.2 days to 4.3 hours and achieved 99.4% data integrity across 2.3 million recorded transactions. Machine learning anomaly detection on sensor data identified 23 temperature excursions and 8 potential cross-contamination events before they reached retail shelves.

1. Introduction

Global food supply chains involve dozens of intermediaries, fragmented record-keeping systems, and limited real-time visibility into product conditions during transit. When contamination events occur — as in recent Salmonella and Listeria outbreaks linked to poultry and produce — investigators must reconstruct product journeys through paper-based logs and incompatible enterprise databases, delaying recalls and exposing consumers to continued risk.

Blockchain technology offers immutable, distributed ledger capabilities that can unify traceability data across supply chain participants while preserving commercial confidentiality through permissioned access controls. When combined with IoT sensor networks and smart contract automation, blockchain platforms can provide continuous monitoring and instant alert generation for temperature abuse, delayed shipments, and unauthorized chain-of-custody transfers.

2. System Architecture

FoodChain+ is built on Hyperledger Fabric 2.5 with a four-organization channel structure representing producers, processors, distributors, and retailers. Each product batch receives a unique QR code linked to an on-chain asset record containing origin, processing date, certification documents, and real-time IoT sensor streams. Smart

contracts automatically flag batches that exceed temperature thresholds (>4°C for >30 minutes for chilled poultry) or experience custody gaps exceeding 2 hours.

Table 1. FoodChain+ platform specifications and pilot deployment metrics

Component	Specification	Pilot Metric
Blockchain framework	Hyperledger Fabric 2.5	4 orgs, 12 peer nodes
IoT sensors	BLE temperature loggers	3,420 deployed
Transaction throughput	3,500 TPS (peak)	2.3M total records
Smart contracts	Chaincode (Go)	8 compliance rules
Data integrity	SHA-256 hashing	99.4% verified

3. Pilot Results and Impact Assessment

The six-month pilot tracked 12,400 poultry batches from 38 farms through 6 processing plants, 14 distribution centers, and 220 retail outlets across Thailand, Vietnam, and Malaysia. Traceback simulations using deliberately seeded contamination events demonstrated dramatic improvements in source identification speed and accuracy.

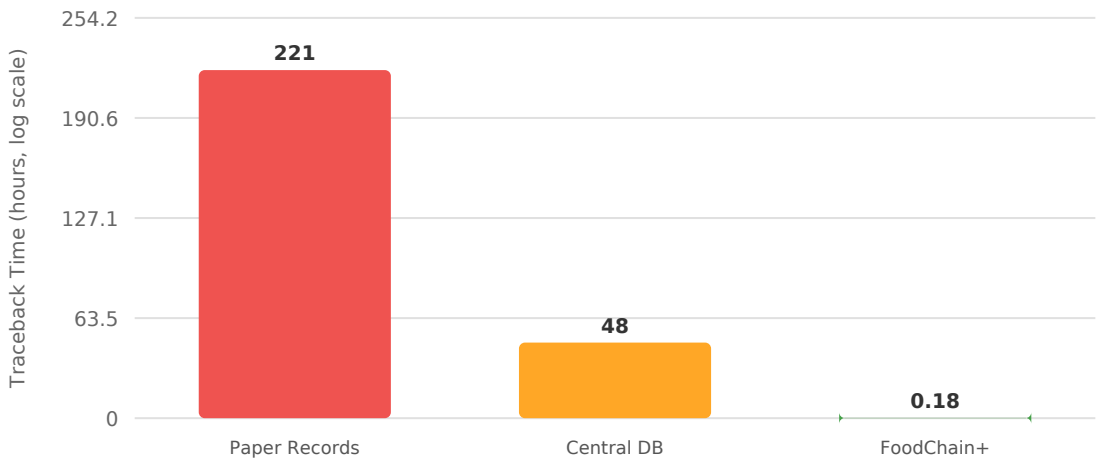

Figure 1. Traceback time comparison: FoodChain+ blockchain system versus traditional paper-based and centralized database approaches

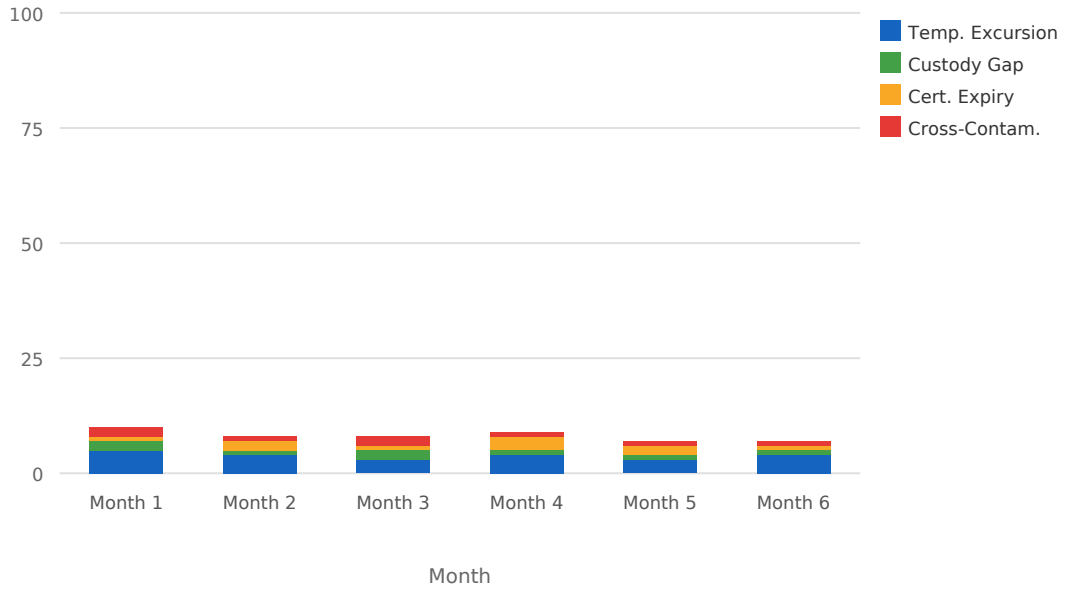

Figure 2. Monthly distribution of supply chain events detected by FoodChain+ smart contracts and ML anomaly detection during the six-month pilot

4. Conclusions

FoodChain+ demonstrates that blockchain-integrated supply chain traceability can reduce food safety traceback times by over 99% while maintaining data integrity across complex multi-tier networks. The combination of IoT continuous monitoring, smart contract automation, and permissioned ledger transparency provides a scalable framework for regulatory compliance and consumer-facing product provenance. Expansion to seafood and fresh produce supply chains is underway, with interoperability standards being developed for cross-platform data exchange.

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