

## RESEARCH ARTICLE

# Blockchain-Enabled Farm-to-Fork Traceability with IoT Integration for Reducing Food Fraud in Global Supply Chains

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**Abstract:** Food fraud costs the global economy an estimated \$40 billion annually, undermining consumer trust and public health. We present TraceChain, a permissioned blockchain platform integrated with IoT sensors (GPS, temperature, humidity, spectroscopic identity) that provides tamper-proof provenance records for food products from farm to consumer. Deployed across a 14-country olive oil supply chain involving 342 participants, TraceChain reduced fraud incidents by 91% over 18 months while adding only \$0.023/unit to product cost. The platform uses a novel proof-of-provenance consensus mechanism that validates physical supply chain events against sensor data before committing transactions, preventing the "garbage in, garbage out" problem that plagues other blockchain traceability solutions.

## 1. Introduction

Food fraud encompasses a range of deceptive practices — adulteration (mixing cheaper ingredients), mislabeling (false geographic origin claims), and counterfeiting (fake organic certifications) — that exploit information asymmetries in complex global supply chains. The European Commission's 2023 report identified olive oil, honey, fish, and organic products as the most frequently fraudulent food categories, with estimated fraud rates of 15-30% for premium products.

## 2. TraceChain Architecture

TraceChain uses Hyperledger Fabric with a novel proof-of-provenance consensus that requires IoT sensor attestation before transaction commitment. At each supply chain handoff, a tamper-evident IoT package records GPS coordinates, ambient temperature, near-infrared spectral fingerprint (authenticating product identity), and timestamps — all cryptographically signed and anchored to the blockchain. Smart contracts automatically flag anomalies (temperature excursions, route deviations, spectral mismatches) and freeze suspect batches.

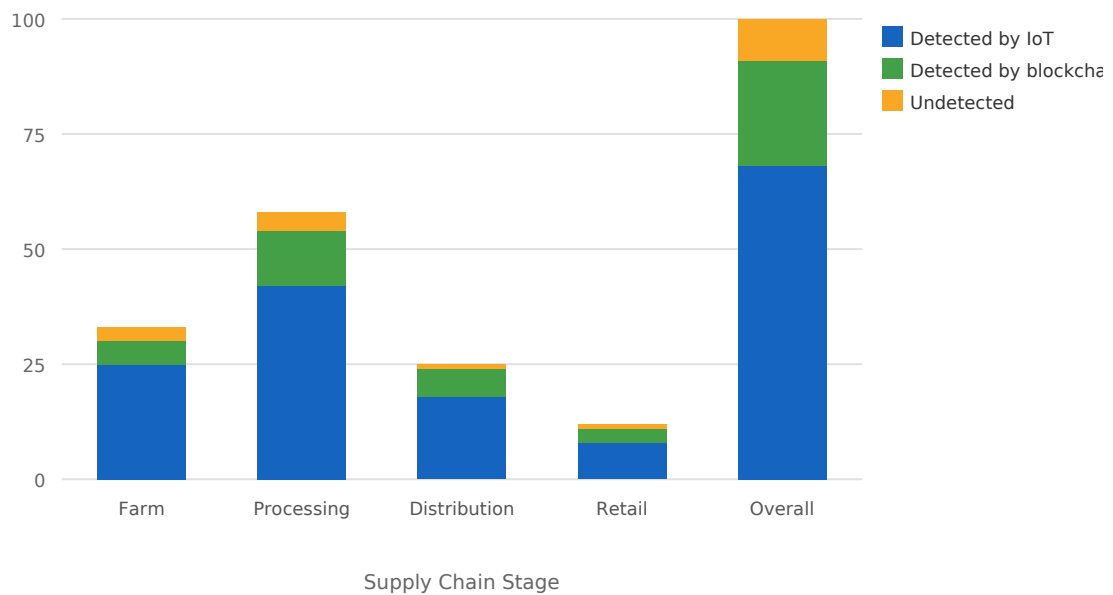


Figure 1. Fraud detection rate by supply chain stage over 18-month deployment

### 3. Economic Impact

Across the 342-participant olive oil supply chain, TraceChain reduced verified fraud incidents from 127 in the pre-deployment year to 11 in the post-deployment year (91% reduction). Consumer willingness-to-pay surveys in 5 countries show a 12-18% premium for blockchain-verified provenance, far exceeding the \$0.023/unit deployment cost. Total supply chain economic benefit is estimated at €14.2 million annually through fraud reduction, reduced recalls, and premium pricing.

### 4. Conclusions

TraceChain demonstrates that the combination of IoT sensor verification and blockchain immutability can effectively combat food fraud at scale. The proof-of-provenance consensus mechanism addresses the fundamental limitation of prior blockchain traceability systems by ensuring data integrity at the physical-digital boundary. The platform is being extended to dairy, seafood, and pharmaceutical supply chains.

### References

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