Organic Food Traceability System Using Blockchain Technology

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***Abstract*—Consumers who pay a premium for organic food have few dependable ways to confirm that a product was really grown organically or to find out where it came from. Along the organic supply chain, records are usually kept on paper or in separate, centrally controlled databases, which makes them easy to alter, prone to entry errors and closed to the buyer. This paper presents an Organic Food Traceability System that follows an organic product from the farm to the consumer. The work is carried out in three phases: a comparative study of existing food traceability systems, the design of the system architecture and database, and the development of an initial working version. For every batch of produce the system records farmer details, cultivation practices, harvest date, organic certification data and transport details. The complete record is kept in a database, and a cryptographic hash of it is written to a blockchain through a smart contract, so any later change to the stored data can be detected. Each batch receives a QR code that a consumer scans with a smartphone to see the product's origin, its path through the supply chain and whether its records are intact. The system aims to make the organic supply chain transparent, strengthen consumer trust, reduce organic food fraud and help certifiers and retailers confirm that a product is genuinely organic.**

***Index Terms*—Blockchain, Database, Food Safety, Organic Farming, Organic Food Traceability, QR Code, Smart Contract, Supply Chain Management.**

I. INTRODUCTION

Demand for organic food has grown steadily as people become more conscious of health and of the environmental cost of farming. Organic produce is grown without synthetic fertilisers or pesticides and is sold at a higher price than conventional produce. That price difference also creates a reason to sell ordinary produce under an organic label. In India, organic production is regulated under the National Programme for Organic Production (NPOP) [1], and the Agricultural and Processed Food Products Export Development Authority (APEDA) runs TraceNet, a web-based system that records certification and traceability data for organic exports [2]. These systems serve regulators and exporters well, but a shopper in a local market still has no simple way to check whether an organic label is genuine.

Traceability is the ability to follow a food product through every stage of production, processing and distribution [3]. In a typical organic supply chain the farmer, the certification body, the transporter and the retailer each keep their own records. Because these records are held separately and controlled by single parties, an entry can be changed or deleted without the others knowing, mistakes are passed along, and the consumer sees none of this history.

A blockchain is a shared ledger in which records are grouped into blocks, each block is linked to the previous one by a cryptographic hash, and copies of the ledger are kept on many nodes [4]. Changing an accepted record would mean rewriting every later block on most of those nodes, so tampering becomes evident. Smart contracts, which are programs stored and executed on the blockchain, can enforce rules such as which participant is allowed to add which type of record [5]. When this ledger is paired with Quick Response (QR) codes, which almost any smartphone can read [6], a consumer can look up the verified history of a product in a few seconds.

This paper proposes an Organic Food Traceability System built on these ideas. Its contributions are: 1) a comparative study of existing traceability systems and the gaps they leave for organic products; 2) an architecture that keeps full records in a database and their hashes on a blockchain, which keeps blockchain costs low while still exposing any tampering; and 3) an initial version in which consumers verify products by scanning a QR code.

II. LITERATURE SURVEY

Aung and Chang [3] reviewed traceability in food supply chains from the point of view of safety and quality. They noted that most companies keep traceability data in their own internal systems, which limits visibility across the whole chain and slows down recalls.Tian [7] proposed an agri-food traceability system for China that combines Radio Frequency Identification (RFID) tags with blockchain so that data captured during production, processing, storage, distribution and sale can be shared and trusted by all parties. In later work [8], The author integrated blockchain with HACCP and IoT.

Caro et al. [9] built AgriBlockIoT, a decentralised traceability solution that feeds data from IoT devices into a blockchain, and compared deployments on Ethereum and Hyperledger Sawtooth. Salah et al. [10] used Ethereum smart contracts to trace soybeans through the supply chain and stored supporting files in the InterPlanetary File System (IPFS) [11], removing the need for a central trusted authority.

Several reviews summarise the field. Kamilaris et al. [12] surveyed blockchain projects in agriculture and food and identified cost, scalability and the reliability of data entry as the main barriers. Galvez et al. [13] discussed how blockchain can support food traceability analysis and listed open challenges, including integration with existing systems. Demestichas et al. [14] reviewed blockchain-based agricultural traceability systems and their use alongside IoT, RFID and QR codes.

Table I compares the main approaches. Existing work concentrates on sensor data, a single crop or export certification. Few systems connect the organic certificate of a batch to a consumer-facing check that works with only a phone camera, which is the gap this work addresses.

Table I
Comparison of Existing Traceability Approaches

Ref.	Technology	Focus	Limitation for organic retail
[7]	RFID and blockchain	Agri-food chain in China	Tag cost; no organic certificate check
[9]	IoT, Ethereum, Sawtooth	Farm sensor data	Does not cover certification or consumer access
[10]	Ethereum and IPFS	Soybean supply chain	Single crop; consumer view not the focus
[2]	Central web system	Organic export certification	Single authority; aimed at exporters
This work	Blockchain, database, QR code	Organic produce, farm to consumer	-

III. PROBLEM STATEMENT AND OBJECTIVES

A. Problem Statement

Organic food records are scattered across farmers, certifiers, transporters and retailers, are often kept on paper or in centralised databases, and can be altered without detection. Consumers therefore cannot verify the origin of an organic product or whether it is certified, and mislabelled products can enter the market unnoticed.

B. Objectives

1) To record the details of each organic batch, including farmer, cultivation method, harvest date, certification and transport, in one structured system.
2) To make every stored record tamper-evident by anchoring its hash on a blockchain.
3) To let each stakeholder add only the records that belong to their role.
4) To let consumers view a product's origin and journey by scanning a QR code.
5) To reduce organic food fraud and increase consumer trust in organic labels.

IV. PROPOSED METHODOLOGY

The work is organised into three phases, each producing an output used by the next.

A. Phase 1: Comparative Study

Published traceability systems and government platforms were studied and compared on the technology used, the data recorded, who can view the data and how tampering is prevented. The findings, summarised in Table I, fixed the data that the proposed system must capture and the weaknesses it must avoid.

B. Phase 2: Architecture and Database Design

The stakeholders, their roles and the data each one produces were identified. A layered architecture (Fig. 1) and a relational data model (Table II) were

designed. It was decided which data stays off-chain and which is written to the blockchain, and the functions of the smart contract were specified.

C. Phase 3: Development of the Initial Version

The database, the smart contract, the web portal for stakeholders and the QR-based consumer page are built and connected. The initial version is tested with sample batches that pass through every stage of the supply chain.

V. SYSTEM ARCHITECTURE

The system follows the layered design shown in Fig. 1. Stakeholders interact with an application layer that validates their input, stores the full record in an off-chain database and writes a hash of that record to the blockchain. The application also generates the QR code printed on the product label.

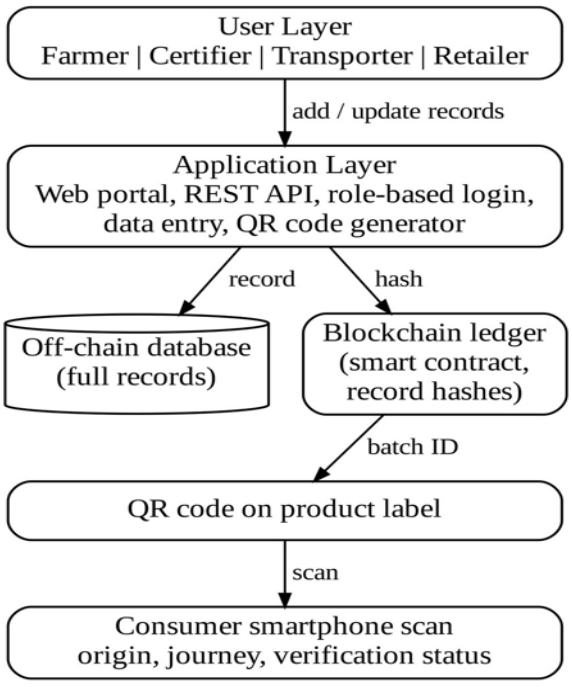

Fig. 1. Architecture of the Organic Food Traceability System.

A. Stakeholders and Roles

Farmer: registers the farm, records the cultivation method, inputs used and harvest date, and creates a batch. Certifier: links a valid organic certificate to the farm or batch and approves it. Transporter: records pickup, delivery and storage conditions. Retailer: records receipt of the batch and prints the QR label. Consumer: scans the QR code and views the history without needing an account. Administrator: registers stakeholders and assigns their blockchain addresses and roles.

B. Data Model

The main entities stored in the off-chain database are listed in Table II. Each record also stores the transaction identifier of the blockchain entry that anchors it.

Table II
Main Entities of the Data Model

Entity	Key attributes
Farmer	Farmer ID, name, contact, location, blockchain address
Cultivation	Farm ID, crop, organic practices, inputs used, sowing date
Certification	Certificate number, certifying body, scope, validity period
Batch	Batch ID, crop, quantity, harvest date, QR code
Transport	Batch ID, vehicle, source, destination, dates, storage condition
Retail	Batch ID, retailer, receipt date, shelf location

C. Hashing and Blockchain Storage

Storing complete records on a public blockchain is expensive, so only a fixed-length digest of each record is written on-chain. When the i-th record D_i of a batch is added, its hash is computed with SHA-256 [15] and chained to the hash of the previous record:

$$H_i = \text{SHA-256}(D_i \,\|\, H_{i-1}), \quad H_0 = \text{SHA-256}(B) \quad (1)$$

where B is the batch identifier and $\|$ denotes concatenation. The smart contract stores H_i together with the sender's address and a timestamp. To verify a batch, the system recomputes the hashes from the database records, giving $\hat{H}_i$ for each record, and compares them with the on-chain values:

$$V = 1 \text{ if } \hat{H}_i = H_i \text{ for every I} \quad (2)$$

Otherwise, V = 0. A value of V = 1 means the stored history is unchanged since it was recorded; V = 0 means at least one record has been altered or removed, and the consumer page shows a warning.

D. QR Code Workflow

1) The farmer creates a batch, and the system assigns a unique batch ID.

2) The certifier, transporter and retailer add their records; each record is hashed and anchored on-chain.
3) The retailer generates a QR code that encodes a verification URL containing the batch ID.
4) The consumer scans the code and the page retrieves the batch history from the database.
5) The page recomputes the hashes using (2) and displays the origin, the journey and the verification status.

VI. IMPLEMENTATION OF THE INITIAL VERSION

The initial version is developed as a web application. The smart contract is written in Solidity and deployed first on a local Ethereum test network for development and then on a public Ethereum test network. The back end, written in Node.js with Express, exposes a REST interface, communicates with the contract through the ethers.js library and stores records in a MySQL database. The front end is built with HTML, CSS and JavaScript, and QR codes are generated with an open-source QR library.

The smart contract provides the functions registerStakeholder, createBatch, addCertificate, addTransportRecord, addRetailRecord and getBatchHistory. Each write function checks the role of the calling address, so a transporter, for example, cannot add a certificate. Every successful call emits an event that the back-end stores with the matching database record.

VII. EXPECTED RESULTS AND DISCUSSION

Table III compares the proposed system with conventional record keeping on the properties that matter most for organic food. The comparison is qualitative, since the initial version has not yet been evaluated at scale.

Table III
Conventional Record Keeping Versus the Proposed System

Property	nventional records	Proposed system
Data integrity	Records can be edited unnoticed	Any change is detected through on-chain hashes
Consumer access	Not available	Full history through a QR scan
Certificate check	Manual, by paper copy	Linked to the batch and approved by certifier
Accountability	Hard to tell who made an entry	Every entry signed by a stakeholder address
Recall tracing	Slow, across separate records	Batch history available in one place

The planned evaluation of the initial version will measure transaction confirmation time, the gas cost of each type of record, the time from QR scan to display of the verification result, and user feedback from farmers and consumers.

The approach also has limitations. A blockchain proves that a record has not changed since it was entered, but it cannot prove that the record was true when it was entered; the system therefore depends on the certifier's approval and on role-based permissions. Public blockchain transactions carry a fee, which is kept low by storing only hashes. Farmers in rural areas may have limited connectivity, so offline data entry with later synchronisation is needed. Finally, a QR label can be copied onto a fake product; tracking the number and location of scans for each batch can help detect such cloning.

VIII. CONCLUSION AND FUTURE SCOPE

This paper presented an Organic Food Traceability System that records the journey of organic produce from farm to consumer. By keeping full records in a database and anchoring their hashes on a blockchain, the system makes any later change to the history detectable without the cost of storing all data on-chain. Role-based smart contract functions make each stakeholder accountable for their own entries, and a QR code gives consumers direct access to a product's origin and verification status. The system can improve transparency in the organic supply chain, build consumer trust and make organic food fraud harder to carry out.

Future work includes IoT sensors that record temperature and humidity during transport automatically, storage of certificate documents in IPFS [11], a mobile application for farmers with offline support, integration with government platforms such as TraceNet [2], and a field trial with local organic farmers and retailers.

ACKNOWLEDGMENT

The authors thank the Department of Computer Engineering, Sharadchandra Pawar College of Engineering, Pune, for its guidance and support throughout this work.

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