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Enhancing Food Safety and Traceability using Blockchain Technology

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***Abstract*— Blockchain Technology is building vast nowadays. To use case food safety and keep the track of authenticity of the food we used a blockchain method to keep track of every authentic food so that no one alter the code number assuring that every package is verified. It provides fast traceability and maintenance of the authenticity packet the proper supply chain security**

***Index Terms*— supply chain, food traceability, product safety, QR code.**

I. INTRODUCTION

The system faces three main problems because of its centralized design which creates possibilities for data manipulation and lacks transparency and prevents stakeholders from sharing information in a timely manner. The system needs an advanced method which will track food items throughout all stages of the supply chain while maintaining product safety and process monitoring and supply chain security.

II. NOVEL CONTRIBUTIONS

The research study delivers its main findings through two primary functions which demonstrate its research objectives. The system which enables food traceability through permissioned blockchain technology operates secure access to data between supply chain participants according to its design for data protection and access rights management and complete system monitoring. The system uses smart contract technology to automate food testing procedures while its testing system checks product safety through its ability to track IoT sensor data and detect violations of established standards. The proposed system uses an integrated track and trace system which combines three technologies to verify product origins and current location through blockchain and Internet of Things devices and QR code access for users. The developed system shows better performance than traditional centralized traceability methods because it increases three essential measurement outcomes which include recall efficiency and data integrity and accountability during system evaluation. The research study delivers its main findings through two primary functions which demonstrate its research objectives.
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III. RELATED WORK

A. Blockchain-based Food Traceability Systems

The initial research project utilized blockchain technology to develop permanent records which monitored the entire journey of food products from their initial point until their final point of delivery. Tian demonstrated that distributed ledger systems maintain data integrity through an agricultural food supply chain monitoring system which combines blockchain technology with RFID technology to show organizational accountability [1]. Verma and Singh [2] developed an Android-based application focused on improving safety through real-time alert mechanisms and location tracking. Their system enhances communication efficiency during emergency situations by enabling quick response and information sharing. Although primarily designed for women's safety, the study highlights the importance of decentralized data handling and real-time monitoring, which are also critical requirements in modern food supply chain systems. Aung and Chang conducted research which demonstrated that traceability systems function as essential tools which help companies maintain their food safety and quality standards throughout their international supply chain activities [3]. The study displays these principles through current blockchain technology implementations which build innovative logistics and supply chain management systems. Lin et al. developed a food traceability system that uses blockchain technology to improve both product verification and shipment tracking processes [4].

B. Integration of IoT with Blockchain for Food Safety Monitoring

The combination of Internet of Things (IoT) technologies with blockchain systems has been suggested to provide continuous tracking of food quality metrics. The IoT sensors function to record environmental parameters which include temperature and humidity and location data that are essential for safeguarding food safety during its storage and transport. Li et al. developed an IoT–blockchain system for automated food supply chain systems which improved operational efficiency and eliminated the need for manual data processing [5]. Kshetri studied how blockchain technology helps supply chain management because IoT data provides better visibility and response capabilities when used with distributed ledger systems [6].

Other researchers demonstrated that IoT sensors can continuously track perishable products while blockchain technology secures and protects sensor data from unauthorized access and tampering [7] [8].

Kouhizadeh and Sarkis [9] examined the impact of blockchain technology on sustainability in food supply chains. The researchers emphasize the ability of blockchain technology to enable stakeholders to share data transparently and securely. Blockchain also promotes environmentally sustainable practices in supply chains and enables the development of circular economic models through its capacity to promote traceability.

C. Smart Contracts for Automated Compliance and Food Authentication

Blockchain-based food traceability systems which use smart contracts for verification processes achieve their legal requirements through automated verification methods. The study by Wang and Zhang demonstrated that Ethereum-based smart contracts enable automated food safety checks which activate alerts for violations of regulatory thresholds [10]. Xu et al. demonstrated that smart contracts enable safety rule enforcement through their ability to limit contaminated product movement throughout the supply chain [11].

Researchers have investigated blockchain-based authentication systems to combat food adulteration and mislabeling. Sharma et al. developed a blockchain-based authentication system that uses QR codes to help consumers verify product authenticity [12]. Zang and Zhou created automated food batch validation systems that use smart contracts for their operational process [13]. The studies show how smart contracts enable compliance and authentication but the research mainly examines individual functions instead of complete system designs. The present work aims to unify traceability, compliance, and consumer transparency within a single framework.

Figure 1: Blockchain-Based Food Traceability System complete blockchain-based food traceability system operates through a blockchain system which Figure 1 depicts. The proposed approach users to see how food products move through the supply chain from farmers to consumers. The product delivery process starts when the farmer receives the product and ends when the distributor delivers the product to the consumer. Digital flow activities receive support from the blockchain network because all network members must exchange essential

production data together with quality control information and shipment progress details. Each product will receive a unique QR code which security personnel will use at various points to track the product through the blockchain system. The customer can use the internet to scan the QR code and trace the product's entire supply chain journey. The dual-flow system enables transparent and authentic operations while creating unchangeable blockchain records which verify food safety and quality assurance.

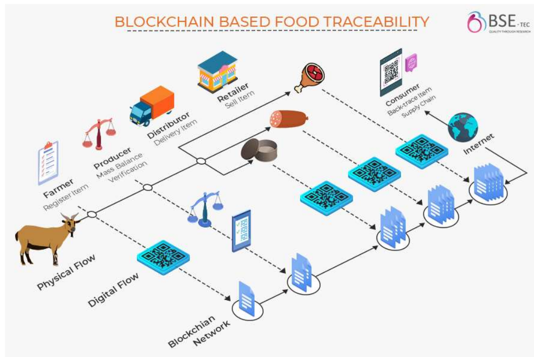

Figure 1: Blockchain-Based Food Traceability System

IV. System Implementation Details

The primary components of this study encompass blockchain technology food safety food traceability supply chain management smart contracts internet of things IoT transparency data security and decentralized ledger technology.

A. Blockchain Platform

The blockchain-based food traceability system requires real-world testing which needs to identify three locations for testing because the system must achieve three goals which are secure information sharing and regulatory compliance and rapid processing of food supply chain operations through fast transaction handling. The system operates its functions through Hyperledger Fabric which functions as its primary technology by utilizing a permissioned blockchain network. The system operates through a permissioned network design which allows only verified users from specific groups including farmers processors distributors retailers and regulatory authorities to access the system. The system secures information through its security features which ensure food safety requirements and enable user identity verification.

B. Smart Contract Logic

Smart contracts on the blockchain network execute automated tasks which validate data and track data and check compliance with regulations. The smart contract system operates through three main functions which define its basic framework.

The product registration function controls supply chain operations by registering all new food products together with their respective batches. The IoT sensors continuously track environmental conditions through my monitoring activities.

V. Experimental Evaluation

The section provides details about the testing process which was used to evaluate both the performance and the practical use of the blockchain-based food traceability system. The researchers needed to evaluate system performance through actual conditions which real-world large-scale tests could not provide so they performed simulation-based evaluations.

A. Experimental Setup

The research setup conducted testing on Hyperledger Fabric which the team installed to a local test network for all experimental work. The test network simulation established multiple peer nodes which acted as different supply chain participants such as producers, distributors retailers and regulatory bodies. The system generated synthetic IoT sensor data transactions to replicate actual time updates about food transportation and storage temperature and humidity information. The system used smart contracts to validate transactions while establishing automated enforcement of compliance requirements.

B. Performance Metrics

The proposed framework effectiveness gets evaluated through these performance metrics. The first performance metric evaluates transaction latency which measures the time needed to complete a transaction from submission until the network confirms it. Real-time food monitoring applications require lower latency because they need to process multiple IoT sensor updates which occur at high frequency.

C. Throughput

The throughput of the blockchain network measures its capacity to process successful transactions at a rate of one transaction per second. The system scalability assessment shows how the system handles increased

TABLE I. COMPARATIVE SUMMARY OF TRACEABILITY SYSTEMS

Metric	Traditional System	Proposed Blockchain System
Data Tampering Risk	High	Negligible
Recall Identification Time	Manual	Automated
Transparency	Limited	End-to-End

TABLE II: MODEL DESCRIPTION OF BLOCKCHAIN-BASED CLOUD STORAGE SYSTEM

Model Component	Description
Blockchain Network Module	The system functions as a decentralized ledger which records and secures all supply chain transactions in blocks that cannot be altered. The system provides three main data protection features which allow authorized users to view data while preventing any unauthorized access.
Smart Contract Module	Contains automated digital agreements that validate transactions, enforce safety standards, and trigger alerts when violations or discrepancies are detected, thereby eliminating manual verification.
Data Encryption and Security Layer	Ensures the confidentiality and integrity of all transmitted data using cryptographic hash functions, digital signatures, and encryption protocols. Protects against unauthorized access and data manipulation.

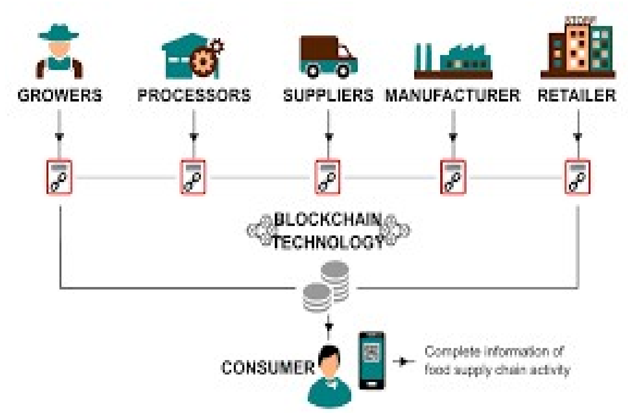

Figure 2: Workflow of Blockchain in Food Supply Chain

Figure 2: Workflow of Blockchain in Food Supply Chain based on blockchain technology shows all its operations through Figure 2: Workflow of Blockchain in Food Supply Chain which demonstrates how data moves through the entire supply chain from producers to users. All network participants from growers to retailers need to document their business activities and product information by using the blockchain system to record their data. The system creates a digital record that maintains product origin information together with quality assessment results and transport information and handling specifications for each operational stage. The blockchain network functions as a decentralized digital ledger that interlinks all the parties by providing them with a very clear and non-repudiable data structure. The method provides data protection because all inputted information becomes permanent which establishes integrity and accountability standards. The consumer can access the complete history of the food item through QR code scanning or mobile application use at the final consumption point.

VI. Findings and Interpretation

- IoT sensor integration enables continuous environmental parameter monitoring which includes temperature and humidity detection
- The smart contracts use automated systems to perform data validation and compliance checks which decrease the need for manual work and eliminate human mistakes
- The use of QR codes enables customers to authenticate their products' origins and track their product handling history in a completely transparent system

TABLE III. COMPARATIVE SUMMARY

Feature	Conventional Systems	Proposed System
Data Storage	Centralized	Distributed
Data Integrity	Vulnerable	Tamper-resistant
Compliance Checks	Manual	Automated
Recall Process	Slow	Efficient
Consumer Access	Limited	QR-based

VII. Future Enhancement

The future enhancement of the project will use Artificial intelligence (ai) to give possibilities of fake detection and use of large language model and building a genetic aid to give assurance assistance to the consumer of the supply packet. This is how the authenticity will be maintained and optimal storage.

TABLE II: OVERVIEW OF ISSUES APPROACHES, METHODS

No./Reference	Issue Discussed	Approach & Method
F. Tian, 2016	Lack of reliable traceability in China's agri-food sector.	Proposed a blockchain and RFID-based system ensuring transparent and tamper-proof recording of supply chain data for enhanced traceability.
S. Verma and S. Singh, 2021	Insufficient real-time safety applications.	Developed an Android-based alert and tracking system improving communication and emergency response; relevant for decentralized data security models.
M. M. Aung and Y. S. Chang, 2014	Food safety and quality management challenges.	Highlighted the importance of integrated traceability systems for maintaining food quality across global supply chains.
J. Lin et al., 2021	Need for IoT integration in food traceability.	Designed a blockchain-IoT architecture for real-time monitoring and ensuring authenticity in food transportation.
J. Li et al., 2022	Manual errors in traditional tracking systems.	Proposed IoT–Blockchain integration to automate data collection and strengthen traceability in smart food logistics.
N. Kshetri, 2018	Limited visibility in supply chain management.	Analyzed blockchain's role in improving transparency and meeting core objectives of supply chain management globally.
A. Kamilaris et al., 2019	Lack of trust among agri-food stakeholders.	Demonstrated blockchain use cases in agriculture, emphasizing transparency, traceability, and data-driven decision-making.
Y. Wang et al., 2019	Inefficient traditional logistics systems.	Investigated how blockchain could reshape future supply chains through decentralization and automation.
M. Kouhizadeh and J. Sarkis, 2018	Unsustainable data sharing practices.	Introduced blockchain applications for green and sustainable supply chains focusing on circular economy practices.
Y. Wang and T. Zhang, 2023	Delays in compliance validation and recalls.	Implemented Ethereum-based smart contracts for automatic quality checks and food safety compliance enforcement.
X. Xu et al., 2021	Difficulty in tracking food safety violations.	Developed a blockchain-enabled food safety tracking system using smart contracts to automate violation alerts.
R. Sharma et al., 2023	Food adulteration and mislabeling.	Proposed a blockchain-based authentication framework integrated with QR codes to ensure authenticity of food products.

VIII. Conclusion

The system works on blockchain to trace the authentic food and build trust to consumers and provide optimal storage and maintenance. The framework enables organizations to meet regular rules while it decreases fraud activities and promotes eco-friendly sustainable technology-based food management methods and makes recall processes more efficient.

Appendix A Appendix Title

The system uses a permissioned blockchain as its chosen blockchain technology. The system uses Chain-code (Go/Node.js) as its official programming language for smart contracts. The system processes two types of transactions which include IoT sensor data and product registration records. The evaluation tool used in this study is Hyperledger Caliper. The system functions inside a testing environment which replicates a local network environment. The authors express their deep appreciation to the Department of Computer Science and Engineering at Anjuman College of Engineering in Nagpur because they provided all required academic facilities to conduct this study.

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