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A Decentralized Blockchain Framework for Safe Food Supply Chain Management

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Abstract: ***A block chain-powered system for safe food supply and supervision improves transparency, security, and traceability throughout the entire supply chain. By utilizing block chain's decentralized and tamper-proof ledger, it enables real-time monitoring of food products from their origin to the end consumer, reducing risks such as fraud, contamination, and mislabeling. Smart contracts help automate regulatory compliance, ensuring that all safety standards are met. This system allows key stakeholders—including farmers, suppliers, distributors, retailers, and consumers—to access verified and trustworthy data, enhancing accountability. By improving food safety, reducing waste, and streamlining recalls, this technology transforms the food industry into a more secure and efficient ecosystem.***

Keywords: ***Block chain, Food Supply Chain, Traceability, Transparency, Security, Decentralization, Smart Contracts, Food Safety, Regulatory Compliance, Real-time Monitoring, Tamper-proof Ledger, Fraud Prevention***

I. INTRODUCTION

The food supply chain operates as an intricate framework with several participants including farmers together with processors and distributors while including retailers and consumers who make up the final user group. Food safety problems including contamination together with fraud and unclear transparency levels have created substantial worries that threaten public wellness along with consumer trust. The standard methods for food safety tracking face two major problems: they fail to be efficient and they tend to produce mistakes from human operators. This results in several challenges in tracing how food items move from origin to market.

Blockchain technology solves safety and security obstacles by offering secure decentralized tracking capabilities that track food products through their entire distribution path. The project utilizes blockchain technology through IoT sensors to boost food traceability while fighting against fraud and maintaining safe standards in the food industry. The permanent transaction record enabled through blockchain allows all stakeholders to verify authenticity and find contamination origin points in real-time. In addition to tracking temperature and humidity IoT sensors make continuous food supply chain monitoring possible by ensuring safety throughout the distribution process. The implementation of this system will produce a food industry with higher efficiency while ensuring transparency and build trust which ultimately benefits businesses and consumers.

The authors in [1]Designed a hierarchical multi-domain blockchain network with enhanced food safety functions that included supervision and traceability and decentralized management abilities. Operational monitoring through this system maintains tamper-evident data storage capabilities that align with regulatory requirements.

A blockchain platform with information supervision capabilities for rice supply chains was developed by [2] which created better traceability and reduced regulatory violations while fighting against fraud. The system provides stakeholders with data sharing efficiency together with protection for their privacy details.

The blockchain system uses intelligence to supervise vaccine distribution through automatic verification which secures the supply chain by maintaining safety and authentic vaccines. Concurrent smart contracts support automated verification functions and prevent vaccine counterfeiting within this system [3]. A refined supervision system for rice supply chains based on multi-blockchain architecture was described by [4] through implementation of encryption protocols

together with consensus protocols. Food safety monitoring receives better protection through the system which also defends against tampering activities and strengthens the accuracy of recorded data.

The authors of [5] introduced a rice supply chain monitoring system that combines parallel blockchain technology with smart contracts. This method provides better data protection and improved transparency alongside stronger regulatory ability between different supply chain members. The author introduced a blockchain-enabled safety management framework dedicated to grain distribution systems where food tracing alongside fraud avoidance and vulnerability reduction receive attention. [6] The system provides a method to track and authenticate sources at an effective pace.

The authors studied AI-enabled blockchain systems for food traceability while improving supervision capabilities and ensuring data security along with regulatory compliance to safety regulations. The combination of AI algorithms provides both anomaly detection capabilities along with predictive analytics functions to improve food safety management.

Anauthentication system based on blockchain technology was created [8] to combine three key functions: food safety checks and COVID-19 verification and consumer privacy protection. Real-time monitoring through the system generates automatic alerts which enable fast response to detect safety violations. [9] Introduced an IoT and HACCP-integrated blockchain system for real-time food safety monitoring and supply chain transparency. The system achieves automated quality assessments together with blockchain-powered data analytics through IoT sensor integration.

II. LITERATURE SURVEY

The current food supervision system encounters two main shortcomings through data scatter and poor oversight methods which create slow response times. An HMDBC network provides a solution to this problem through its transparent decentralized efficient supervision approach. A secondary-check process within the system functions as a mechanism to replace malicious nodes by implementing a trust-enhancing fuzzy comprehensive evaluation model for credibility assessment. The designed data block format allows for active supervisor node switching which creates immediate food quality analysis capabilities alongside automatic warning notifications through smart contracting protocols. Most blockchain systems transmit data slowly while HMDBC implements secure transmission with fewer communication procedures in place. [1]

Public health depends critically on the quality and safety assessment of rice as this staple crop constitutes an essential food source worldwide. The effective supervision of food items remains limited due to complications in supply chain complexity and extended circulation durations and privacy protection challenges. The proposed research presents an investigative model which employs blockchain technology to improve both security and regulatory efficiency within rice supply chain supervision. The system achieves data protection through secured information classification alongside encryption methods which still allows for transparent oversight capabilities. The Practical Byzantine Fault-Tolerant consensus algorithm enables improved node selection processes which results in both high efficiency and low cost. A blockchain-based rice supply chain management system operates through Hyperledger Fabric while improving regulatory procedures with a secure and extendable solution for rice supply chain operations. [2]

Supply chains continue to face two important obstacles regarding infectious disease prevention through immunizations: vaccine expiration issues and fraudulent medical records. A proposed vaccine management system implements both blockchain and machine learning to resolve existing issues. Electronic systems backed by blockchain technology create a secure platform for vaccine tracking and use smart contracts as antifraud protection. Machine learning models operate within the system framework to give data-backed proposals both to practitioners working in immunizations and the vaccine recipients. The convergence of blockchain trust technology with Artificial Intelligence analytics in this system enhances vaccine security while increasing transparency and better decision support for stronger vaccine delivery. [3]

The development of Agriculture 4.0 requires establishments of sustainable precision

agriculture methods. Rice serves as a main source of nutrition which demands the preservation of quality standards for the welfare of public health and social recovery. The researcher establishes MBRRSM (Multi-blockchain Rice Refined Supervision Model) which enables secure data management together with transparent and effective supervision of the rice supply chain. Secure data transmission storage and verification processes in the model achieve their purposes by combining multi-party hybrid encryption with secure multi-party computing and SPOP (Supervision Proof of Peers) consensus algorithm. The MBRRSM prototype system shows its operational effectiveness in actual conditions by providing refined monitoring capabilities and protecting data security and improving tracking capabilities. This study develops agricultural blockchain applications which help ensure food security while implementing smart agricultural solutions. [4]

The global importance of rice requires that both its quality and safety maintain perfect standards for human health advancement. Challenges such as the COVID-19 pandemic, pesticide residues, insect pests, and heavy metal contamination pose risks to the rice supply chain. Because rice undergoes a lengthy growth period and has various stakeholders and different hazards it must face an effective supervisory system is indispensable. A supervision model across chains depends on parallel blockchain theory and smart contracts for better data security and traceability alongside enhanced efficiency. This model works through its combination of a hash lock system with smart contracts and relay chains as well as K-means concurrency and SPBFT (Supervision Practical Byzantine Fault Tolerance) consensus algorithm components. The combination of parallel blockchains proves effective for security protection and cost reduction while strengthening supply chain coordination according to simulation data. As part of food industry digital transformation initiatives this investigation provides an adaptable method for rice supply chain oversight which delivers efficient operation. [5]

The authors Zhang et al. (2020) developed a blockchain safety management system for grain supply chains designed to create enhanced capabilities for tracking and securing operations and achieving better transparency throughout the supply chain. The research explains how standard grain supply systems face multiple weaknesses that result in fraud schemes and contaminated products and inadequate continual tracking. Blockchain technology enables this system to create invulnerable data records and operates through decentralized management alongside automatic smart contract processing. The authors implemented IoT sensors for live grain condition tracking which stops quality degradation from occurring. The authors discovered that blockchain technology boosts both food safety measures and regulatory compliance and makes grain logistics more efficient. [6]

The authors at Ling et al. (2021) established an intelligent food traceability supervision system which combined blockchain capabilities with artificial intelligence (AI). The research solves food safety supervision problems with blockchain technology to establish unalterable recordkeeping and artificial intelligence analytics which help identify future operational risks. Real-time anomaly detection in food supply chains depends on machine learning algorithms which run through their system to provide early warning mechanisms. Food safety management experiences transformative benefits from AI-blockchain partnership through improved system transparency and automated regulatory checks as well as enhanced official decision capabilities.[7]

III. PROPOSED METHOD

Food supply and production are crucial for a country's development, boosting business growth and ensuring a healthier population, but corrupt companies sometimes exploit genuine product labels or modify expiry dates, leading to consumer dissatisfaction and economic setbacks. Currently, supply chain data is managed in a centralized server, which is vulnerable to manipulation through bribery or cyberattacks, resulting in data loss and fraudulent product entries. To counter these issues, we propose a blockchain-based system for secure food supply chain management, leveraging encryption for data security, decentralization for reliability, and immutability for transparency. Blockchain records transactions as unique blocks linked by hash codes, ensuring data integrity through Proof of Work (PoW) verification. By integrating blockchain platforms such as

Hyperledger or Ethereum and utilizing smart contracts, the system can securely store and retrieve supply chain data, preventing fraud and enhancing trust in food safety.

Food supply and production are crucial for a country's development, promoting economic growth and public health. However, fraudulent activities such as counterfeiting genuine product labels and modifying expiry dates undermine consumer trust and national revenue. Traditional centralized database systems are vulnerable to bribery, hacking, and data manipulation, leading to significant risks in food safety and supply chain transparency.

To address these challenges, we propose a Block chain-Based System for Safe Food Supply & Supervision. Block chain technology provides:

- **Data Security**: Encryption ensures secure storage and transmission.
- **Reliability**: Decentralized storage prevents single points of failure.
- **Transparency**: Immutable records ensure tamper-proof data integrity.

Block chain maintains transaction records as blocks, each with a unique hash code. Verification using Proof of Work (PoW) or other consensus mechanisms ensures data integrity. We utilize Hyperledger or Ethereum Smart Contracts to facilitate secure and automated interactions within the supply chain.

A blockchain-based food supply chain management system seeks implementation through a method which concentrates on food safety together with transparency while fighting off fraud attempts. Blockchain technology enables the system to build a tamper-resistant decentralized ledger system which tracks food products from supplier origin points to consumer destinations. The decentralized blockchain network provides stakeholders with secure unalterable data records unlike the centralized systems that remain vulnerable to cyberattacks and data modification. The implementation of IoT sensors enables real-time monitoring through which food storage conditions are regularly checked for safety standards compliance during transportation and storage. Predefined rules through smart contracts help automatic regulatory compliance while also activating alerts whenever rules get violated.

The system adopts three essential modules to let administrators manage network members while smart contracts automate payments and enable users to validate products starting from the source. Utility in the proposed system includes machine learning for predictive analytics that enhances forecasting capabilities and optimizes supply chain inventory operations. The blockchain-based food supply chain system delivers higher operational effectiveness and end-user trust because it fights product fraud and shuts out counterfeits while keeping recall procedures efficient.

3. Key Modules and Functionalities

3.1 Admin Module

- Secure login as 'admin'.
- Adds supply chain partners (Raw Material Suppliers, Manufacturers, Distributors, Retailers).
- Generates supply orders.
- Uses Machine Learning (ML) algorithms to forecast product demand.
- Monitors supply chain tracing via an interactive map.

3.2 Stakeholder Raw Material Supplier Module

- Receives orders from admin.
- Supplies raw materials to manufacturers.
- Updates blockchain with transaction details.

3.3 Manufacturer Module

- Receives raw materials.
- Manufactures food products.
- Supplies products to distributors and logs transactions in the blockchain.

3.4 Distributor Module

- Receives manufactured products.
- Distributes products to retailers.
- Updates blockchain records for traceability.

3.5 Retailer Module

- Sells products to consumers.
- Updates sales details in blockchain for transparency.

3.6 Consumer/Government Official Module

- Uses product ID to verify supply chain details.
- Ensures product authenticity and safety compliance.

3.7 Recommendation Module

- Consumers input a product (e.g., Beef), and the system recommends alternatives (e.g., Chicken).
- Uses ML-based algorithms to suggest related purchase items.

IV. RESULT

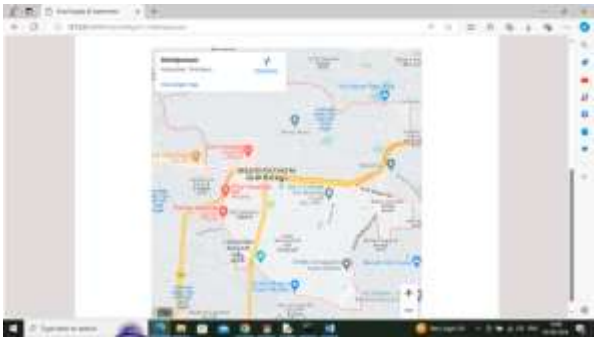
In above screen click on 'Admin Login' link to get below login page

In above screen admin is login and after login will get below page

Now admin can click on 'View Partners' link to view all partners' details and get below page

In above screen admin can view details of all added Partners and now click on 'Generate Orders' link to get below page

In above screen admin will see the tracing of order which went to Raw Material Supplier who will login and receive order to further process and admin can click on 'View on Map' link to view generated order location in map like below page (this you can consider as enhancement)



In above screen can see order generated location MAP and now admin can click on 'Run ML' link to get below page.

'Run Decision Tree' link to train Decision tree on dataset to forecast product demand and get below page

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In above screen can see forecast result of decision tree where tabular output contains forecast of next 10 days and in that table we are showing algorithm name along with TEST data demand and predicted demand and can see both test and predicted values are very closed and in last row can see Decision Tree R2 Score as 99% and can see MSE error also. In graph x-axis represents number of days and y-axis represents forecast values and then red line represents TEST data demand value and green line represents Predicted demands and can see both lines are fully overlapping so we can say both test values and predicted values are accurate. Now click on 'Run Random Forest' link to train Random Forest and get below page

In above screen raw material supplier can click view receive order details and

In above screen click on 'Click Here' link to update further process

In above screen distributor can click on 'Click Here' link to update trace to retailer

In above screen Retailer can click on 'Click Here' link to sale products to N consumer and get below page

In above screen consumer can view or trace all stages of product processed and can click on 'View Map' link to view all trace location to map

In above screen can see recommended list for 'Beef'.

So by using above screens you can run project to trace product details, forecast and recommend items.

V. CONCLUSION

Incorporating block chain technology into the food supply chain offers a revolutionary approach to enhancing food safety, transparency, and fraud prevention. By utilizing a decentralized and tamper-proof ledger, the system enables seamless traceability of food products from their source to the end consumer, fostering trust and accountability at every level. The integration of real-time monitoring, supported by IoT sensors, ensures optimal storage and transportation conditions, reducing risks of contamination and spoilage. This solution not only streamlines issue resolution but also empowers consumers with reliable information, enabling them to make safer and more informed purchasing decisions.

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