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BLOCKCHAIN DRIVEN SUPPLY CHAIN TRANSPARENCY

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Abstract - *The food supply chain is the most complex and fragmented of all supply chains. The production is found all over the world both on land and in water. A lot of the producers and intermediaries are difficult to identify and track. For all the participants in the production chain this creates uncertainty and risk. Mitigating this uncertainty comes at a cost, and the outcome may still be insufficient. Examples of problems that have been difficult or impossible to solve with current technologies include establishing reliable provenance and preventing fraud and counterfeiting. These issues can have knock-on effects on public health and the environment, and reduce financial costs of unnecessary recalls of food products. The project "supply chain traceability solution: enhancing accountability using solidity for blockchain" is a comprehensive initiative geared towards elevating preserved food safety standards through the implementation of an advanced traceability system. Recognizing the critical importance of accountability in the context of food supply chains, the project leverages the solidity programming language to establish a secure and transparent blockchain-based solution. To overcome the above challenges, a blockchain based food traceability system (BIFTS) is proposed in this study, to achieve the integration of blockchain technology for effective and efficient traceability and support shelf life adjustment and quality decay evaluation for improving quality assurance. For the sake of better computational load, the blockchain is modified as a lightweight blockchain to be associated with cloud computing to support monitoring, and can be vaporized after the entire life cycle of traceability to release computational resources of the system. By using such a reliable data source, the decision support in food quality can be made by using fuzzy logic to determine adjustment of shelf life, rate, and order of quality decay, according to different situations for each batch of perishable foodstuffs at food processing sites. Therefore, the proposed traceability model is extended to the modern food supply chain environment, resulting in reliable and intelligent monitoring, food tracking, and quality assurance. Preserved foods, susceptible to contamination and spoilage risks, demand a unique approach to traceability. the proposed system meticulously records and timestamps key information at each stage of the supply chain. solidity, a programming language specifically designed for smart contracts on the Ethereum blockchain, plays a pivotal role in ensuring the integrity and immutability of the recorded data. By utilizing blockchain technology, the project addresses the inherent challenges of trust and transparency within the supply chain. stakeholders can access a decentralized ledger that offers a tamper resistant record of the entire journey of preserved food products. This not only facilitates real time monitoring but also expedites the identification and resolution of issues, thereby enhancing overall food safety. The traceability solution's emphasis on accountability serves as a proactive measure to mitigate risks associated with preserved food products. The decentralized nature of the blockchain, coupled with the programming robustness of solidity, provides a resilient framework for safeguarding the integrity of the traceability data. In conclusion, this project not only addresses the specific challenges of preserving food safety but also contributes to advancing the broader field of supply chain traceability through innovative blockchain technology.*

Key Words: *Blockchain, ledger, Traceability, Stakeholders, Immutability, Accountability*

1. INTRODUCTION

Blockchain technology has the potential to significantly enhance the global food product supply chain (FPSC) by improving safety and productivity. With the CDC reporting millions of foodborne illnesses and deaths due to expired or adulterated products, real-time monitoring of food quality is essential. Current tracking technologies, such as RFID and QR codes, focus on package-level tracking and lack insights into actual food quality, leading to costly recalls. By integrating blockchain with sensor data, stakeholders can achieve comprehensive visibility, enabling real-time tracking, identification of bottlenecks, prevention of adulteration, accurate shelf-life calculations, and targeted recalls. This decentralized and secure system enhances data integrity and trust among supply chain participants, making it crucial for effective traceability in a complex and sensitive food supply chain. Overall, blockchain presents a promising solution for improving food safety and reducing waste in the FPSC.

1.1 Background of the Work

The implementation of traceability systems in food supply chains presents various challenges and opportunities. Maintaining lot identification in bulk grain supply chains is difficult, necessitating a systems approach for both internal and chain traceability. Identifying critical data capture points and modeling traceability information can enhance communication among supply chain actors. Meticulous data collection is essential for effective product recalls during food safety emergencies, and new standards for evaluating traceability system performance are needed. Traceability plays a significant role in ensuring food safety and quality, particularly in responding to food crises. Blockchain technology can enhance authenticity and combat counterfeiting in the post-supply chain, while also addressing IoT security challenges. Overall, these concepts highlight the critical role of traceability and technology in improving food safety, quality, and security across supply chains.

1.2 Motivation and Scope of the Proposed Work

The increasing demand for transparency and accountability in the food supply chain (FSC) has exposed significant gaps in current traceability systems. These systems often rely on centralized data storage, making them vulnerable to tampering and inefficiencies. Additionally, consumers have limited access to real-time product quality data, relying solely on static expiration dates, which may not accurately reflect the product's condition. The need to enhance trust, minimize waste, and ensure safety across the FSC motivated the development of this blockchain-based traceability solution. The proposed work focuses on leveraging blockchain technology and IoT sensors to create an advanced traceability system. This system enhances real-time monitoring, ensures data integrity, and improves decision-making across the FSC. The solution is scalable and adaptable, capable of addressing challenges across various food industries, including perishable goods, packaged foods, and beverages.

2. METHODOLOGY

The proposed system integrates blockchain technology, IoT sensors, and smart contracts to enhance traceability and quality assurance in the food supply chain. Real-time data acquisition is achieved through IoT sensors, which monitor critical parameters like temperature, humidity, and pH levels at various stages of the supply chain. This data is securely transmitted to a blockchain network, ensuring tamper-proof storage and transparency. An anomaly detection model, powered by machine learning, identifies deviations from quality standards and triggers automated actions using smart contracts. A user-friendly interface provides stakeholders and consumers with real-time access to detailed product information, fostering trust and improving decision-making across the supply chain.

2.1 System Architecture

The system architecture integrates blockchain technology, IoT sensors, smart contracts, and a consumer-facing interface to create a seamless and secure FSC traceability solution. The blockchain acts as the backbone, ensuring decentralized, tamper-proof storage of supply chain transactions. IoT sensors deployed at various stages of the FSC monitor environmental parameters such as temperature, humidity, and pH levels, which are crucial for maintaining food quality. Data from these sensors is transmitted securely to the blockchain in real time, where it is processed and stored. Smart contracts embedded within the blockchain automate critical actions like quality alerts, payment processing, and targeted recalls based on predefined thresholds. Additionally, the architecture includes a user-friendly interface accessible via mobile applications or QR codes, enabling consumers and stakeholders to interact with the system and access detailed product information.

2.2 Data Acquisition

Data acquisition is a critical component of the system, relying on IoT sensors to gather real-time information from various points in the FSC. These sensors are strategically deployed to monitor key quality metrics, including temperature fluctuations, pH levels, and humidity changes. The collected data is then transmitted to the blockchain through secure communication protocols, ensuring its integrity and accuracy. To enhance reliability, the system employs redundancy by cross-verifying data from multiple sources before storing it on the blockchain. This robust data acquisition mechanism provides a comprehensive view of product conditions throughout the supply chain, facilitating accurate decision-making and traceability.

2.3 Anomaly Detection Model

Anomaly detection is central to ensuring the quality and safety of food products. The proposed system utilizes a machine learning-based anomaly detection model that analyzes data collected from IoT sensors. This model identifies deviations from expected patterns, such as sudden temperature spikes or prolonged exposure to adverse conditions. By leveraging historical data and predefined thresholds, the model can accurately predict and detect anomalies that may compromise product quality. Detected anomalies trigger automated alerts through smart contracts, prompting immediate corrective actions such as halting the shipment or initiating targeted recalls. This proactive approach minimizes the risk of distributing compromised products and enhances consumer trust in the FSC.

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2.4 User Interface

The user interface serves as the primary interaction point for consumers and stakeholders, offering intuitive access to the system's functionalities. Designed for accessibility and ease of use, the interface allows users to scan product-specific QR codes to retrieve detailed information about the product's history, quality metrics, and supply chain journey. Stakeholders can use the interface to monitor real-time data, view anomaly alerts, and track product status across the supply chain. Additionally, the interface supports regulatory compliance by providing verifiable records of food safety standards. The user-friendly design ensures seamless engagement, empowering consumers with transparency and enabling stakeholders to optimize their operations effectively.

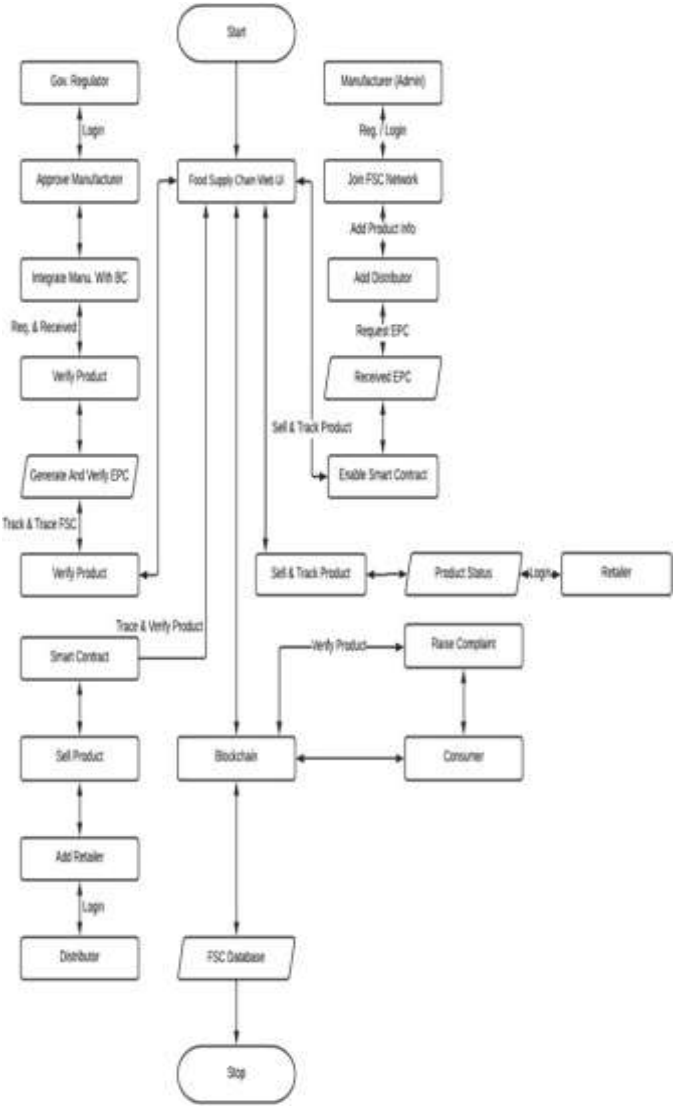

Fig -1- Flowchart

3. CONCLUSIONS

A blockchain-based food supply chain monitoring (FSC) architecture was proposed in this work. The detection method has been integrated with small-area identification to monitor and control food packaging quality. As food packaging is scanned at different retailers, at different logistics or storage stages in the supply chain, real-time sensor data is updated in the blockchain providing a technical anti-tamper digital ledger. Any consumer or retailer can consult the public ledger for information about specific food product packaging. This information helps to update shelf life, identify key bottlenecks in FSC, perform targeted recalls and further increase visibility. Embedding a unique secret ID has been demonstrated in this work. The proposed architecture requires consensus from participating terminals in the network before updating blockchain data. Wider participation of all nodes helps maintain the decentralization of the network. Security analysis shows that false block validations decrease with higher number of nodes participating in the network and more consensus stages.

Suggestions for Future Work

In the future this system provides more security. More security in terms of privacy of user data and details also the transparency and accountability can be enhanced by adding a complaint filling feature for customers to higher officials in case of anomalies and discrepancies in supplied goods and product. Furthermore this solution can be adapted to trace and track other commodities like electronic products and automobiles.

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