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Empowering Food Safety with Blockchain: A new Era of Organic Food Supply Chain Management

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***Abstract*— Blockchain Technology is valued for its ability to document and distribute transactions in an enduring, jumbled record. Right now, food supply data is stored in a single central system, which can be easily hacked or changed by corrupt officials, leading to fake or expired products being sold to consumers. With Blockchain, every step in the supply chain management supplying of food products from raw material suppliers to manufacturers, distributors, retailers, and finally consumers is secure, transparent, and tamper-proof. Each transaction (like sending food from one place to another) is stored in blocks with a unique hash code, making it impossible to alter. The system also includes Machine Learning (ML) algorithms to predict future demand for products, helping suppliers, manufacturers, consumers plan better and KMeans cluster also used to recommend the related food items of the purchased product. Consumers and government officials can use a product ID to check the entire history of a food item.**

***Keywords*—** Food Supply Chain, Blockchain Technology, Smart-contract, Secure, Ethereum, Transparency, Machine Learning Algorithms, Authenticity

I. INTRODUCTION

Bangladesh's economy relies heavily on agriculture. Approximately 70% of individuals have some sort of connection to agriculture[19]. The appropriate usage of the agricultural sector to provide our basic necessities must be taken into account due to the population's rapid growth. Bangladesh is a major producer of agricultural products worldwide. The largest producer of rice, jute, wheat, tobacco, and other commodities in the world is Bangladesh[11]. By increasing agricultural production, food security can be achieved. Food quality and nutritional concerns are important factors for consumers health and must be ensured in every food factory or organization. The aim is to guarantee a stable food supply for the world's fastest growing population. When purchasing food in a secured food network system, a consumer must be knowledgeable of the food's production process and its ingredients. Additionally, all participants in the organic food supply chain must exchange product information with all other participants in the food supply chain. Lack of transparency, difficulty of managing the quality and safety of the products, lack of communication among participants involved in the supply chain, unable to track the product's origin means where the product is coming from and processing method are only a few of the problems that arise in the traditional supply chain[12]. When purchasing food in a secured food network system, a consumer must be knowledgeable of food's production process and its ingredients. Tracing raw materials and processing methods of each product is the best way to create a secure food system in our nation. We can use blockchain technology to solve our issue. One new technology that works best in this situation to address the issue with the conventional supply chain structure is blockchain. FSC networks can employ blockchain technology, which is a decentralized database that enables transparent, safe, tamper proof trades or sales. Cryptographic hash technology is a feature of the Blockchain. Every block contains information that is encrypted to prevent unauthorized access or alteration. The blockchain's ability to encrypt user data encourages users to rely on it, which boosts demand for the product. We concentrated on minimizing the attackers improper data. After thoroughly examining the issues surrounding the conventional supply chain, we plan to develop a blockchain based solution that will benefit all participants involved and that ensures accurate information. Following the investigation, the objectives can be achieved by this study:

- The system that guarantees the accuracy of the data provided by producer.
- This technology will assess the reliability of producer's information.

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- Using product ID the Consumer can trace all details of the product.
- Ensuring the consumer can easily check the location of the product where it is actually coming from such as farm place.
- It also provides the demand of the each and every product the consumer wants to buy.

II. LITERATURE SURVEY

Transparency, traceability, and fraud prevention are major issues for the organic food sector. Conventional techniques for confirming organic certifications are frequently ineffective and prone to mistakes. These issues may be resolved by blockchain technology, which is renowned for its immutability, security, and transparency. Zhou et al.'s research from 2021 emphasizes how blockchain can improve supply chain transparency, which makes it a perfect tool for tracking the movement of organic products[12]. In order to ensure product authenticity and decrease fraud, Bertoglio et al. (2021) suggest utilizing blockchain technology to validate organic certificates at every level[21]. One of blockchain's primary features, smart contracts, can automate certification procedures and transactions, cutting down on administrative burden.

The usage of smart contracts, which can automate transactions and certification procedures, is one of the most notable aspects of blockchain. In addition to improving operational effectiveness, this automation lessens administrative workloads. According to Liu et al. (2019), smart contract integration with blockchain can streamline organic certification and payment procedures, which will benefit all parties involved, from large-scale producers to small-scale farmers[23]. Blockchain's capacity to offer verified product histories promotes consumer trust, which is crucial in the organic food industry, according to Pereira et al. (2020)[17].

However, there are a number of obstacles to blockchain adoption despite its many benefits. Significant obstacles include difficulties with scalability, integration with current systems, and data privacy. Both Bian et al. (2021) and Carpenter et al. (2022) have emphasized these constraints and stressed how crucial it is to solve them for successful implementation[22]. All things considered, these studies show how blockchain might transform the organic food supply chain by improving authenticity, transparency, and trust—as long as the related difficulties are successfully addressed.

III. PROPOSED METHODOLOGY

There are multiple steps in the suggested process for incorporating blockchain technology into the supply chain management of organic food, beginning with need analysis and problem identification. Initially, surveys and interviews with stakeholders, including farmers, distributors, and consumers, will be used to identify the issues facing the organic food industry, such as fraud, a lack of transparency, and inefficiencies in certification. These observations will be used to create a blockchain system, choose a suitable blockchain platform (such as Ethereum), In order to create an open and safe traceability system, it only uses blockchain technology and ML Algorithms for prediction of demand in future. In order to comprehend stakeholder needs, such as guaranteeing product authenticity and offering tamper-proof supply chain records, requirements must first be gathered. A blockchain-based architecture is described in the system design phase, which also incorporates Map for finding the location of product's farm. Smart contracts are used during development to automate compliance checks and permanently record transactions on the blockchain.

During the implementation phase, a prototype system is deployed which is used to connect stakeholders and customers to store data in Blockchain securely. It also includes Encryption Techniques for securing the stored data in blockchain from the unauthorized users and it also ensures tamper-proof.

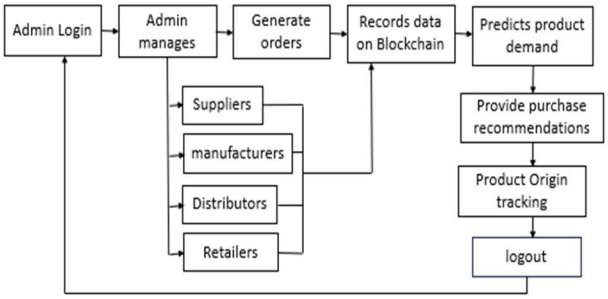

Figure 1 : System Architecture

Admin: Admin can login to system by using username and password as 'admin' and 'admin'. After login admin will add details of all supply chains partners (stakeholders) and give login details to each partners. This partners can be raw material suppliers or farmers, Manufacturer, Retailers and Distributors. Admin will generate orders for required supply and can run ML algorithms to predict or forecast demand of particular product in future. Admin can view details of all available partners and can view all tracing details of product processing in the map.

Farmer details: The admin will add details of the Farmer or Raw material supplier. When farmer will receive order from admin and then forward all raw materials to 'MANUFACTURER' and all this trace details will be updated in Blockchain.

Manufacturer Login: Manufacturer can login to system and receive raw material and can manufacture product and supply to distributor.

Retailer Login: Retailer can login to system and then sale product to N consumer.

Consumer or any government official: by using product ID can trace all details of the product.

Recommendation: any consumer can run this module to get recommendation of particular purchase items. If he purchase Milk then he will enter MILK and system will recommend 'Yogurt' as he may also purchase yogurt.

IV. SYSTEM DESIGN

Blockchain enhances our nation's agriculture food supply method. Agribusiness is incredibly essential to the lives of the vast majority of people on the planet. The system is designed as a decentralized food supply chain management platform using Blockchain and Machine Learning (ML). It consists of multiple stakeholders like Admin, Farmers, Manufacturers, Retailers, Distributors and Consumers. They will interacting through a web-based interface. The Admin registers supply chain participants, generates orders, and uses ML algorithms such as Decision Tree, Random Forest to forecast the product demand. Raw Material Suppliers receive orders and send materials to Manufacturers, who process them into final products and send them to Distributors. Distributors then pass the products to Retailers, who sell them to Consumers. Every transaction and movement is recorded in Ethereum Blockchain using Smart Contracts, ensuring security, transparency, and tamper-proof tracking. Consumers can verify a product's history using a unique product ID. The system enhances food safety, prevents fraud, and optimizes supply chain efficiency.

V. EXECUTION AND WORKING PROCESS

We will demonstrate the application process to illustrate the operational mechanism of our assigned blockchain based system. State variables declared and initialized in Solidity in contract section, which we have used in our Solidity based Ethereum code.

Solidity is an object-oriented programming language used primarily for Ethereum blockchain development. It allows developers to create self-executing contracts that store and manage supply chain data in a secure and decentralized way. State variables and local variables are the two categories of variables found in Solidity language. The contract section declares state variables, which can be accessed by smart contracts. By keeping the state in a blockchain block, the state variables usually hold the state of a smart contract. In Solidity, three significant regions for variable and data storage are: stack, memory, and storage. Local variables, which are usually declared inside functions, are initialized and stored only for the duration of the function call. After the function completes, these variables are no longer accessible, and the memory they occupied is freed. Since local variables are stored on the stack, they cannot maintain their values after the function has finished executing.

Smart contracts are programmed with Solidity, a language that has been specially designed to construct decentralized applications on the Ethereum blockchain. A Solidity contract consists of multiple functions and variables that specify how it will behave. These functions may take actions such as token transfers, financial transactions, or calling other contracts.

The contract is written and then compiled into bytecode and uploaded to the Ethereum blockchain. Ethereum, being a decentralized platform, enables the deployment and execution of such smart contracts such that their operation is permanent, transparent, and secure.

By implementing a logistics management system within a blockchain environment, we can lower the total costs of delivering products and services to consumers while enhancing transparency throughout the process. If each step of a product's journey is recorded on the blockchain, it becomes possible for anyone to track the product's progress. The initial step in creating a decentralized web interface for the supply chain is to identify the information and operations necessary for that interface to offer the necessary features. To perform its role effectively, our supply chain decentralized web interface will require four kinds of data.

Creating the products: Creating a products and display the product information.

Adding participants: Adding participants details and display their information.

Transfer details: It records every Transaction data within the supply chain, such as the manufacturing, shipping, receiving, storage.

Check the Location: The consumer can check the product's farm location through map.

And also we have used Machine Learning Algorithms such as Random Forest, Decision Tree. They are mainly used to predict demand of the particular product in the future to the consumers and KMeans cluster also used to recommend the related items of purchased product.

VI. RESULT AND DISCUSSION

We have created a system based on the needs of our proposed solution to showcase how blockchain can be applied within our framework. The results of our system can be summarized as follows

- Our system guarantees transactions between participants in the blockchain network.
- An encryption method is implemented to safeguard the data stored within the blockchain. Each participant in the network has a private key, which is used for conducting transactions and acts as a digital signature. If any participant tries to modify the data, it will become unacceptable in the blockchain system.
- The consumer can trace the origin of raw materials at any time through map.
- And consumer can check demand of the particular product in future at a time.
- We are also trained Decision tree on dataset to forecast product demand and a example graph is given below

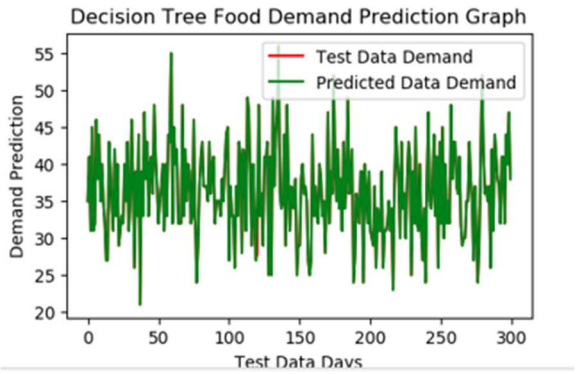

Figure 2: Demand Prediction Graph of Decision Tree

Figure 2 represents the Food Demand Prediction through graph. 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.

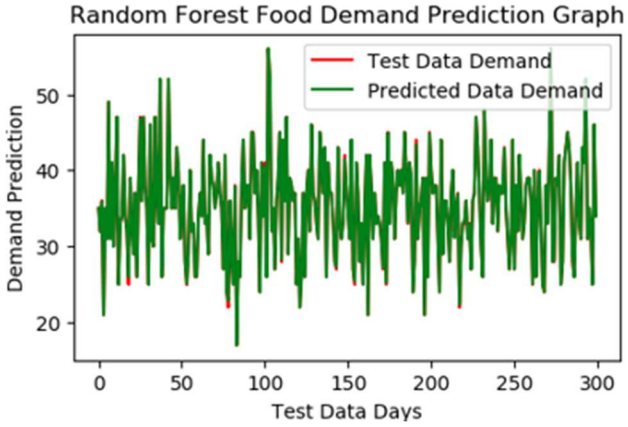

Figure 3: Demand Prediction Graph of Random Forest

Figure 3 represents results of random forest is slightly higher than the decision tree. This means Random Forest performed a bit better.

Blockchain offers three key advantages to the shipper: better transparency, greater scalability, and enhanced security. It enables participants to use the supply chain process from almost any point, while also ensuring protection against damage and data tampering throughout the product's entire lifecycle.

VII. CONCLUSION AND SCOPE

The Traditional supply chain system has been examined with a number of queries and challenges. This system effectively uses the blockchain supply chain system and Machine Learning Algorithms to refine the protection of data, transparency, performance of the food supply chain management. It guarantees that product information cannot be changed or manipulated by preserving all transactions in the Ethereum Blockchain, avoiding fraud and fake goods. The system ensures supply chain safety and confidence by enabling real-time tracking of food items from suppliers to consumers. Furthermore, machine learning algorithms help in forecasting product demand, which helps manufacturers and suppliers maximize inventory and cut down on waste. Customers can increase their confidence in food safety by utilizing a unique product ID to confirm the authenticity of the product. It integrates IoT for real-time data capture and smart contracts for compliance automation It encourages authenticity, lowers fraud, and boosts efficiency, which benefits farmers, distributors, certifiers, and customers. It makes product details easily accessible through user-friendly apps and QR codes. With the ability to integrate AI and increase product categories in the future, the project promotes ethical consumption and environmental practices while being scalable for international markets and compliant with organic standards.

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