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Food Safety Transparency And Traceability System Based On ML Enabled Blockchain using Design Thinking

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Abstract

The food supply chain is the most complex and fragmented of all supplychains. The production is found all over the world both on land and inwater. A lot of the producers and intermediaries are difficult to identifyand track. For all the participants in the production chain this createsuncertainty and risk. Mitigating this uncertainty comes at a cost, and theoutcome may still be insufficient.Examples of problems that have been difficult or impossible to solvewith current technologies include establishing reliable provenance andpreventing fraud and counterfeiting. These issues can have knock-oneffects on public health and the environment, and reduce financial costs ofunnecessary recalls of food products. To overcome the above challenges, a ML enabled blockchain–cloud-based food traceability system (MBCFTS) is proposed in this project, to achieve the following: (i)to design a blockchain-based FSC framework to provide product traceability, which guarantees decentralizedsecurity for the food product tracing data in FSCs. (ii) to integrate blockchain and cloud technology for effective and efficient traceability, and (iii) to 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 IoT monitoring, and can be vaporized after the entire life cycle of traceability to release computational resources of the system. 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.

I.INTRODUCTION

Food is defined as any substance that people and animals eat to survive. Animals and plants are the main sources of food. It is eaten because they provide energy and nutrition and keeps people and animals healthy. Fruits, vegetables, grains, seeds, herbs, are the obtained from the plant sources. While dairy products, seafood, meat, and eggs are obtained from the animal sources. Food is any substance consumed to provide nutritional support for an organism. Food is usually of plant, animal, or fungal origin, and contains essential nutrients, such as carbohydrates, fats, proteins, vitamins, or minerals. The substance is ingested by an organism and assimilated by the organism's cells to provide energy, maintain life, or stimulate growth. Different species of animals have different feeding behaviors that satisfy the needs of their unique metabolisms, often evolved to fill a specific ecological niche within specific geographical context.

A product is something that is produced and sold in large quantities, often as a result of a manufacturing process.The factories were also instructed on the need to submit requests to evaluate food labels of any new food product to make sure it met the food label requirements as per the approved food standards.The recovered product, the chamber claims, must be stored in an area which is separated from any other food product. Companies must also maintain records of the amount of recovered product and the batch codes of the product recovered.

Figure 1.Food

A Smart Contract for Coffee Transport and Storage with Data Validation Recently there has been an increase in the use of Blockchain technology for multiple purposes; one of them has been food traceability. This technology has increased quality control, safety, and reliability. So, the producers are looking for better ways to trace the products at any supply chain stage to ensure their quality. A smart contract is a transaction protocol that execute automatically when a predefined set of conditions are met.

II. METHODOLOGY

The smart contract will bridge the real world and the Blockchain network, collecting data and updating the traceable variables logs. The author deployed a test Blockchain network using the Hyperledger Fabric to evaluate our proposed smart contract. The test network consists of two organizations with two and three transactional endpoints known as Peers; the peers will be in charge of sending the transaction to the network on the dedicated channel; an organization can be a multinational corporation, a national company or a single individual. In Hyperledger Fabric the channels are the way of communication for peers; a peer can join multiple channels at the same time, each transaction made by a peer must have a target channel and smart contract.

However, the proposed smart Contract is still in an early development stage. More variables and knowledge will be needed to make it more robust and practical to use on another stage of the coffee supply chain. More work is required to make sure it is feasible and has practical significance, and future iterations will include validations rules not considered at this point. In-situ validations are needed to find problems not presented in controlled environments.

III. TRACEABILITY

A. Evo-Nfc: Extra Virgin Olive Oil Traceability Using Nfc Suitable For Small-Medium Farms:

Food traceability is a fundamental requirement for the agriculture of the future. A food traceability system should ensure food safety and quality control, allow authentication, fraud prevention and control by the authority, improve consumers' safety and confidence. The agri-food supply chain is complex and difficult to handle due to the presence of various stakeholders and control authorities. Consequently, the complexity and the cost of traceability systems make it inapplicable for small and medium enterprises (SMEs).

The novelty of the proposed solution is the use of the same NFC technology for food traceability from production directly to the consumer. Furthermore, unlike conventional QRcode, the app installed in the consumer smartphone allows a bidirectional interaction between the company and the consumer. This allows market analysis and gives to the company feedback on consumer habits, taste and preferences, fundamental for market purposes. Block chain has not applied in the transcription of the data in the proposed solution, but it could be applied.

A great work has been carried out carried out on the acquisition the knowledge and best practice of the extra virgin olive oil from small farms, that are the main target of this research. The knowledge allowed the definitions of the specification of the traceability system.

B. Secure Identification, Traceability and Real-Time Tracking of Agricultural Food Supply During Transportation Using Internet of Things:

Food supply chain process comprises crops collection, processing of food, shipping & delivery to the whole seller in the market. Harvested foods decompose from the moment they are harvested due to attacks from enzymes, oxidation, and microorganisms. These include bacteria, mold, yeast, moisture, temperature, and chemical reaction. The spoilage of fresh food has increased over time due to the multistage slow food supply chain process. The identification, traceability, and real-time tracking of goods in supply chains have always been a challenge. The advent of the Internet of Things and cloud computing has brought a new approach to the food supply chain process for better cooperation among supply chain partners. The supply chain management (SCM) benefit greatly through automation based on key technologies of IoT, Radio Frequency Identification (RFID), and Wireless Sensor Networks (WSN). These technologies collect the data relevant to the food supply chain system, such as identifying tag-possessed objects or individuals and sensing capabilities of the surrounding environment. However, the collected data can be tempered or modified by attackers to provide false information about environmental conditions. They can destroy or damage the product due to false identification of dynamic environmental conditions. Furthermore, the current automation systems in industry-based retail logistics and SCM do not provide efficient solutions for monitoring the quality of perishable products with integrated solutions. This research aims to develop a secure monitoring and reporting system based on IoT to update the quality of the perishables along with the SCM with a focus on transportation without any human intervention.

Supply chain management owns substantial worth in all business aspects. The conventional SCM methods are inefficient, sluggish, and do not keep pace with the modern revolutionarybusinessneeds. This study proposes a reliable, auditable, andtrackable SCM framework that ensures transaction integrity,immutability, and transparency in the entire course of shipments of perishable products. The system provides a coherentdigital representation of valuable assets to all stakeholders,from raw material suppliers to end-users or consumers. In the proposed Blockchain-based SCM, each of the stakeholdersjoins as Blockchain node to make Blockchain transactionsas well as participate in keeping Blockchain up to date.On joining the Blockchain, each node is given a public/privatekeypair to process secure cryptographic operations according to Block chain architecture.

The proposed system bestowed secure monitoring andreporting based on IoT and Blockchain frameworks to override the conventional supply chain management mechanisms that are economically and computationally expensive. Thesystem empowered the stakeholders to update the quality ofthe perishables preserving the privacy and security aspectswithout any human intervention.

C. Smart Contract-Based Agricultural Food Supply Chain Traceability:

The complexity of a supply chain makes product safety or quality issues extremely difficult to track, especially for the basic agricultural food supply chains of people's daily diets. The existing agricultural food supply chains present several major problems, such as numerous participants, inconvenient communication caused by long supply chain cycles, data distrust between participants and the centralized system. The emergence of blockchain technology effectively solves the pain-point problem existing in the traceability system of agricultural food supply chains. This paper proposes a framework based on the consortium and smart contracts to track and trace the workflow of agricultural food supply chains, implement traceability and shareability of supply chains, and break down the information islands between enterprises as much as possible to eliminate the need for the central institutions and agencies and improve the integrity of the transaction records, reliability and security. Smart contracts have the ability to integrate agricultural andagricultural food safety into an integrated intelligent system thus ensuring the quality and safety of agricultural food andthe health of consumers. This paper presents a frameworkfor the use of automated smart contracts on the Hyperledger platform. According to the information in the agreed contract, when the trigger condition is met, the smart contracts automatically send out the present data resources, including theevents of the trigger condition. This is a system of transactionprocessing modules and state mechanisms that do not generate or modify smart contracts but only enable a complex set of digital commitments with trigger conditions to be executed correctly according to the will of the participants. Smart contracts are executed by tens of thousands of nodes distributed around the world and are the result of consensus.

In the end, the smart contracts algorithmsare implemented in order to realize tracking and tracing of the agricultural food supply chain. However, regarding the existing problems of blockchain scalability, privacy and regulation, the author presented a solutionwhich does not take into account the reliability and auditability of data transactions and payments, and with the development of the agricultural food supply chain, the decentralizedautomatic payment mechanism is needed to ensure that allsystem entities abide by the promise of deficiencies in thedeal.

D. Nutritional Quality and Safety Traceability System for China's LeafyVegetable Supply Chain Based on Fault Tree Analysis and QR Code:

Food quality and safety are important to human health. The focus of current research is on the use of traceability technology to obtain information on food quality and safety; First, to develop an optimal means by which consumers could obtain information on leafy vegetable quality and safety online, we studied the entire process from the production to the sale of leafy vegetables. Specifically, we traced several different types of information across the entire supply chain and proposed a quality and safety traceability system for China's leafy vegetables. Second, as the existing traceability system lacks assessments of the nutritional quality of leafy vegetables, this study explores a method for the comprehensive evaluation of the nutritional quality of leafy vegetables, analyses the indicators reflecting quality, proposes nutritional quality grading standards, and uses nutritional index content and the results of evaluations to characterize the nutritional quality of the products.

Employing the principles of the Hazard Analysis and Critical Control Point (HACCP) system combined with fault tree analysis (FTA), a traceability model for the entire production and sale process of leafy vegetables is constructed. The HACCP system is a food safety assurance system that is recognized and accepted internationally. It is a scientific, reasonable, and systematic method for hazard identification, evaluation, and control. y. A nutritional quality and safety traceability system based on browser/server architecture and quick response (QR) code is then designed and developed for full traceability of leafy vegetable quality.

The HAACP system ensures quality in production, processing, manufacture, and preparation of food in consumption, as well as safety during consumption. This method can ensure food safety and hygiene through the control of key factors affecting food safety throughout the entire supply chain process.

IV.BLOCKCHAIN-BASED SAFETY MANAGEMENT SYSTEM FOR THE GRAIN SUPPLY CHAIN

The grain supply chain is characterized by a long-life cycle, complex links, various hazards, and heterogeneous information sources. Problems with traditional traceability systems include easy data tampering, difficult hazardous-material information management, the "information isolated island" problem, and low traceability efficiency in the whole supply chain. Blockchain is a distributed computing paradigm characterized by decentralization, network-wide recording, security, and reliability. As such, it can reduce administrative costs and improve the efficiency of information management.

This study aimed to build a grain supply chain information management solution based on blockchain technology. Its main contributions can be summarized as follows. First, to achieve information security management in the entire grain supply chain, we propose a new system architecture based on blockchain to realize the management and privacy protection of different roles. Second, to improve system storage capacity, we propose a multimode storage mechanism that combines chain storage and a distributed database with multilevel backup. Third, to manage business data and hazard information, improve data reliability, and reduce risk, we used a customized smart contract to control the reading and writing of data.

V.SYSTEM ANALYSIS

A. Existing System:

Post Supply Chain using QR Code-In this system the manufacturer will enroll him with valid information on the blockchain with company name and other details and assigns a unique ID to each product with QR code. Every product has its own QR code, so through the QR code we get the product history. The product history from manufacturing to shipping details is stored in the DB with the unique ID by using blockchain technology. So, after scanning product QR code we get the unique identification number and through it we get the overall product history.

RFID smart tag for traceability-This RFID based system consists of a smart tag and a commercial

reader/writer. The smart tag, attached on the product to be tracked integrates light, temperature and humidity sensors, a microcontroller, a memory chip, low power electronics and an antenna for RFID communications. These sensors logged data can be stored in the memory together with traceability data

Miniaturized device, called Flexible Tag Data logger (FTD)-This miniaturized device integrates three sensors (temperature, humidity and light) and a microcontroller, which manages the sensors in a power safe mode and records the ranges of the measures on its memory. The transmission of data is based on an infrared communication (as alternative to the RFID technology), making the device able to communicate with the most common personal devices, such as Smartphone or PDA with integrated infrared port.

Figure 2. Barcode and barcode printed food pack

Traditional Supply Chains-Traditional SCM systems do not prove the product ownership. They still use a traditional method to maintain the supply chain process. Counterfeiting products, such as branded goods, is one of the most important and difficult issues to deal with in national/international markets.

Figure 3. Challenges

B. Disadvantages:

- Lack in digitalization and weak supporting systems.
- Lack of connectivity, particularly with upstream suppliers.
- Coordinating process and digital transformation across multiple, disbursed, and often disconnected supply chain actors.
- Onerous and costly data reconciliation processes.
- Ineffective solutions for handling large amounts of disparate and potentially inconsistent data.
- Its main drawbacks are the unit cost of the RFID and the integration cost, which make it unrealistic for most large deployments.
- NFC chips isnot suitable for all types of products. For instance, fresh food or small commodities.
- unscrupulous merchantscan directly steal QR codes of genuine products, then makethousands copies of the code.
- merchants have the authority tochange the database, thus merchants can manipulate thedatabase by themselves, making online verification no longercredible.

- RFID tagsare expensive and require reading devices.
- Barcode, such as QR code is a pervasive ID carrier, the printable graphical code is proved to be clone able. Existing scheme cannot guarantee that the product the consume rpurchased from the seller is not a counterfeited one.

C. Proposed System:

The proposed Food Safety Traceability System based onblockchain and EPCIS consists of enterprise-user server and consumer traceability client. The design of enterprise-userserver is based on the architecture of EPCIS, which is mainlyused for the acquisition and management of key traceability information of products. While consumers trace the information of the products, they purchased mainly through theconsumer traceability client. The blockchain is a new set of tools for digitization. The reason blockchain technology is interesting is that there are certain functions that are very valuable for the digital world that hasn't been invented before the blockchain.

D. Supply Chains with Block chain:

Figure 4. Benefits

This system presents a BIFTS to design an adaptive blockchain monitoring and data management system for Food traceability, and to customize Food shelf life and quality decay performance under various circumstances.First, IoT technologies are applied todevelop an environmental monitoring application with multipleTRUs for upward, downward, and batch dispersion inthe supply chain. Subsequently, the collected data are storedin a cloud database, whilst association keys and Food lifecycles are managed by using blockchain technology.This aims to provide Food identification and environmental monitoring, along with shipmentjourneys and supply chain activities. The collected dataare then sed to evaluate Food shelf life and quality decay.In the device layer, environmental sensors and relay nodesare installed to collect data on environmental conditions,

while the collection timestamp is also recorded. In the connectivitylayer, the data transmission between sensor nodesand relay nodes is performed by using wireless communicationtechnologies (such as Bluetooth and Wi-Fi), whiledata transmission between relay nodes and designated IoTplatforms is achieved by machine-to-machine (M2M) communicationtechnologies (such as message queuing telemetrytransport (MQTT)). In the application layer, IoT developmentplatforms such as IBM Cloud, are applied to develop andmanage the applications, and external systems and databasescan be linked by using application programming interfaces(APIs). Further, the collected data can be structured andstored in a centralized cloud database for further querying.

Moreover, the adoption strategy of IoT technologies is basedon various level of TRUs, including container-, batch-, andpiece-levels. An optimized numberof sensors and relay nodes (according to a temperature andhumidity mapping analysis) are applied in the containerlevel.This facilitates striking a balance between deploymentcosts and the effectiveness of environmental monitoring. The Food items in the container-level are typically transportedbetween suppliers, post-harvesting centers, and Food processingcenters, by using active cold chain packaging throughinternational freight forwarding. For the batch-level, a sensoris attached for item palletization to monitor each batch of Food items. Then the pallet of items is normally shipped by roadtransportation between processing and distribution centers.Eventually,the Food items can be either sold in supermarkets or suppliedto restaurants, and handled by using passive cold chainpackaging. The outer packaging of Food items provides quickresponse (EPC) codes that contain Food information, such asname, list of ingredients, and source of origin. In addition,information related to Food quality (including shelf life andquality decay), and environmental monitoring is associatedwith the EP codes in the cloud-based applications.

In the block chain mechanism, there are several protocolsto achieve consensus between devices or stakeholders ona distributed network, such as proof of work (PoW) and proof of stake (PoS)To create blocks in the blockchain, proof of work was developedfor mining blocks. However, this requires huge energy

consumption and computational equipment to complete withother miners. Proof of stake is then developed to solve the above problems in cryptocurrency, by choosing the creatorof the new block based on various selection criteria, such as wealth. In the scenario of Food traceability, proof of supply chain share (PoSCS), which mimics PoS, is thus proposed tomint or forge blocks by validators instead of miners, where validators are the stakeholders in the Food supply chain.

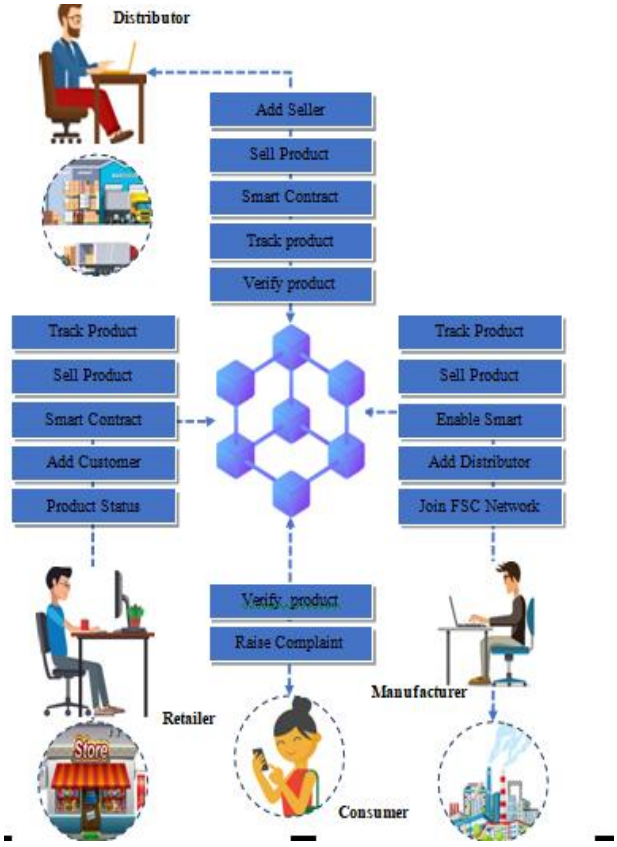
Electronic Product Code Blockchain-Enabled Product Anti-Counterfeiting and Re Packing Verification Each and every product will have a pair of global Id and unique Id in the manufacturing unit to identify the product in the Manufacturing Unit generated using KYPC Generator anti-counterfeiting identification code, and other information of the product are added to the blockchain.

It is powered by an advanced blockchain protocol that ensures secure storage of data on the product's manufacturer and origin. It allows tracking and monitoring products from production lines to distribution centres to the point of sale and the consumers.

E. Advantages:

- Increased time effectiveness due to the real-time transactions.
- Direct Transactions eliminate the overheads and intermediary costs.
- Reduced risks related to cybercrimes, frauds and tampering.
- More transparent processes with a proper record creation and tracking.
- Highly secure due to cryptographic and decentralized Block chain protocols.
- Blockchain supply chain network proof of concept.
- Web platform for managers to access product tracking data.
- Universal access to manufacturers details & distribution history.
- Digital identities for supply chain participants.
- No expensive reader needed.

VI. SYSTEM DESIGN



VII. MODULE DESCRIPTION

A. FSC Dashboard:

The application layer consists of the business system and the application service system. The business system is developedbased on the blockchain platform, which is mainly used toobtain and manage key information in the grain supply chain.The application service system is used to query and supervisethe supply chain information of all roles in the supply chain.The business system includes a coding module, blockchaininteraction module, data processing module, and monitoringmodule.

1.1. Coding module: This module mainly assigns codes toinformation that needs to be on the chain. By identifyingthe key information generated in each link of the grainsupply chain, it creates corresponding codes for theuploaded data, which are convenient for data archivingand querying.

1.2. Blockchain interaction module: This module supports data interaction and smart contract deployment. Data interaction includes building a suitable block chain platform for querying key information in the supply chain. Smart contract deployment ensures data authenticity andexpands the supply chain information management systemby verifying contracts for all roles in the supply chain.

1.3. Data processing module: This module mainly focuseson the various data interaction channels of data producersin the supply chain so that all participants can perform data synchronization, data chain functions, anddata view functions, among others.

1.4. Monitoring module: This module monitors the wholelife cycle of the grain supply chain and the operation ofthe whole system. Tracing, risk assessment, prediction, and early warning are achieved by analysing supplychain data stored in the database.

1.5. Business interaction module: This module supportsinformation interaction with the business systemthrough the interface and visually processes informationin the grain supply chain. It is an interactive interface forusers to manage information in the grain supply chain.

1.6. Privacy protection module: This module mainly performsrights controls for system users, the encryptionand decryption of private information, and the generationof keys.

B. Cloud Service Layer:

The cloud service layer includes the node database and theinformation database. The node database is the independent database of each node in the blockchain network, which isresponsible for storing the data of the entire grain supplychain and the data of the blockchain network. The information database is responsible for storing some data the system does not need to reach consensus. The database architecture for grain supply chain information management wasconstructed by a cloud server. The advantages of a clouddatabase are its convenient deployment and perfect security mechanism, which can realize rapid database deployment, reduce operational costs, and improve resource utilization.

C. Block chain Network Layer:

The block chain network layer is the system architecture,which differs from traditional systems. It takes the enterprises,regulatory departments, and third-party research institutions in the grain supply chain as the nodes of theblockchain, builds the blockchain network, and deploys andimplements the smart contract.

D. Government and Regulatory Agencies:

Macro control of the operation of the whole supply chainand the maintenance and guarantee of grain safety are themain responsibilities of governments and regulatory agencies.Therefore, building a comprehensive information managementsystem for the grain supply chain is conducive toimproving the management level and processing efficiencyof governments. Governments and regulatory agencies thusneed to record all trading information in the grain supplychain through the information management system to facilitatethe supervision of the entire grain supply chain andensure food safety.

E. Distributor:

The finished product may go through multiple levels of distribution before reaching the retailer. The distributor is responsible for storing processed agricultural products and selling them to retailers in batches. Company information, product selling time, price and other information is stored in Blockchain, and like the situation for the quality supervision bureau, the hash value is stored in blockchain to ensure that the subsequent data is not tampered with.

F. Retailer:

The retailer buys processed produce from the distributor and sells it in small quantities to consumers. Basic information of the retailer, time of selling, quantity sold and other information is recorded in Blockchain, and the hash value is also recorded in the blockchain.

G. Enterprises:

For the enterprises that occupy the main body of the food supplychain, collecting and sorting data in the food supply chainwill help them master market dynamics, analyse changes insupply and demand, and improve operational efficiency andprofits. The main needs of grain supply chain enterprisesare as follows: 1) data shared on the blockchain must haveaccess rights to ensure that sensitive data are not leaked,and 2) the blockchain system should be easy to deploy andoperate.

7.1. Traceability Information Capture Module: This module is designed to collect key traceability information brought forth by the process of production, storage, circulation of food. It can work automatically and manually to identify and create detailed event information from the circulation of food in the supply chain.

7.2. Event Information Database: This database is mainly used for the preservation and management of all food information from the capture module.

7.3. Information Extraction Module: This module is primarily devised for extracting information that needs to be uploaded on blockchain from the traceability information database as well as preparing the data for the uploading.

7.4. Blockchain Module: Blockchain module has two functions. One is the data interaction including the upload of key traceability information on blockchain, the request of on-chain information and the verification of event information. The other is to provide options for users to be the full blockchain node or the light-weight blockchain node i.e., to decide whether or not to participate in the maintenance of the blockchain.

7.5. Interaction Authority Management Module: This module is in charge of the verification of enterprise identity when there is any event information interaction i.e., to determine whether the requester who initiates the request for event information is in this supply chain.

H.Consumers:

The supply chain information management system shouldprovide consumers with supply chain information about thegoods they buy to ensure the traceability of the information.According to consumer needs, the system should ensure thatdata cannot be tampered with to improve credibility. At thesame time, consumers should control their data access rightsto prevent the disclosure of sensitive information.

8.1. Blockchain Module: This module is designed for the link between the client and system, through which it can request information on the blockchain and verify the legitimacy of the information. A light node is chosen for this module to lower user's maintenance cost.

8.2. Information Cache Database: This cache database is built to cache the corresponding food traceability data requested by users.

VIII. CONCLUSION AND FUTURE WORK

In this paper, we first design a block chain-based framework to guarantee the agri-food safety with product traceability in ASC systems. Next, we propose a DR-SCM method to make decisions on the production and storage of agri-food products for optimizing product profits in ASCs. The extensive simulation experiments verify the effectiveness of the proposed block chain-based framework and the DR-SCM method for ASC optimization. More specifically, the results show that proposed block chain-based ASC framework can well guarantee reliable product traceability. Moreover, the DR SCM out-performs common heuristic and Q-learning methods in terms of rewards (i.e. product profits) while achieving high learning efficiency in different scenarios of ASC management. Meanwhile, the DR-SCM has higher flexibility than others in arranging production and storage. In the real-world ASC environment, the demands from consumers are changing during different time periods. Based on the simulation experiments conducted by using the DR-SCM, the macro for the production and storage of agricultural products can be effectively performed. Thus, according to demands and costs, the production of factories can maintain available for retailers in a cost-effective way while the stock of retailers can well satisfy the demands from consumers. The DQN

algorithm utilizes a mechanism of experience replay to facilitate convergence, but the experience data in the playback memory reveals strong relevance, which may cause the low efficiency of training for achieving the optimal performance. To address this problem, in the future, we will continue our research by applying other advanced DRL based algorithms (e.g. asynchronous advantage actor-critic) in more complex scenarios of ASC management with the demands constructed by using real-world data. Meanwhile, we will evaluate the robustness and potential improvements by using these algorithms and explore their feasibility in real world ASC environments.

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