Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı 37, S. 59-64, Haziran 2022

Derleme Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue 37, pp. 59-64, June 2022

Review Article

Establishing Agri and Food Supply Chain Provenance Based on Blockchain: Literature Review

Ergün Arat[1+], Ufuk Cebecı[2*]

[1*] Istanbul Technical University, Faculty of Management, Engineering Management Department, Istanbul, Turkey (ORCID: 0000-0001-6270-5792), arate21@itu.edu.tr
[2] Istanbul Technical University, Faculty of Management, Engineering Management Department, Istanbul, Turkey (ORCID: 0000-0003-4367-6206), cebeciu@itu.edu.tr

(5th International Symposium on Innovative Approaches in Smart Technologies– 28-29 May 2022)

(**DOI:** 10.31590/ejosat.1131779)

ATIF/REFERENCE: Arat, E. & Cebeci, U. (2022). Establishing Agri and Food Supply Chain Provenance Based on Blockchain: Literature Review. *Avrupa Bilim ve Teknoloji Dergisi*, (37), 59-64.

Abstract

The demand for food, which is the indispensable basic need of people, has turned to healthier and safer alternatives with increasing awareness all over the world, especially in developing countries. At the same time, food safety management in accordance with society's health goals, customer demands, and international food standards is increasing its importance day by day in a period of increasing food-borne diseases. As a result of this, the maximum risk level that manufacturers can take in the production of products has decreased. The food supply chain, which consists of production, collecting, packaging, warehousing, processing, distribution, and transfer processes, is so sensitive and complex process and has high risks. Traditional methods are insufficient for food supply chain risk management due to the increasing demands of consumers for transparent information and food safety concerns.

In recent years, technological research and studies have accelerated in the agriculture and food industry to protect and improve the trust of consumers. In 2008, with the publication of the white paper on "Bitcoin: Peer-to-peer Electronic Cash Payment System" by Satoshi Nakamoto, the world met with blockchain technology, where there are no middlemen and transfers are made securely. In the following years, with the development of Ethereum by Vitalik Buterin and the interpretation of the concept of Smart Contracts with blockchain technology, blockchain technology has begun to influence all sectors, thanks to its benefits such as increasing transparency and reliability in contracts between parties. Blockchain technology, in addition to providing solutions to financial systems that have become dysfunctional, also brings alternatives to supply chain management, where data needs to be transferred securely and quickly. Blockchain applications used in FSC emerge as a technology that will enable us to solve problems such as food security, food integrity, food fraud, etc.

In this paper, It has been studied on how to use blockchain technology in the food supply chain, how to choose the suitable blockchain platform, and how It will be facilitating for solutions such as tracking from field to fork, back-tracking are examined the data saved in the blocks and the working mechanism will be discussed in the background.

Keywords: Agriculture and food supply chain, Food safety, Risk reduction, Blockchain, Smart contracts, Trust, Information transparency.

Blockchain Tabanlı Tarım ve Gıda Tedarik Zinciri Kaynağı Oluşturma: Literatür İncelemesi

Öz

Tüm dünyada, özellikle gelişmekte olan ülkelerde artan bilinçlenmeyle, insanların olmazsa olmaz temel ihtiyacı olan gıdalara yönelik talebi, daha sağlıklı ve daha güvenli alternatíflere yönelmistir. Aynı zamanda toplumsal sağlık amaçlarına, müşteri ihtiyaçlarına, uluslararası gıda güvenliği standartlarına uygun gıda güvenliği yönetimi, gıda kaynaklı hastalıkların arttığı bir dönemde önemini günden güne artırmaktadır. Bunun etkisi sonucu üreticilerin üretimde göze alabileceği maksimum risk düzeyi düşmüştür. Üretim, toplama, paketleme, depolama, işleme, dağıtım ve taşıma süreçlerinden oluşan gıda tedarik zinciri, en hassas ve kompleks işlemlerden bir tanesidir ve riskleri yüksektir. Tüketicilerin artan şeffaf bilgi talepleri ve gıda güvenliği endişelerinden dolayı geleneksel

yöntemler gıda tedarik zinciri risk yönetimi için yetersiz kalmaktadır. Bu sebeple son yillarda tarim ve gida sektöründe, tüketicilerin güvenini korumak ve iyileştirmek için teknolojik araştırmalar ve çalışmalar hızlanmıştır. 2008 'de Satoshi Nakamoto tarafından "Bitcoin: Eşten-eşe Elektronik Nakit Ödeme Sistemi" konulu teknik dökümanın yayınlanmasıyla birlikte, dünya, aracıların olmadığı ve transferlerin güvenli bir şekilde gerçekleştiği blokzincir teknolojisiyle tanıştı. İlerleyen yıllarda Vitalik Buterin tarafından Ethereum'un geliştirilmesi ve Akıllı Şözlesmeler kavramının blokzincir teknolojisi ile birlikte yorumlanmasıyla, taraflar arası sözleşmelerde şeffaflığın ve güvenilirliğin artması, aracıların ortadan kaldırılması gibi faydaları sayesinde blokzincir teknolojisi tüm sektörleri etkisi altına almaya başlamıştır. Blockzincir teknolojisi, başta işlevsiz kalmış finansal sistemlere çözüm getirmenin yanı sıra verilerin, güvenli ve hızlı şekilde aktarılmasına ihtiyaç duyulan tedarik zinciri yönetimine de alternatifler getirmektedir. Tarım ve gıda tedarik zincirinde kullanılan blockzincir uygulamaları, küresel açlik, gıda güvenliği, gıda bütünlüğü, gıda kaçakçılığı gibi sorunları çözmemizi sağlayacak bir teknoloji olarak karşımıza çıkmaktadır. İşte bu makale de blockzincir teknolojisinin tarım ve gıda tedarik zincirinde nasıl kullanılabileceği, artı yönleri, entegre edilmesi ve gelecekteki etkisi üzerine çalışılmıştır.
Bu bildiride, blok zinciri teknolojisinin tedarik zincirinde nasıl kullanılabileceği, uygun blok zinciri platformunun nasıl seçileceği ve tarladan çatala takip, geri izleme gibi çözümlerin nasıl sağlanacağı incelenmiştir. Bloklara kaydedilen veriler incelenecek ve arka planda çalışma mekanizması tartışılacaktır.

Anahtar Kelimeler: Tedarik zinciri, Tarım ve gıda tedarik zinciri, Gıda güvenliği, Risk azaltma, Blokzincir, Akıllı sözleşmeler, Güven, Bilgi Şeffaflığı.

1. Introduction

In the 21st century, food safety increases its importance as a result of globalization, growth of economies, and increasing population rates, as a result of changing people's living standards and consumption habits. Food safety is physical, chemical, biological and all kinds of damage that may occur in food refers to the measures taken to eliminate; and safe (healthy) foods can be defined as clean and healthy food whose nutritional values have not been lost in terms of physical, chemical and biological hazards (Erkmen, 2010). In the past years, a couple of serious food safety issues occurred, such as "Sudan red", "clenbuterol", "Sanlu toxic milk powder". It is worth noting in the world these kinds of scandals have broken out during the past 20 years, including Escherichia coli in hamburgers, Salmonella in eggs, poultry, and pork, Listeria in pates, and cheeses, and the "horsemeat scandal" in 2013 (Tian 2016). According to the World Health Organization, contaminated food causes 600 million cases of foodborne disease and 420.000 deaths per year around the world. Children under the age of five account for 30% of all foodborne deaths. Each year, the World Health Organization estimates that 33 million years of good life are lost owing to eating unsafe food, and this figure is likely underestimated. These and similar food problems have not only worried people day by day, but also damaged their trust in companies and institutions.

In addition to these problems, in the agriculture and food supply chain, the food goes through a dynamic operation in the process according to the manufacturer, producer, wholesaler, distributor, and retailer, in short, from farm to fork. Food quality can be affected by uncertain conditions like weather, related heat, humidity, and coolness. The limited shelf life, delivery delays, and volatile demand structure of food products increase uncertainty and risk. These events also reminded people of the many problems and the inadequacy of traditional methods in the already complex food production, supply chain, and processing environment. The process of the supply chain is summarized in Figure 1 (Awan et al., 2021).

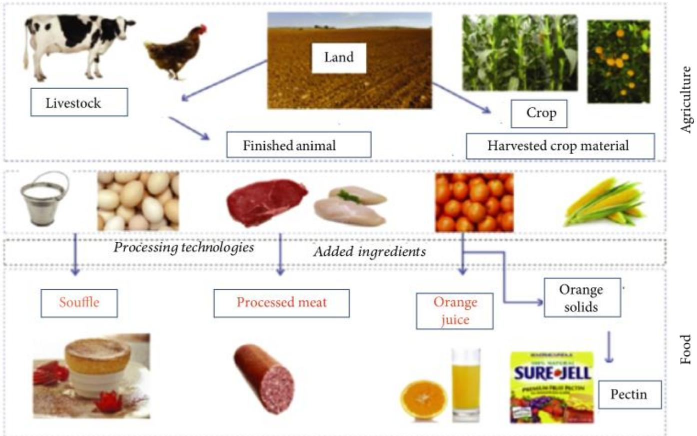

Figure 1- Agricultural food supply chain process (Awan et al., 2021).

.

With the acceleration of technological developments and their integration into many industries, technological infrastructures have begun to be created against problems in supply chain management, food, and agriculture sectors. Quality and assurance in the food chain process can be monitored with modern technologies and all information can be transmitted to the consumer without changing it. When there is a threat to health, it is necessary to trace the process backward and find the source of the problem and establish an information system for crisis management by following it forward. There may be different definitions between businesses in the food chain, incompatibility problems may arise between administrative and physical units, or food-related information may not be verified. In order to follow the food, all members should be connected to a transparent information network, and information about the features and location of the product should be shared instantly. For this purpose, tracking technologies such as paper tracking, product labeling, barcode, temperature, light, and humidity sensors embedded with RFID (radio frequency identification) can be used. As a result of the adoption of Internet of Things (IoT) technologies and their usage in many sectors of daily life, they have started to be used in agriculture and food production and distribution processes, and studies on reliable, traceable, and auditable systems have increased. Current IoT-based traceability and provenance systems for Agri-Food supply chains are built on top of centralized infrastructures and this leaves room for unsolved issues and major concerns, including data integrity, tampering, and single points of failure (Caro et al., 2018). However, the majority of the current IoT solutions still rely on heavily-centralized cloud infrastructures, where there is usually a lack of transparency, and by nature presents security threats including availability, data lock-in, confidentiality, and auditability (Armbrust et al., 2010). IoT includes a system of devices that can collect, transfer and store data over a wireless network. Using blockchain with IoT devices enables smart devices to exchange data and other financial transactions in a scalable, private and reliable way (ReportLinker, 2022). At the points where IoT is lacking, Blockchain can be used as a solution with its decentralized structure, auditability, immutability, and encryption where IoT is insufficient.

2. Material and Method

2.1. Blockchain Technology

Blockchain is the basic infrastructure of digital currencies, known as crypto money, which everyone is familiar with. Although cryptocurrencies are the most well-known application area of Blockchain technology, Blockchain is a strong and general subject that is not limited to the financial sector.

Blockchain is completely decentralized and the place where every transaction or every data is recorded in the parts we call blocks. Each block contains all transaction data in a given time period and these act as digital IDs that can be used for verification. In blocks, each block is linearly linked to each other, sequentially with each other in time, and contains the hash value of the previous one.

Especially with the emergence of Ethereum, the concept we call 'Smart Contracts' has gained meaning again today. Smart contracts and blockchain technologies will be a solution to the classical methods that are insufficient in almost every field and in every subject and will provide benefits such as saving documents or transactions in a secure environment, sharing, traceability, control, and immutability, automation of ongoing manual processes.

Blockchain technology can be visualized as a general term for technical schemes which are similar to NoSQL (Not Only Structured Query Language), and it can be realized by many kinds of programming languages (Tian, 2016). The key characteristics of blockchain are shown in Figure 2 (Puthal et al., 2018).

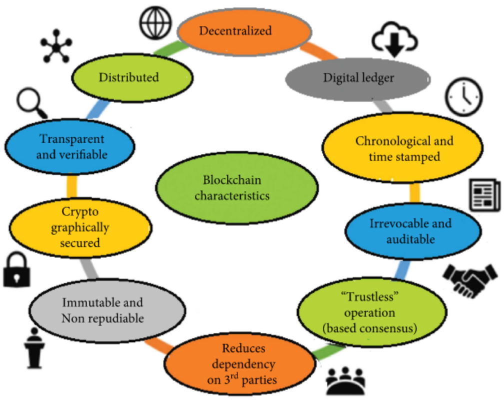

Figure 2 - Key characteristics of Blockchain Technology (Puthal et al., 2018).

By integrating the blockchain into the supply chain and saving every piece of information on a block, the whole process is tracked and reviewed. It provides the consumer with all information about the product they buy. Product owner, logistic business, and purchaser are the three key entities involved in the trade and delivery system. A product owner is someone who sells a product in the supply chain; a logistic firm is a corporation that transports products; and a consumer, as the name suggests, is someone who wishes to spend ethers on a product. As previously stated, the logistic firm is a system-registered entity. Arbitrators are in charge of off-chain dispute resolution in the event of a transactional dispute. Figure 3 depicts the trading and delivery business, though (Shadid et al., 2020).

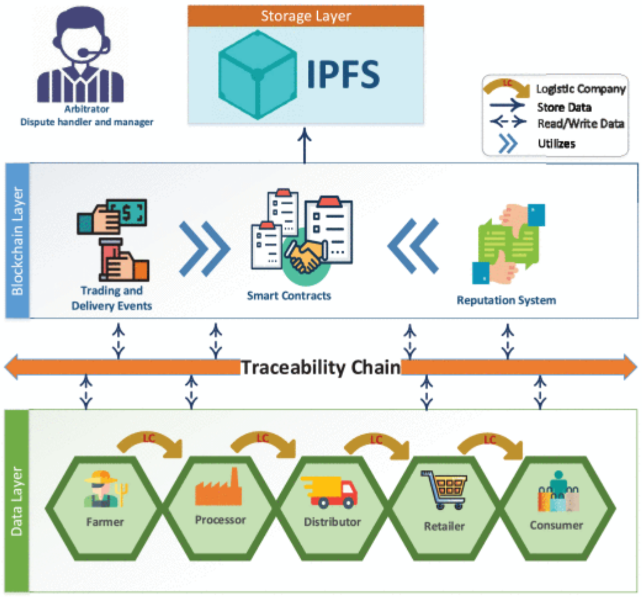

Figure 3 - Blockchain-based end-to-end solution for agri-food supply chain (Shadid et al., 2020).

2.1.1. Consensus Mechanism

X In the applications of blockchain, we need to solve two problems-double spending and Byzantine Generals Problem (Lamport et al., 1982). Using a digital asset more than once at the same time is called double-spending. Since blockchain networks work with a distributed ledger system, every transaction is verified. Transactions performed on networks such as Bitcoin are processed on the blockchain with the approval of the miners. If the same transaction is attempted a second time, full nodes indicate that the transaction is fraudulent. This protects users against the possibility of double-spending. The Byzantine Generals Problem; deals with the stalemate that generals, who can only send messages to each other via messenger, reach consensus on the move to attack or retreat. It is a consensus problem about coordination and integration problems in software technologies, especially in distributed systems. Data would be transmitted between nodes via peers. Some nodes may be attacked, which may cause the relevant content to change. Normal nodes need to distinguish the information that has been tampered with and obtain consistent results with other normal nodes (Mingxiao et al., 2017). This requires the design of the consensus mechanism needed.

Consensus (mechanism) algorithms are the decision-making process for a group where its members form and support the decision that is best for the rest of the group. The algorithm basically says: If this happens then this if this happens and so on… The consensus algorithm for blockchain allows a group of people to make sure that all transactions are authentic and real. There are some methods for achieving that, such as POW (Proof of Work), POS (Proof of Stake), DPOS (Delegated Proof of Stake), and PBFT (Practical Byzantine Fault Tolerance).

POW (Proof Of Work)

Its core idea is to distribute accounting rights and rewards through hash power competition between nodes. Hashing is the name given to the process of creating a fixed-size output from different-sized inputs. This is done using mathematical formulas (implemented as hashing algorithms) known as hash functions. Based on the information from the previous block, the different nodes calculate the specific solution to a mathematical problem. (Mingxiao et al., 2017).

The proof of work mechanism works on the principle that adding transactions to the network is difficult but easy to verify. It is very easy to understand whether a transaction is valid or not, as all previous transactions stop transparently on the network. If a malicious user attempts to commit fraudulently, their transaction will be rejected by the rest of the network. However, this is a very expensive method and poses big problems in terms of energy consumption. In addition to these, there are long processing times and certain security problems.

POS (Proof Of Stake)

The core idea of PoS evolves around the concept that the nodes who would like to participate in the block creation process must prove that they own a certain number of coins at first (Ferdous et al., 2020). Proof of stake is a consensus mechanism that has become popular in recent years, using different variations of some cryptocurrencies. Proof-of-stake architecture does not require huge amounts of processing power and devices as in proof-of-work. Instead of miners, there are validators called "validators" on the network and they do the work of adding blocks. In the proof of stake architecture, each block is added every 10 seconds. This provides a much faster transaction processing time than the bitcoin blockchain.

DPOS (Delegated Proof Of Stake)

In the Proof of Stake protocol based on cryptocurrency ownership, a user has the right to verify transactions and generate blocks by keeping their crypto assets in their wallet connected to the relevant blockchain. dPoS, on the other hand, comes with some additional features and leverages the power of stakeholders to resolve consensus by voting fairly. It uses a social reputation system to drive consensus across its Delegated Proof-of-Stake (dPoS) blockchain network. Referred to as the least decentralized protocol compared to others, dPoS aims to give cryptocurrency holders a say in the management of the network. Unlike the Proof-of-Stake system, users delegate their crypto assets in their wallets to another user. Cryptocurrency asset is not transferred from the wallet but is considered as the asset of the delegated user, increasing the delegated user's voice in the network. The person who receives the right to delegate from other users receives a larger share of the revenues in the network and shares the revenue with the delegates in proportion to their shares.

PBFT (Practical Byzantine Fault Tolerance)

When we evaluate it through the blockchain structure, the generals represent the nodes in the network. Nodes in the network must reach a consensus for the transaction to occur. Thus, proven data is transferred to the blocks. In simpler terms, a consensus is needed by the majority of network participants, given that erroneous or incomplete information may occur.

The algorithm is designed to work in asynchronous systems. It is optimized to provide high performance and fast execution time. In fact, all nodes in the pBFT model are pipelined. One of them is the master node (leader), the others are called backup nodes. All nodes in the system interact with each other. The purpose of all honest nodes is to agree on the state of the system based on the majority opinion. It is important not only to prove that messages came from a particular peer-to-peer node but also to make sure that the message did not change during transmission.

2.2. Blockchain Platforms

Two of the most suitable blockchain platforms for use in the supply chain will be examined and compared according to their purpose, operating logic, privacy level, programming languages , and consensus mechanism.

Ethereum and Hyperledger

Ethereum is an open-source distributed public blockchain network that uses Smart Contract technology to allow decentralized applications to be built on top of it.

Hyperledger Fabric, an open-source project like Ethereum, is a widely accepted platform for enterprise blockchain platforms with its modular structure. Designed to develop enterprise-grade applications and professional solutions, the convenient, modular architecture uses "plug and play" components to adapt to many use cases. The most important point of the project is to create intersectoral cooperation by enabling blockchain-based projects to interact with each other. Hyperledger hosts several enterprise-grade blockchain-based software projects. Projects are designed by the developer community for vendors, organizations, service providers, and academics to build and deploy blockchain networks or commercial solutions.

Each peer in Ethereum has a role, which means that whenever a transaction occurs, numerous nodes must participate in order for it to be completed, which causes scalability, privacy, and efficiency difficulties. Hyperledger, on the other hand, is a distributed ledger technology (DLT) that does not require each peer in the network to be informed in order to complete a transaction.

The anonymity of users within the system is one of the most emphasized issues in crypto money projects. However, this is not always required. Keeping data on a public network and making it accessible to everyone can cause issues in some projects. Hyperledger is a permissioned blockchain that uses an identity management module to enable us authenticate.

For this reason, It can store some information specific to a certain user group by using Hyperledger due to the private structure.

Figure 4 shows the differences between Ethereum and Hyperledger.

Feature	Ethereum	Hyperledger
Confidentiality	Public Blockchain	Private Blockchain
Purpose	Client-side B2C apps	Enterprise-level B2B apps
Governance	Ethereum Developers	Linux Foundation
Participation	Anyone	Organizations having Certificate of Authorization
Programming Language	Solidity	Golang, Java
Consensus Mechanism	Proof of Work Mechanism	Practical Byzantine Fault Tolerance
Speed of Transactions	Less	More
Cryptocurrency	Ether or Ethereum	None

Figure 4 – Difference between Ethereum and Hyperledger

Since the blockchain to be integrated into the supply chain will only provide information flow between the stakeholders, in short, it will be a B2B application, Hyperledger is a more suitable platform for this.

2.3. Blockchain-driven IoT Technology

IoT aims to provide food identification and monitoring and collecting pieces of information about heat, humidity, cold chain protection, in short, concentration product-related in the agricultural supply chain. Agricultural production personnel can analyze environmental big data by monitoring pests and diseases and various risk factors so that targeted agricultural production materials can be put in place; various execution equipment can be mobilized as required to perform temperature control, dimming and ventilation, as well as other actions to achieve intelligent control for the growing environment of agriculture (Lin et al., 2018).

Wireless communication technologies (such as Bluetooth and Wi-Fi) are used in the connection layer to transmit data between sensor nodes and relay nodes, while machine-to-machine (M2M) communication technologies are used to transmit data between relay nodes and specified IoT platforms. IoT development platforms are used to develop and manage applications at the application layer, and application programming interfaces are used to connect external systems and databases (APIs). It should also be incorporated with ERP for things like managing and controlling internal resources and expenses. In terms of decentralized control, data transparency, auditability, distributed information, decentralized consensus, and high security, blockchain may currently bridge the gap in IoT systems.

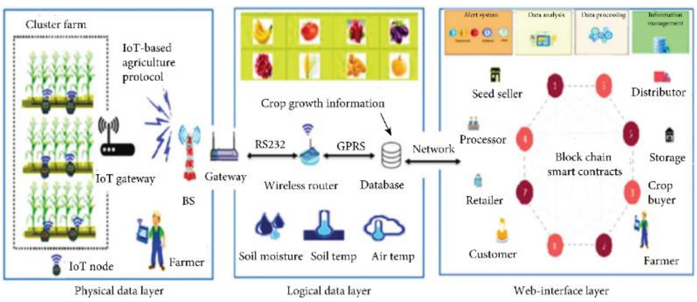

Figure 5- Blockchain-driven IoT Technology (Awan et al., 2021)

3. Results and Discussion

Blockchain technology provides a solution to many problems in the FSC with the visibility and traceability it provides. We examined the benefits and possible consequences of the integration of blockchain with IoT. The disadvantage of the IoT system being centralized can be overcome by using blockchain technology. The blockchain is a powerful technology that is able to decentralize computation and management processes that can solve many IoT issues, especially security (Lin et al., 2018).

While the data stored with the use of the Hyperledger platform can be retrieved later, especially due to its performance and its openness to members only, It is possible to write smart contracts and include them in the system so that the data is automatically generated by the sensor creates certain conditions. Both platforms are suitable for making complex smart contracts. However, Hyperledger allows a custom transaction structure to be defined.

The suggested blockchain-based paradigm has numerous advantages and benefits, including increased trust, efficiency, quality, durability, and stability. In terms of efficiency, it reduces overall traceability process handling and, as a result, relevant traceability-related operating expenses, and eliminates hidden costs and paper burden from the FSC traceability process. The self-fulfillment provided by the creation and inclusion of smart contracts also serves as a cost-reduction mechanism and ensures the authenticity and real-time synchronization of incoming information

4. Conclusions and Recommendations

The combined use of blockchain and IoT can enable the creation of a self-governing, intelligent agriculture and supply chain management that connects all parties transparently from the beginning in the FSC processes which information is transmitted in the flow without changing it. This proposition minimizes the human factor, which includes traditional tracking and the security of information.

In conventional practice, insufficient information on the delivery and traceability of processes is inefficient and unreliable. By using IoT, all collected data is stored and managed in a remote database, with the addition of the blockchain, this information is recorded in blocks and cannot be changed, forming the basis of reliable information flow. All this information can be used in the analysis of food process management and predictions can be made about food life. As a result, consumers can access information such as the way food is grown, and the time of collection and distribution, rather than just learning about the shelf life of the product they buy. Thanks to this data, companies can implement different strategies in the production and distribution process, making improvements both operationally and costly.

The use of blockchain will provide benefits such as creating a completely transparent and reliable system in all processes, and self-disclosure, thanks to its features such as its distributed and decentralized structure, being closed to outside interference, and creation of smart contracts. Blockchain applications currently used in agriculture and the food supply chain are only used for supply chain management, except for the benefit of tracking food products to the source they come from. IoT technologies are currently limited to monitoring the agricultural environment or being used in processes such as the cold chain, and the manufacturers of the first product cannot communicate with the buyers. In this article, we developed a complete approach by integrating IoT and blockchain into the whole process. With this approach, it can provide information to the first producer about the environmental conditions necessary to produce products with high efficiency and quality, and provide the know-how to create suitable conditions or improve the production process. One of the most important features of this model is that the collaborators can transmit the information flow between each other and cross in real-time and cannot be accessed from the outside, protecting information security. The smart model will greatly boost the efficiency and reliability of the food supply chain, which will inevitably increase food safety and regain customer trust in the food industry (Awan et al., 2021).

This paper presents a blockchain and IoT-based framework for farm-to-fork traceability of the food and agricultural supply chain. Organizations, processes, functions, and their interaction with each other are explained. Through smart contracts, the benefits of establishing and maintaining a standard of product definition throughout the process, enabling processes to be carried out without the need for parties to trust each other, and providing an improved supply chain management are discussed.

References

Armbrust, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R., Konwinski, A., Lee, G., Patterson, D., Rabkin, A., Stoica, I., & Zaharia, M. (2010). A view of cloud computing. *Communications of the ACM*, *53*(4), 50–58. https://doi.org/10.1145/1721654.1721672

Awan, S., Ahmed, S., Ullah, F., Nawaz, A., Khan, A., Uddin, M. I., Alharbi, A., Alosaimi, W., & Alyami, H. (2021). IoT with BlockChain: A Futuristic Approach in Agriculture and Food Supply Chain. *Wireless Communications and Mobile Computing*, *2021*, 1–14. https://doi.org/10.1155/2021/5580179

Caro, M. P., Ali, M. S., Vecchio, M., & Giaffreda, R. (2018). Blockchain-based traceability in Agri-Food supply chain management: A practical implementation. *2018 IoT Vertical and Topical Summit on Agriculture - Tuscany (IoT Tuscany)*. https://doi.org/10.1109/iot-tuscany.2018.8373021

Erkmen, O. (2010). Gıda kaynaklı tehlikeler ve güvenli gıda üretimi. *Çocuk Sağlığı ve Hastalıkları Dergisi*, *53*(3), 220-235.

Feng Tian. (2016). An agri-food supply chain traceability system for China based on RFID & blockchain technology. *2016 13th International Conference on Service Systems and Service Management (ICSSSM)*. https://doi.org/10.1109/icsssm.2016.7538424

Ferdous, M. S., Chowdhury, M. J. M., & Hoque, M. A. (2021). A survey of consensus algorithms in public blockchain systems for crypto-currencies. *Journal of Network and Computer Applications*, *182*, 103035. https://doi.org/10.1016/j.jnca.2021.103035

Lamport, L., Shostak, R., & Pease, M. (1982). The Byzantine Generals Problem. *ACM Transactions on Programming Languages and Systems*, *4*(3), 382–401. https://doi.org/10.1145/357172.357176

Lin, J., Shen, Z., Zhang, A., & Chai, Y. (2018). Blockchain and IoT based Food Traceability for Smart Agriculture. *Proceedings of the 3rd International Conference on Crowd Science and Engineering - ICCSE'18*. https://doi.org/10.1145/3265689.3265692

Mingxiao, D., Xiaofeng, M., Zhe, Z., Xiangwei, W., & Qijun, C. (2017). A review on consensus algorithm of blockchain. *2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*. https://doi.org/10.1109/smc.2017.8123011

Puthal, D., Malik, N., Mohanty, S. P., Kougianos, E., & Yang, C. (2018). The Blockchain as a Decentralized Security Framework [Future Directions]. *IEEE Consumer Electronics Magazine*, *7*(2), 18–21. https://doi.org/10.1109/mce.2017.2776459

ReportLinker, "Blockchain In Agriculture And Food Supply Chain Global Market Report 2022," https://www.reportlinker.com/p06246504/Blockchain-In-Agriculture-And-Food-Supply-Chain-Global-Market-Report.html?utm_source=GNW

Shahid, A., Almogren, A., Javaid, N., Al-Zahrani, F. A., Zuair, M., & Alam, M. (2020). Blockchain-Based Agri-Food Supply Chain: A Complete Solution. *IEEE Access*, *8*, 69230–69243. https://doi.org/10.1109/access.2020.2986257

World Health Organization, "Estimating the burden of foodborne diseases," https://www.who.int/activities/estimating-the-burden-of-foodborne-diseases