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Blockchain in Food Supply Chain: Benefits, Challenges and Review

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Abstract: ***Blockchain technology has the potential to revolutionize the food supply chain by increasing transparency and traceability. With blockchain, every step of the food supply chain can be recorded and verified, allowing for greater accountability and trust between suppliers, manufacturers, distributors, retailers, and consumers. This study inclines towards the study of blockchain technology in use with food supply chain management. It also mentions the advantages and barriers to use this technology. To better comprehend the development of pertinent study and shed light on the benefits, issues, and difficulties with blockchain technology, there has been a review of the literature and an logical assessment of the supply chain exploration based on blockchain. Several intermediaries, trust issues, and subpar performance are all factors in traditional supply chain operations. Supply chain operations may be disrupted utilizing blockchain technology to enhance performance, disperse governance, and automate procedures. From the standpoint of literature analysis, this study contributes to our understanding of blockchain applications in supply chain management and offers a roadmap for these applications.***

I. INTRODUCTION

The topic of distributed ledger has just come up. Nearly every industry is seeing new ventures made possible by this technology. Centralized databases have a database file, kept at a single location on a given network, and users cannot access any data without the use of a central computer[5]. These centralized systems frequently experience crashes, malicious assaults, single points of failure, unauthorized data change, and malicious attacks. The blocks contain the data that is tacked onto the chain. A connection exists between these blocks. Once inserted into the block, data cannot be altered or deleted; it is decentralized and irrevocable in nature. Blocks become permanent and are added to this timeline after they are full.[2]

Blockchain is a system of record keeping that generates confidence without the need for a trusted mediator. It is distributed all over the nodes connected to the blockchain network in a decentralized manner. Due to this blockchain is an immutable, secure, and trustless model [1]. According to the breakdown of the blockchain market value by different industries, the banking sector accounts for 29.7% of all industries, process manufacturing makes up 11.4%, discrete manufacturing makes up 10.9%, professional services make up 6.6%, retail makes up 6%, and other industries make up 35.5%. A supply chain powered by blockchain can assure the elimination of flawed or perilous goods before they are shipped to the client and can prohibit any cases of disease brought on by tainted food. It boosts certainty as food goods become secure to use. Blockchain technology is also being used by a number of businesses, including IBM, Carrefour, Nestle, and Unilever. Their key goals were to boost sequence clarity and enable consumers to track the items. [37].

II. SHORTCOMINGS IN EXISTING FOOD SUPPLY CHAIN

There are several potential lacunas in the existing food supply chain, including:

1) *Lack of Transparency:* The food supply chain can be complex, with many players involved in different stages of production, distribution, and retail. This can make it difficult for consumers to trace the origin of their food and ensure that it meets certain standards.
2) *Food Waste:* Food waste is a major issue in the food supply chain, with estimates suggesting that up to one-third of all food produced is wasted. This can occur at various stages of the supply chain, including during production, transportation, and retail.
3) *Sustainability:* There is growing concern about the environmental impact of the food supply chain, including issues such as deforestation, greenhouse gas emissions, and water use.
4) *Inefficient Logistics:* The food supply chain can be hindered by inefficient logistics, such as long transport times, delays at border crossings, and inadequate storage facilities. These inefficiencies can lead to higher costs and longer delivery times for consumers.
5) *Food Safety:* The safety of the food supply chain is a key concern, with the potential for contamination, adulteration, and other safety risks. Ensuring food safety requires monitoring and regulation at all stages of the supply chain.

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III. USE OF BLOCKCHAIN IN FOOD SUPPLY CHAIN

Systems may be instantaneously checked for product tampering and food fraud using Blockchain technology. Additionally, it is possible to identify and categorize product waste in supply networks[44].

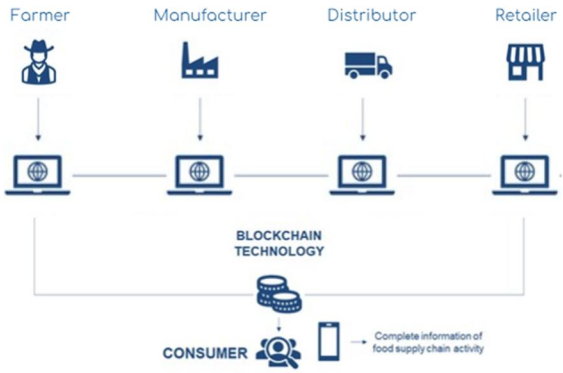


Fig.2:Food Supply chain using Blockchain

Farmers, manufacturers, distributors, retailers, and customers are the five nodes that make up the food supply chain in general. Each node may provide reports to the blockchain with information about the condition of the goods they are handling. Using the product id, all reports are accessible, increasing transparency throughout the supply chain by enabling all nodes to see the specifics of the process the product is undergoing. Customers may use product identifiers or QR codes to track products back, strengthening the blockchain's traceability.

IV. LITERATURE SURVEY

This section covers the work done by various researchers in the field of food supply chain using blockchain technology.

In [38], M. P. Caro et al. discussed the application of blockchain technology in Agri-Food Supply Chain using two technologies Ethereum and Hyperledger Sawtooth. They have compared the two implementations, in terms of three performance metrics, namely latency, CPU load, and network usage. They performed a series of 100 tests on both the technologies and measured the latency and CPU load for each test. They observed that the Hyperledger Sawtooth based implementation had better results in terms of latency and CPU utilization which makes Hyperledger Sawtooth a more feasible option for small IoT devices. Hyperledger Sawtooth has the ability of implementing logic using different languages and enables faster implementation and easier integration with other systems. Ethereum provides high scalability, reliability and enables larger participation hence its high latency can be bargained off. Since Ethereum offers a better-developed programme while Hyperledger Sawtooth is still in its infancy state, Ethereum is typically preferred over Hyperledger.

In [39], K. Salah et al have discussed blockchain-based soyabean traceability in the agricultural supply chain. The existing traceability approach in the agricultural supply chain suffers greatly from data fragmentation and centralized controls, which make the data vulnerable to management and alteration.

It is difficult to find out the source of contamination and to take that product out from the chain to ensure safety. The benefit of implementing traceable functionality in the soybean supply chain using the suggested blockchain-based solution leveraging smart contracts is that all stakeholders will have access to the verified and immutable information by eliminating the need of a central authority.

The use of traceable identifiers for each batch and the capability to track all relevant transactions between the stakeholders further assure continuous monitoring for achieving quality compliance. Using IoT enabled containers and packages with sensors, cameras, GPS locators and 4G networking, the quality of shipment and its conditions can also be surveilled. These sensors can continuously rely and provide notifications about the state of the crop, product and the items sent during the shipping process. Due to blockchain, such information and notice may be instantly made available to all parties in a trusted, decentralized manner without intermediaries, and they cannot be changed or tampered with. Using standard identifiers like global location identifiers or by geotagging the stakeholder location, which can be sent by GPS sensors installed within shipping or storage containers, additional attributes can be added to the address to trace precise physical location of the product or the stakeholder.

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In [40], A. Shahid et al. presented a complete solution of blockchain-based Agriculture and Food (Agri-Food) supply chain. It leverages the key features of blockchain and smart contracts, deployed over Ethereum blockchain network. The authors have suggested a whole blockchain-based Agri-Food supply chain system. They have provided comprehensive details on the intended solution for trade, delivery, reputation, and traceability. They have thoroughly considered and assessed the degree of performance of smart contracts operation in order to assure trustworthiness. The reputation system is suggested to uphold the genuineness of the entities and the product dignity positions. They have offered algorithms and gone into great length on smart contracts. A certain amount of gas is consumed to compile and deploy smart contracts.

They introduce strategies to ensure privacy of a few details needed to keep the chain secure. The reputation system similarly keeps track of evaluations left by actual customers, some of which may be skewed or false. In this regard, they have incorporated a technology that will yield the trueness of the product.This will help the reputation system identify phony customer reviews. Security studies that concentrate on assaults against reputation systems will also be taken into account.

In [41], Qin et al. suggested a Digital Watermarking and QR code-based anti-fake figure watermark technique. To assure the security of the watermark, this post encrypts it using the chaotic XOR technique. The three layer wavelet decomposition of the QR code picture and the integration of chaotic encryption and singular value decomposition are used to create the new water-marking barcode. The simulation results demonstrate that the method successfully extracts and embeds watermarks, extracts accurate content from watermarked QR images, and satisfies the invisibility of watermarking requirements. They will eventually include QR code watermarking to their image segmentation and learning-based technology.

In [42], M. C. Jayaprasanna et al have mentioned the need of a method for identifying fake goods and security mechanisms to warn the manufacturer and the consumer in the supply chain.

By connecting the product's barcode to a BlockChain Based Management (BCBM) system, barcode readers can identify counterfeit goods. Therefore, the suggested system may be utilized to store product information and its unique code as database blocks. It obtains the customer's unique code, then checks it against records in the blockchain database. If the code matches, it notifies the buyer; if not, it asks the consumer where they purchased the product in order to identify the maker of any counterfeit goods.

Manufacturers can maintain pertinent product sales data on the openly available block chain using the block chain management system. It is clear how many sales the vendor can make overall and how many of those sales will be left unfilled. The user can utilize an encryption algorithm to carry out vendor-side verification. Utilizing the owner's private key is the only way to decrypt. In this research, we suggested a block chain management system that enables both individual consumers and large-scale businesses to trace and recognize the real goods using a smartphone. For both end users and enterprise vendors, it will also identify fake goods and the validity of the producer.

In [43], Q. Lin, H. Wang, X. Pei and J. Wang have proposed a food safety traceability system based on the blockchain and the EPC Information Services and developed a prototype system. The traceability system is suggested as a management architecture for on-chain and off-chain data, which will help the blockchain's problem with data explosion for the Internet of Things. The Ethereum platform served as the foundation for the prototype system. The framework of EPCIS, which is primarily utilized for collection and maintenance of important traceability information of goods, served as the foundation for the design of the enterprise-user server. While customers primarily use the consumer traceability client to track the details of the things they bought.

In [45], Dianhui Mao et al., have discussed the Credit Evaluation System Based on Blockchain. This model collects and imposes the evaluation points of dealers in the food supply chain. By producing and reporting the results of the credit evaluation to regulators, it increases the effectiveness of management and monitoring. In the end, the objective of enhancing food safety measures in the food supply chain is accomplished .They investigated the interpretation of the assessment criterias in various models and with various indicators while confirming and examining the accuracy of the credit evaluation network through various trials .This paper delivers a parameter to measure vagueness of performance of of metrics of evaluation

Input is given by traders to the system to create a credit evaluation score. Then the input is processed by a deep learning network named Long Short Term Memory

In [46] ,Showkat Ahmad Bhat et al., have discussed about Agriculture- Food Supply Chain Management Based on Blockchain and IoT .In order to address the storage and scalability optimization, interoperability, security and privacy concerns, as well as storage issues and integrates blockchain with the already present technologies. This study presented an IOT based blockchain technology in agriculture Supply Chain Management.

Sr. no	Title	Advantages	Limitations
1	Blockchain-based Traceability in Agri-Food Supply Chain Management: A Practical Implementation	Ethereum and Hyperledger Sawtooth for implementation offers various degrees of adaptation for the transactions incorporated on the ledger. Ethereum uses a fixed and single structure for transactions whereas Hyperledger Sawtooth permits a framework for customized deals.	Ethereum allows higher participation because of its scalability. It is also highly reliable. However ethereum gives high latency but hyperledger sawtooth has less maturity than ethereum.
2	Credit Evaluation System Based on Blockchain for Multiple Stakeholders in the Food Supply Chain	The system proposed in this paper integrates the technology of blockchain and deep learning long short-term memory networks to gather and scrutinize the credit evaluation of entities in the chain. It enhances the influence of supervision and management by propagating the credit evaluation result to the actuator.	This study considers only two degrees, positive and negative . A better clarity and extent of emotion expression should be presented in detail. The experiment considers only a Chinese data set for evaluation.
3	Blockchain-Based Agri-Food Supply Chain: A Complete Solution	This study gives elaborate data of the proposed answer in terms of traceability, transactions, delivery and report. They have estimated and cautiously dissected the performance of smart contracts in order to ensure that the suggested solution is efficacious and vigorous. The system is proposed to conserve the reliability of the Agri-Food supply chain individuals, quality ratings of the produce and also preserves the immutability and probity of the sale.	The reputation system stores feedback from final customers which can be biased,distorted or counterfeit.
4	Blockchain-Based Soybean Traceability in Agricultural Supply Chain	This study shows how our solution can be applied for tracing and tracking soybean supply chain and how the presented aspects and particulars are universal enough and can be applied to provide trusted and decentralized traceability to any harvest or produce in the agrarian supply chain.	Blockchain technology still faces pivotal difficulties appertaining to scalability, governance, identity registration, confidentiality, specifications, and supervision.
5	Food Safety Traceability System based on Blockchain and EPCIS	The system is decentralized which can dodge the monopoly and ameliorate the credibility of the system. Guarantees the tamper proof and lost-prevention ability of the system. Sensitive business data will not be easily divulged. Decentralized data can still be tamper proof with blockchain technology	The vastness of data restraints the attainment of the methodology. The speed of data passed to the blockchain is constricted by the consensus algorithm.

6	Agriculture-Food Supply Chain Management Based on Blockchain and IoT: A Narrative on Enterprise Blockchain Interoperability	The proposed system has advantages like system storage and performance enhancement, privacy and security enhancement. There is cross chain interaction between varied blockchain platforms IoT device authentication, data authentication and integrity guarantees more safety.With IoT and smart contracts, blockchain could track down the origin of product,give synchronized updates, and form certitude amongst the entities.	The framework should be built to use as few resources as possible . It is a challenging task to ensure safety, privacy and morality due to the lack of ability of detectors.
7	A Blockchain based Management System for Detecting Counterfeit Product in Supply Chain	QR codes are used as an anti-counterfeiting constituent to aid customers to distinguish whether the produce is authentic or counterfeit. The system will ferret out counterfeit products using a barcode reader, where a barcode of the product is enchained to a blockchain network so that you can scan the barcode using the user's smartphone. It will inform you whether the product is fake or not.	One of the crucial challenges for original items is counterfeiting. It will result in a loss of revenue and harm the company's takings. Occasionally, it has been found that retailers obtain liquidation from websites that promote their commodities and proffer concession and fraudulent customer feedbacks to surge the valuation of the product. Consumers are unable to differentiate between authentic and bogus commodities because they deficit understanding regarding counterfeit products.

They also explored various blockchain-based protection mechanisms and the classification of security threats to IoT infrastructure. Lastly, we spoke about the characteristics of the suggested supply chain architecture.

V. BENEFITS OF BLOCKCHAIN IN FSC

Blockchain is thought to boost confidence during food recalls by improving traceability and efficiency. Big food brands generally opt to issue just a fragment of data in the existing supply chain with the intention of benefiting the firms themselves, which can result in customers being under informed about the goods and financial information of their suppliers [24]. Food security may be affected by incomplete information, as Reyna et al. [25] suggested. Translucency in the food supply chain is crucial for particular items with unique standards, in order to confirm product quality and sustain the trust of customers[26]. Although the government and other agencies have imposed regulations and repeatedly examine the grade of foodstuffs, their impact can be the prey of bribes and help considerable brand corporations conceal malpractices.

Decentralization, which enables authorized users to carry out transactions and directly access history without the involvement of a central authority, is therefore one of the key characteristics of the blockchain. Every legitimate individual who has registered has the same authority to retrospect transactions and obtain a replica of their history [27].This feature can reduce information imbalance between stakeholders, remove any significant authority over the information flow, and increase supply chain transparency. In the meanwhile, the records are made permanent once the data are uploaded onto the blockchain. Running the blockchain mining process will enable the immutability feature [28]. The transaction details are saved whenever a majority of miners or users decide to validate a particular transaction, and they are never modified without alerting all users [28]. The items can be traced and all information about the previous states of the items can be known. Additionally, product information, including its movement and specific certifications, may be updated and digitized, enabling authorized users to access it whenever they want [20].

Verifications are required for food goods in order to demonstrate a company's eligibility to produce or sell them. Records and documents can be digitized to reduce risks of data tampering and inaccuracies as well as time spent manually checking paper records.

IoT in conjunction with blockchain can help provide real time information of food products. By adding conditions in smart contract we can ensure that the alarm is triggered once the limits are reached , for example milk products that need to be delivered within a time span ,etc

The food supply chain is proven to be more sustainable by adopting blockchain since it operates more effectively and can target product recalls. Stakeholders will be better informed about the flow of products and be able to respond to problems more quickly when product information is updated on the blockchain at almost real-time rates. Walmart acknowledged that fresh imports like mangoes might take up to four days to be scrutinized at the border [20]. In this situation, Walmart may monitor product movements, quicken the product inspection procedure, and prolong product shelf life.

One of the main reasons for food wastes is the unintended food recall. Food items can contain a complex blend of several substances. Food recalls due to single ingredient contamination were difficult and time-consuming, necessitating a highly effective traceability mechanism.

Blockchain-based traceability makes it feasible to access necessary data, isolate items from certain suppliers, and reduce the scope of product recalls. Companies may also predict client demand more precisely using point-of-sale data, [29]. By maintaining records in blockchain platform-based water trade, Zhao et al. [30] also noted that implementing blockchain technology might result in sustainable water management.

Improved traceability: Blockchain provides a tamper-proof and transparent record of every transaction in the food supply chain, making it easier to track the origin, movement, and quality of food products. This can help to quickly identify and isolate contaminated products, reducing the risk of foodborne illnesses.

Enhanced transparency: The use of blockchain can increase transparency and accountability in the food supply chain by providing a shared and immutable record of every activity and transaction. This can help to detect and prevent fraud and unethical practices, such as counterfeiting and mislabeling.

Increased efficiency: Blockchain can automate many processes in the food supply chain, such as record-keeping and verification, reducing the need for manual intervention and saving time and costs.

Better supply chain management: Blockchain can help to optimize the food supply chain by providing real-time information on inventory, demand, and delivery, enabling more efficient planning and management.

Improved consumer trust: With blockchain, consumers can access information on the origin, quality, and sustainability of the food they consume, increasing their confidence in the food supply chain and promoting more informed purchasing decisions.

VI. CHALLENGES

The challenges observed by our review of related study papers are as follows:

Decentralization, scalability, and security cannot all be done at once, Vitalik Buterin–founder of Ethereum[31] claims; only two of the three can be obtained simultaneously [31, 32].

For instance, Bitcoin was intended to be decentralized and secure, but its scalability was compromised. The network's capacity is determined by the network's scalability. While other systems can manage transactions at a much faster rate, in the smart contract platform, 15 transactions can be treated every second. Blockchain may accomplish a high degree of decentralization and security by running the complex mining process to validate transactions and retain all transaction copies in each node. It can also lead to crowding which may lead to lagging of processes.

According to [17],globally ,the food supply chain is estimated to reach around Petabyte each year. The food supply chain is often extensive with several users participating in a single transaction.

To boost the usage of blockchain as well as preserving high security and decentralization, developers are thus still searching for a better solution. Because of issues related to scalability, Pearson et al. [17] discussed that blockchain is useful especially in the case of organic food chains.

With keeping records of transactions we can also change raw data. Third parties can find it useful by ensuring verification at regular intervals. .Supply chain entities take responsibility of their products as blockchain is immutable and authorized

For many countries the expensive application of blockchain technology can be a big challenge. Kamilaris et al. [34] found that blockchain was mostly preferred by countries who could bear the cost of establishing a blockchain network. Therefore Blockchain technology can be useful if only it is efficient and easy to use

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Blockchain is an open system which provides users all the necessary information. At the same time we also need to maintain certain policies so that some confidential details are preserved. They should cover all types of controls like the type of data that should be uploaded and who has the authority to do so.

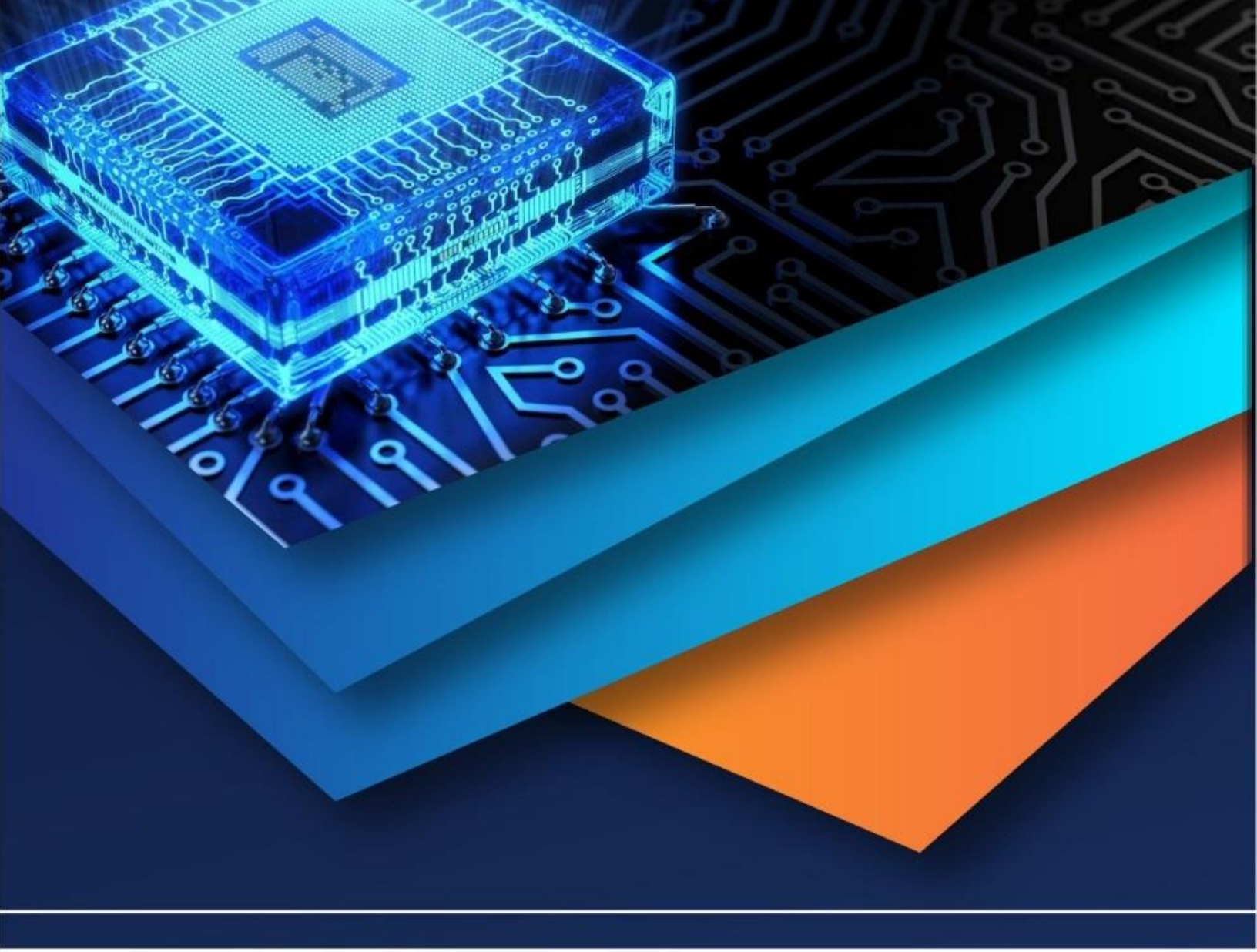
VII. CONCLUSION

This study presents an exhaustive retrospect of blockchain based food supply chains. The above mentioned papers coincided on the propitious advantages that are made available by the blockchain. Blockchain has much more to do in terms of usage in everyday life like food chains. Blockchain has the scope to bring about safety in food quality. Due to the high number of entities in any chain it can lead to crowding and inefficiency of the system. This paper provides an insight of how blockchain can revolutionize the food supplychain. It can be used in the real world to optimize applications including transactions.

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