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Blockchain for Traditional Food Traceability:

Protecting Authenticity and Provenance in Global Markets

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Abstract

Supply chain opaqueness, mislabeling, and widespread counterfeiting present new challenges for traditional food products, which are considered valuable for their cultural legacy and original production techniques, in international markets. Food deception undermines consumer trust, jeopardizes the livelihoods of genuine producers and declines the world economy every year. This paper delves into the way blockchain technology can transform the mechanisms of food traceability for safeguarding the provenance and authenticity of traditional foods in international trade.

The initial portion of the paper examines the current landscape of food deception, emphasizing the shortcomings of traditional paper-based along with strategies for centralized traceability. It investigates the manner in which the common challenges associated with establishing the authenticity of food across intricate international supply chains are addressed by blockchain's primary characteristics such as transparency and decentralized trustworthiness. The paper highlights how blockchain generates tamper-evident records from farmer to consumer by carefully investigating system design, methods of gathering data, and implementation of smart contracts.

Successful blockchain implementations and their quantifiable effects on food safety, customer confidence, and market access are demonstrated by real-world case studies from large retailers like Walmart and Carrefour as well as regional initiatives for wine, coffee and handmade items. Significant advantages are revealed by the investigation, such as quick contamination tracing, premium pricing for products which have been validated, and improved assistance for traditional small-scale producers.

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Nevertheless, the paper also carefully examines the implementation obstacles such as regulatory uncertainty, high adoption costs, scalability constraints, and challenges related to data quality. Alongside social and economic factors influencing the participation of stakeholders, technical obstacles associated with blockchain energy consumption as well as integration challenges have been assessed. This paper ends with evidence-based suggestions for industry stakeholders, policymakers, and technology providers, maintaining the authenticity of traditional foods in the international marketplace.

Keywords

traditional foods, blockchain technology, food authentication, supply chain transparency, food traceability

INTRODUCTION

The production and sale of fake or mislabeled food products which usually deceives consumers by misrepresenting quality and origin or by using inferior substitutes is known as food counterfeiting. It is different from food adulteration in which genuine products are mixed with harmful or inferior quality substances. Notable examples are diluted honey, fake olive oil, and falsely labeled organic items. There are several challenges associated with the global supply chain such as the rise of e-commerce platforms, weak enforcement in developing countries, lack of transparency and fragmented supply chains. Preventing and detecting food deception becomes more difficult due to these challenges. Strict standards have been implemented by regulatory bodies such as European Food Safety Authority (Europe), Food and Drug Administration (USA), and Food Safety and Standards Authority of India (India). Traceability is being transformed by blockchain technology by providing transparent, tamper-proof records of food products which enhances trust and accountability.[2] Food products that have

[2]Acviss | Blog, "Food Counterfeiting in the Global Supply Chain: Challenges and Solutions" (*Acviss* | Blog, December 12, 2024) <https://blog.acviss.com/food-counterfeiting-in-the-global-supply-chain/>.

been passed down since generations and made using local ingredients, time-honored recipes, along with specific methods tied to cultural or regional heritage are categorized as traditional food products. There are distinct features associated with these food products like unique flavors, methods of preparation, along with ties to geographic origin contributing to their identity and authenticity. From a cultural perspective, traditional foods help in fostering community identity, preserving heritage, and plays a crucial role in rituals and festivals.[3] From an economic perspective, they encourage artisans, local farmers, as well as small-scale producers, which enhances regional branding as well as attracts tourism. But their increasing popularity also results in their dilution and counterfeiting. Duplicate versions may bypass traditional methods or use low quality ingredients harming genuine producers and deceiving consumers. This threatens to undermine cultural heritage in addition to having a negative impact on the economy. In order to preserve the authenticity of traditional food products and ensure fair place in the marketplace, it is essential to protect them through traceability systems and certifications.

This paper's framework proceeds from identifying the issue to designing a solution, analyzing its implementation, and making recommendations regarding the future. After analyzing the scope and character of food fraud problems, we investigate how blockchain technology may help by closely evaluating system architectures along with data management strategies. Practical applications along with lessons learned are demonstrated by real-world case studies, and a critical assessment of the difficulties and restrictions offers fair

[3] Manik, Subhadip, Akshay Ramani, Reshab Majumder, Samim Hossain, and Tanmay Hazra. "Traditional Foods for Festivity: Linking Food Diversity with Socio-Cultural Aspects." *In Traditional Foods: The Reinvented Superfoods*, pp. 69-88. Cham: Springer Nature Switzerland, 2024.

insights into the possibilities and limitations of blockchain technology.

The PROBLEM LANDSCAPE: FOOD FRAUD and AUTHENTICITY CHALLENGES

Scope and Nature of Food Fraud

With an increase in e-commerce, food fraud is a major challenge for the food industry, making it easier for adulterated and counterfeit products to reach consumers. Several activities such as counterfeiting, substitution, and tampering which pose serious health risks and deceive consumers come within the scope of food fraud. For example, a research[4] examined that 69% of extra virgin olive oil purchased by stores in the U.S. failed to adhere to international standards. The long term effects of food fraud affect both brand reputation as well as consumer safety in a negative manner. Proactive measures including supplier risk assessments, solid supplier relationships, along with the implementation of technologies to identify fake internet listings are necessary for businesses in order to combat this. In addition, the HACCP system is essential for controlling hazards to food safety. Strict quality control, safe supply chain management, and legal mechanisms like patents and trademarks ought to become part of a comprehensive brand protection strategy. Additional measures to protect brand identification as well as product authenticity incorporate digital watermarking, anti-counterfeiting packaging, and internet platform monitoring. It takes a mix of technology, regulation, and rigorous supply chain monitoring to effectively prevent fraud in the food industry. In addition to protecting against fraud, a solid brand protection plan maintains customer confidence and the company's long-term

[4] UC Davis, Most imported olive oils don't match 'extra virgin' claims, study finds, Phys.org, https://phys.org/news/2010-07-imported-olive-oils-dont-extra.html

viability in the world of digital commerce.[5]

- ***Parmesan Cheese Case Study***
  The successful utilization of intellectual property (IP) and Protected Designation of Origin (PDO) status by Parmigiano-Reggiano to preserve its authenticity and market value is examined in case studies. Despite concerns from food fraud, counterfeiters, and diminishing farm succession, the producer consortium promotes rural development through conventional means and short supply chains. Studies also looks at sustainability issues, the health advantages of cheese's bioactive substances, and novel methods including using it as bank collateral. The Parmigiano-Reggiano approach, which strikes a balance between tradition and technology, emphasizes important topics in the global agri-food scene, including authenticity, supply chain resilience, rural economic support, as well as environmental effect.

- ***Olive Oil Case Study***
  Case studies on olive oil examine the industry's effects on the environment, economy, and health. Circular economy models provide sustainable solutions, particularly in Spain, whereas life cycle assessments point to the significant environmental effects of fertilizer and irrigation. The use of NMR for fraud detection and the significance of logistics for the quality of extra-virgin olive oil (EVOO) are topics covered in quality and supply chain studies. While Italian case studies highlight customer trust in family-owned firms, Spain's market leadership and climate vulnerability

[5] Kathryn Olivier and Kathryn Olivier, "The Global Problem of Fake Food" (Authentication & Anti *Counterfeiting Solutions*, October 17, 2024) <https://www.authentix.com/knowledge-center/the-global-problem-of-fake-food/>.

are important economic concerns. Other studies emphasize olive oil's cultural and therapeutic value founded in traditional practices and religious traditions, while health research linked it to a lower incidence of dementia.

Traditional Traceability Systems and Their Limitations

The ability to track the journey of a food product through all stages in the supply chain- from raw materials and additives to packaging, processing, and distribution is referred to as food traceability. During outbreaks of food-borne illness, this approach makes it possible to quickly identify the sources of contamination, which facilitates timely recalls and lowers threats to the public's health. Organizations profit from better inventory control, adherence to rules, and preservation of brand identity. Within the supply chain, traceability entails tracking both forward (customers) and backward (suppliers). Although enterprises have to maintain traceability for business-to-business transactions and submit data to enforcement agencies upon request, retailers who sell to ultimate consumers are exempt. Public safety organizations, manufacturers, supply chain partners, and consumers are important stakeholders. Food traceability increases operational efficiency, lowers fraud, and increases consumer confidence.[6]

Food traceability systems enable companies to adhere to safety regulations and carry out recalls efficiently by documenting the history and movement of products. By giving products unique codes, serialization improves tracking and customer confidence. Through the creation of a parent-child relationship that tracks the product through the supply chain, aggregation connects serialized data

[6] Vazquez Melendez, Elena Isabel, Paul Bergey, and Brett Smith. "Blockchain technology for supply chain provenance: increasing supply chain efficiency and consumer trust." *Supply chain management: An international journal* 29, no. 4 (2024): 706-730.

across packaging tiers. Additionally, traceability is used in the manufacturing of coffee, cosmetics, and pharmaceuticals, and its significance in the food industry is only likely to increase.[7]

Limitations of Traditional Traceability Systems

risks throughout the network. Im

- ***Trust Issues between Participants***
  Instead of using real-time, reliable data, traditional supply chains frequently rely on bilateral trust developed via connections and reputation, which is insufficient for intricate international operations. This dependence raises the possibility of fraud and counterfeiting since modified records and fake goods can go unnoticed due to a lack of transparency and inadequate verification procedures. Additionally, fragmented and opaque data systems restrict stakeholders' capacity to certify product authenticity and trace supply chain integrity. It becomes challenging to guarantee accountability in the absence of a cohesive and transparent structure, which escalates risks throughout the network. Improving verification and openness is crucial for contemporary, safe supply chain management.

- ***Centralized databases***
  Centralized databases provide serious security risks because they act as a single point of failure that can be compromised by hacking, tampering, or illegal access, thus jeopardizing the system as a whole. Moreover, these systems frequently lack real-time synchronization, which causes delays in data updates

[7] Damini, "Food Traceability: A Complete Guide" (*Deskera Blog*, December 1, 2022) <https://www.deskera.com/blog/food-traceability/#what-is-food-traceability>.

and makes it more difficult to track and verify in a timely manner. Traditional access control methods may also be insufficient or poorly defined, which restricts visibility and authority over user behavior. Particularly in settings where system integrity, user responsibility, and real-time data correctness are crucial, these flaws reduce the dependability and security of centralized systems. Better performance and more robust security may be provided via decentralized systems.

- ***Paper-based documentation***
  Physical documents are unreliable for long-term usage because they can be lost or damaged by fire, water, or normal wear and tear. Large paper storage also requires a lot of physical space, which can be expensive and ineffective. Furthermore, human error, transcription errors, and even possible fraud are increased when data is manually entered from paper records to digital systems. These difficulties demonstrate the drawbacks of using paper-based documentation in contemporary operations, particularly when precision, safety, and efficient utilization of space are crucial. By switching to digital systems, these risks can be reduced and overall data efficiency and reliability can be increased.

- ***Information silos and lack of interoperability***
  Since each member in a supply chain keeps distinct, compartmentalized records, the data is frequently fragmented.[8] Disjointed information is the outcome of this absence of a single system throughout the network. Data exchange becomes challenging and

[8] Henninger, Annegret, and Atefeh Mashatan. "Distributed interoperable records: The key to better supply chain management." *Computers* 10, no. 7 (2021): 89.

unreliable due to inadequate compatibility caused by poorly integrated varied systems and parties. This leads to the need for manual data re-entry or reconciliation between systems, which is time-consuming, ineffective, and prone to human mistake. These inefficiencies impair data accuracy along with decision-making in addition to slowing down operations. Simplifying data flow throughout the supply chain, minimizing the number of errors, and increasing efficiency all depend on a fully integrated, compatible system.

BLOCKCHAIN TECHNOLOGY FUNDAMENTALS for FOOD SYSTEMS

Blockchain Architecture for Supply Chain Applications

Blockchain Technology's (BCT) distinctive features, decentralization, transparency, immutability, irreversibility, autonomy, and smart contracts, offer revolutionary potential in the food supply chain. BCT increases efficiency and traceability by enabling secure data capturing and real-time tracking across numerous platforms reducing any requirement for intermediaries.[9] While ownership and provenance characteristics preserve product authenticity through distinct digital records, open-source accessibility and anonymity guarantee safe yet accessible sharing of information among stakeholders. By automating procedures and enforcing predetermined rules, smart contracts increase responsiveness and reduce the price of transactions. Improved data validation, transparency, efficiency in operations, real-time

[9] Omisola, Julius Olatunde, Damodar Bihani, Andrew Ifesinachi Daraojimba, Grace Omotunde Osho, Bright Chibunna Ubamadu, and Emmanuel Augustine Etukudoh. "Blockchain in supply chain transparency: A conceptual framework for real-time data tracking and reporting using blockchain and AI." *International Journal of Multidisciplinary Research and Growth Evaluation* 4 (2023).

responsiveness, and enhanced consumer trust are some of the benefits of BCT in the food supply chain. It guarantees the rigidity of documents, safeguards intellectual property, and permits accurate product tracking and quality control while in transit. Challenges still exist, which includes problems with energy usage, scalability, system interoperability, and connection with current infrastructure. The goal of programs like IBM Food Trust is to promote standardized and compatible technologies in order to address these issues.[10]

There are three types of BCT : private, consortium, and public blockchains. Open and completely decentralized, public blockchains are appropriate towards financial applications but come with security and scalability issues. Institutional institutions employ consortium blockchains, which are semi-decentralized and provide regulated access but have interoperability problems. Banks and other financial institutions frequently employ private blockchains, which are centrally managed, offer limited decentralization, and have a larger risk of data manipulation.

There are five primary steps in the complicated food supply chain: production, processing, distribution, retailing, and consumption. Conventional supply chains frequently rely on paper-based systems that are vulnerable to fraud and inefficiency, and they frequently lack transparency. These techniques complicate product origin tracking, which raises expenses and may pose safety hazards. Food safety is improved, fraud is decreased, and effective recalls in the event of contamination are made possible by BCT's secure, decentralized solution,

[10] Devraj V Rajput and others, "Blockchain Technology in the Food Supply Chain: A Way towards Circular Economy and Sustainability" (2025) 3 *Sustainable Food Technology* 930 <https://pubs.rsc.org/en/content/articlehtml/2025/fb/d5fb00065c>.

where every step is permanently documented and accessible. Additionally, by offering trustworthy product information, it boosts customer confidence.

Key Features relevant to Food Traceability

Blockchain is a type of digital ledger that securely, openly, and permanently records transactions. Because data added to a blockchain cannot be removed, unlike traditional databases, it is perfect for sectors like the food supply chain that demand a high degree of transparency and trust. Traceability in this sense refers to following a food product from farm to table. Farmers, processors, distributors, and retailers are all involved in traditional food supply chains, which might result in information that is lost, inaccurate, or corrupted.By establishing a digital 'paper trail' that documents each stage of the food's transit, blockchain solves this problem. A permanent and verifiable entry is instantly posted to the blockchain whenever the product is transferred. By giving a clear, unalterable record of how food products are produced, handled, and distributed, this guarantees total transparency and accountability, enhancing food safety, lowering fraud, and fostering consumer trust.[11]

- ***Real-Time Data Sharing Capabilities***: By employing intelligent sensors to collect and send real-time data on variables like location, temperature, and handling conditions, the Internet of Things (IoT) improves food supply chains. In addition, barcodes and RFID offer effective, precise tracking of individual items or batches, guaranteeing safety, transparency, and better inventory control throughout the distribution process.

[11] Tracextech and Tracextech, "Blockchain for Food Traceability | Food Safety and Transparency" (Blockchain for Food Safety, Traceability and Supplychain Transparency, July 4, 2025) <https://tracextech.com/blockchain-for-food-traceability/>.

- ***Transparency and Auditability***: Increased visibility provides a comprehensive picture of a product's route from farm to consumer, improving transparency and auditability within the food supply chain.[12] This facilitates the prompt identification of problems. Accessible, comprehensive records also facilitate simplified audits, which facilitates monitoring for producers, regulators, and consumers.

- ***Tamper-Evident Record Keeping***: Blockchain-enabled tamper-evident record keeping guarantees immutability, which means that once data is uploaded, it cannot be changed, avoiding forgeries or illegal alterations. By maintaining the correctness and validity of data across the supply chain, guarding against fraud, and guaranteeing the dependability and traceability of food items, this ensures data integrity.

- ***Decentralized Trust Mechanisms***: By eliminating the need for a central authority through the use of a distributed, immutable ledger, decentralized trust mechanisms made possible by blockchain technology promote confidence among supply chain players. Blockchain eliminates the imbalance of information by offering readily accessible, reliable, and secure data, lowering the hazards associated with inaccurate or manipulated knowledge throughout the food supply chain.

BLOCKCHAIN-BASED FOOD TRACEABILITY SYSTEMS: DESIGN and IMPLEMENTATION

By integrating smart contracts, Internet of Things (IoT) sensors, and QR codes to

[12] Astill, Jake, Rozita A. Dara, Malcolm Campbell, Jeffrey M. Farber, Evan DG Fraser, Shayan Sharif, and Rickey Y. Yada. "Transparency in food supply chains: A review of enabling technology solutions." *Trends in Food Science & Technology* 91 (2019): 240-247.

permanently record food product data, blockchain-based food traceability systems improve 'farm-to-fork' transparency. A distributed ledger to guarantee data integrity and a multi-layer architecture (user, IoT, blockchain, data, network) are important design features. Implementation often entails a public or permissioned blockchain platform, such as Hyperledger Fabric, where smart contracts automate procedures and Internet of Things devices gather high-quality data in real-time, offering a reliable, unchangeable history that can be accessed through user-friendly apps.[13]

System Architecture and Components

By dividing agricultural, processing, distribution, and retail operations into discrete tiers, multi-tier blockchain networks efficiently handle the intricacies of food supply chains while guaranteeing safe and well-structured data flow from farm to fork.[14] By confirming all parties involved; producers, processors, distributors, and retailers, identity management is essential to building confidence. Information may be shared easily because of data standardization, which guarantees consistency and compatibility across many sources.

Furthermore, in order to avoid isolation of data and to take advantage of existing infrastructure,[15] connection with business systems like ERP platforms is crucial. This will improve the overall efficacy and efficiency of the blockchain in the supply chain.

[13] Ashish Singh and others, "Redefining Food Safety Traceability System through Blockchain: Findings, Challenges and Open Issues" (2022) 82 *Multimedia Tools and Applications* 21243 <https://doi.org/10.1007/s11042-022-14006-4>.

[14] Yadav, Sanjeev, Sunil Luthra, and Dixit Garg. "Modelling Internet of things (IoT)-driven global sustainability in multi-tier agri-food supply chain under natural epidemic outbreaks." *Environmental Science and Pollution Research* 28, no. 13 (2021): 16633-16654.

[15] Banerjee, Arnab. "Blockchain technology: supply chain insights from ERP." In Advances in computers, vol. 111, pp. 69-98. Elsevier, 2018.

Smart Contracts for Automated Compliance

By carrying out predetermined rules for quality control, payments, fines, regulatory monitoring, and dispute resolution, smart contracts within blockchain-based food traceability automate compliance. When parameters like temperature or freshness are satisfied, they initiate automated quality checks and provide tamper-proof records due to their integration with IoT sensors.[16]

When checkpoints are successfully completed, payments are released automatically; if requirements are not met, penalties or recalls are instituted. These contracts lower the risk of breaches by enforcing regulatory compliance in real-time. By automating procedures and providing verifiable audit trails, their clear, unchangeable records serve as a trustworthy source of truth, reducing conflicts and streamlining settlement while boosting productivity and confidence throughout the supply chain.

CASE STUDIES: SUCCESSFUL BLOCKCHAIN IMPLEMENTATIONS

Walmart's Food Traceability Initiative

In response to a fatal E. coli incident in 2018, Walmart started a blockchain-based Food Traceability Initiative for leafy greens with the goal of cutting trace-back times from weeks to seconds. In order to increase openness and facilitate the quick identification of tainted items for recalls, Walmart partnered with IBM Food Trust to require suppliers to upload product data onto the blockchain. The program mandated that suppliers adopt full end-to-end traceability by September 2019 and one-step back traceability by January 2019. The main accomplishment

[16] Shahzad, Inzamam, Muhammad Wajid Maqsood, Sadia Latif, and Hafiz Muhammad Ijaz. "Decentralized Iot-Based Architectures For Tamper-Proof Agricultural Sensor Networks: Ensuring End-To-End Data Integrity And Transparent Governance." Kashf *Journal of Multidisciplinary Research* 2, no. 05 (2025): 39-55.

was significantly accelerating the trace-back procedure, which is essential for reducing waste and safeguarding customers.[17] Problems with supplier engagement, data integration, and expenses were discovered during implementation, particularly for smaller suppliers who found it difficult to embrace new cloud-based technologies. Digitization initiatives were further complicated by the fact that many supply chain partners continued to use paper records.

Walmart understood that investing in staff training and supplier cooperation was crucial to solving challenges; technology alone was not enough. Although the project showed how blockchain may improve food safety and transparency, implementing it throughout the entire food supply chain is still difficult and requires constant cooperation and funding. All things considered, the project demonstrated how crucial it is to integrate organizational, human, and technological elements in order to accomplish significant supply chain transformation.

Italian Wine Provenance Tracking

Analytical chemistry and digital technology are used in Italian wine provenance tracing to guarantee quality and authenticity. NFC/RFID smart labels and QR codes connected to blockchain ledgers are examples of digital techniques that give customers an unchangeable, transparent record of a wine's path from farm to bottle. Customers can establish trust and discourage counterfeiting by scanning these labels to obtain comprehensive information about the wine's provenance, certifications, production methods, and farming methods.

[17] Tang, Jiaohui. "Applications of blockchain technology for enhancing traceability and food safety management in the beef supply chain." *Emirates Journal of Food and Agriculture* 37 (2025): 1-20.

By scientifically confirming the wine's provenance and validity, analytical methods supplement digital tracking. While isotopic and metabolomic tests identify distinct stable isotope patterns and identify adulterations like water or added sugars, multi-elemental analysis uses instruments like ICP-MS to quantify soil and wine components. These techniques give the vineyard's terroir a fundamental 'fingerprint'. The accuracy of origin tracing is increased when these investigations are combined with sophisticated statistics.

Provenance monitoring is used to ensure quality standards, prevent counterfeit goods, verify authenticity, and promote the 'Made in Italy' label.[18] By ensuring authentic Italian wine, transparency in production and provenance builds customer trust, safeguards Italy's wine reputation, and adds value. A strong system that protects the integrity of Italian wines on the international market is produced by combining scientific and digital methods.

BENEFITS & VALUE PROPOSITION

Due to its numerous advantages that go beyond food safety, food traceability is becoming more and more important in developing and impoverished nations. By demonstrating product safety during food accidents, traceability helps safeguard local businesses, such as seafood in Indonesia or mango cultivation in India, maintaining economic stability and the nation's reputation. In order to maintain justice and legality from farm to consumer, it also fights against illicit activities like overfishing, supply chain fraud, and corruption.

Food products that are counterfeit endanger the health of consumers as well as the integrity of the brand.Systems for traceability offer accountability and visibility, assisting in confirming the

[18] MATARAZZO, Agata, Salvatore INGENITO, Grzegorz SUWALA, and Massimo Riccardo. "Avoiding Wine Counterfeiting Using Blockchain Technology: A Proposal For Application." *QFFQ* 2024 (2024): 119.

provenance and authenticity for both high and low-value goods. Improved traceability has even improved labor conditions and reduced linked criminal activity in industries like illicit fishing, which is in line with the ethical sourcing criteria that international customers want. Through facilitating access to global markets and encouraging home consumption along with pride in products made in the region, traceability promotes economic development. Traceability is the only reliable indicator that a product satisfies the growing demands of customers around the world for locally sourced, sustainable, and organic foods. Three categories include the business benefits of traceability: risk mitigation, market access, and operational efficiency.

Operationally, traceability increases inventory accuracy, decreases spoilage, expedites workflows, and strengthens supply chain management. Improved consumer confidence, improved brand reputation, and compliance with international trade rules all contribute to improved market access. Reduced insurance and liability expenses, speedier and more precise recalls, and a quicker recovery from interruptions are all examples of risk mitigation.[19] Traceability provides businesses with easier worldwide compliance, better upstream/downstream data flows, and more accurate inventory visibility, all of which are essential for prompt decision-making as well as demand planning. Additionally, it streamlines product return procedures and cuts down on wasteful expenses brought on by wrongfully identifying the causes of issues. Traceability has the potential to improve agricultural, environmental, along with governance systems in developing nations, particularly. It promotes domestic consumption, makes it easier to export legal food, and

[19] "Benefits of Food Traceability" Food Safety (March 7, 2016) <https://www.food-safety.com/articles/4192-benefits-of-food-traceability>.

expands access to cash. They can avoid having to start from scratch by implementing established frameworks from wealthy countries. Traceability is more than just a legal necessity; it is a strategic investment. It improves supply chains, encourages fair labor, boosts economies, supports food safety, and satisfies customer wants. Traceability is crucial for safe, effective, and sustainable food systems for both regional producers and multinational enterprises.

THE WAY AHEAD

The Global Food Traceability Center has highlighted a number of important obstacles to the effective deployment of food traceability. The fact that customer preferences are changing so quickly is one of the main problems. In addition to being extremely sensitive to product recalls and having their confidence quickly undermined, modern customers expect immediate access to correct information. Real-time traceability is even more important because social media magnifies the impact of any food safety event. Regulations vary and overlap over the world, especially when it comes to allergies, the use of pesticides, and other aspects of food safety. Compliance is made more difficult by these disparate rules, particularly for businesses that get materials from several nations and time zones. Furthermore, food theft and replacement for financial gain remain worldwide issues. The lack of standardized systems and consistent traceability criteria is a significant technological barrier. A lot of internal systems in the food chain are unable to track data quickly and accurately. The provided data is frequently not prepared for prompt decision-making and is challenging to examine. Sector-specific traceability standards may differ significantly. For example, tracking in agriculture involves pesticide or veterinarian data and begins at planting or animal birth. Whereas the emphasis in retail and catering is mostly on receipts and invoices, traceability in

manufacturing tracks ingredients through processing and distribution. When products are separated for smaller shipments, thorough records, including lot/batch IDs, are crucial since product commingling during transportation and logistics might spread contamination.[20]

The absence of thorough and easily accessible records is another enduring problem. The complexity of food products makes manual record-keeping unreliable. Human error, delays, and sluggish trace-back capabilities are all problems with paper-based systems. The transition to electronic data management is necessary for scalability, accuracy, and speed. Another obstacle is still technical infrastructure, particularly for small and mid-sized businesses. Although inexpensive software solutions are available, emergency responses are slow and ineffective due to a lack of system interoperability, which makes it difficult to share or compare data across platforms. Nevertheless, technology is not the obstacle in and of itself. There are efficient traceability solutions in place; the secret is to increase supply chain uniformity, integration, and accessibility. Through effective and responsive traceability systems, these problems must be resolved in order to improve food safety, safeguard the public's health, and foster customer confidence.

CONCLUSION

Blockchain technology is emphasized in this chapter as a game-changing instrument for preserving the provenance and authenticity of traditional foods in international marketplaces. It fills in important holes in traditional food traceability systems by utilizing blockchain's fundamental qualities, which include immutability, transparency, and decentralized trust. Throughout the food supply chain, the technology makes it possible to create tamper-proof records, providing robust security against food fraud and enabling

[20] https://www.who.int/india/heat-waves

genuine producers, especially small-scale and artisanal ones, to access premium markets.

In addition to regional initiatives involving wine, coffee, and artisanal goods, real-world case studies from large retailers like Walmart show observable advantages like increased supply chain transparency, faster traceback times, and increased consumer trust. To guarantee dependability and efficacy, however, issues like exorbitant expenses, restricted scalability, and data quality issues must be addressed strategically.

The potential consequences for interested parties are extensive. While merchants can use blockchain to enhance food safety and customer engagement, traditional food producers can use it to safeguard their legacy and brand. Increased awareness of food production methods and sources benefits consumers. Legislators are urged to foster the adoption of blockchain technology by creating standardized standards that enable international trade and regulatory enforcement easier. Furthermore, fair trade, sustainability, and the tenacity of traditional farming communities are all supported by blockchain. Blockchain is reaching a turning point in its development, progressing from research endeavors to possible widespread use.

Current constraints like interoperability and scaling may be addressed by emerging technologies like artificial intelligence (AI), the Internet of Things (IoT), and consortium-based blockchains. Future blockchain food traceability success will rely on cooperative initiatives that balance socioeconomic factors with technological advancement. In the end, blockchain provides not only technology innovation but also a calculated way to assist sustainable agriculture, protect cultural heritage, and guarantee fair rewards throughout international food supply networks.