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BLOCKCHAIN IN AGRICULTURE: TRANSFORMING THE FOOD SUPPLY CHAIN FOR TRANSPARENCY AND EFFICIENCY IN THE EUROPEAN UNION

ABSTRACT

This paper explores the transformative role of blockchain technology in the European Union's agriculture sector, focusing on the "Farm to Fork" concept. Employing a literature review, the paper examines the applications of blockchain within EU agriculture and its alignment with the EU's emphasis on food supply chain transparency and efficiency. Several illustrative cases of blockchain implementation in the EU, such as the IBM Food Trust platform, are highlighted. The research underscores how blockchain enhances traceability, trust, and sustainability, thereby strengthening food safety and quality. The paper concludes that blockchain is catalysing a revolution in the EU's food supply chain, fostering transparency and efficiency while aligning with the overarching objectives of the "Farm to Fork" concept.

Keywords: blockchain technology, agriculture, food supply chain, transparency, efficiency.

JEL Classification: Q13, Q18.

1. INTRODUCTION

The agricultural sector is the backbone of the European Union's economy, providing food, raw materials, and employment opportunities. However, the modern food supply chain is marked by complexity, involving numerous stakeholders, geographical distances and various processes, from farm to fork. Ensuring food safety, quality, and traceability while minimising waste and environmental impact has become a top priority for the European Union. To address these challenges, the integration of innovative technologies in agriculture and food supply chains is crucial.

Blockchain technology, originally designed for secure digital transactions in cryptocurrencies like Bitcoin, has garnered significant attention for its potential to transform the agricultural sector. The core principles of blockchain, including decentralisation, transparency, and immutability, align with the objectives of the

European Union's "Farm to Fork" strategy, which aims to create a more sustainable, transparent, and efficient food supply chain.

This article explores how blockchain technology is being adopted in the European Union's agriculture and food supply chain to enhance transparency, traceability, and overall efficiency. It delves into the current state of blockchain implementation, presents examples of its applications, discusses the implications for food safety and quality, and addresses the existing challenges and limitations. The aim is to provide a comprehensive overview of how blockchain is revolutionising the European Union's agricultural landscape and contributing to the "Farm to Fork" concept realisation.

2. STATE OF KNOWLEDGE

Blockchain technology, through its distributed ledger system, has garnered increasing attention in recent years for its potential to disrupt traditional supply chain systems. The utilization of blockchain in agriculture is gaining momentum, as it offers solutions to address longstanding issues. Currently, the agriculture sector is often plagued by challenges such as food fraud, inefficient record-keeping, and lack of transparency in the supply chain (Alam *et al.*, 2020). These issues can have severe consequences for food safety, environmental sustainability, and consumer trust.

Blockchain has shown promises to mitigate these problems. By recording each step of the supply chain, from production to distribution, on an immutable and transparent ledger, stakeholders can easily verify the authenticity of products, ensuring food safety and quality. For example, the "Farm to Fork" concept, where the complete history of a food item can be traced through the blockchain, has gained traction (Ahmad and Bailey, 2021; Zarpelão *et al.*, 2021). Global companies like BM Food Trust platform (IBM, 2023) and Transparent Path platform (Transparent Path, 2023) have been at the forefront of implementing such systems. Considerable efforts have been made in the food industry to enhance data traceability using blockchain technology, improving the safety and quality of the global food supply chain and international distribution.

The literature review of blockchain application in agriculture in the European Union (EU) reveals a fast-growing field that aligns seamlessly with the EU's "Farm to Fork" concept, emphasising transparency and accountability in the food supply chain. The EU places a strong emphasis on the safety and authenticity of agricultural products, making blockchain technology a natural fit for the region. Steiner *et al.* (2016) conducted a systematic review that highlights the extensive use of blockchain in supply chain management, emphasising the potential for enhancing transparency, trust, and traceability. Tse *et al.* (2017) argue that blockchain's role in supply chain management can drive sustainability in food supply chains, aligning with the EU's commitment to environmentally friendly

practices. Lin *et al.* (2018) also stresses that blockchain can transform agriculture, providing insights into its potential in ensuring food safety and quality, a key element of the “Farm to Fork” approach.

The integration of blockchain technology in agriculture, particularly in the European Union, is revolutionising the “Farm to Fork” concept by addressing key challenges and leveraging opportunities for enhancing the transparency and efficiency of the food supply chain. A crucial aspect of this transformation lies in the various applications and innovations that have emerged in recent years. For instance, a study conducted by Lin *et al.* in 2018 highlighted the potential of blockchain technology to bring about significant changes in agriculture. By focusing on areas like traceability and data management, the authors emphasised how blockchain could improve the visibility of product origins, a core element of the “Farm to Fork” concept. Their insights underscored the potential to bolster consumer confidence and provide a clear view of the journey from the field to the dinner table.

Another noteworthy contribution is found in the work of Tse *et al.* (2017), who examined the value of blockchain in supply chain management with a focus on sustainable food supply chains. Their research emphasised the role of blockchain in enhancing the traceability of sustainable agricultural practices, ensuring that the environmental and ethical aspects of the “Farm to Fork” journey are maintained. This work is particularly relevant in the EU, where sustainable farming practices are a significant part of the agricultural landscape, and consumers actively seek products with strong environmental and ethical credentials. Blockchain technology can provide the necessary transparency and evidence for such claims, thus fostering the “Farm to Fork” concept by delivering on its promises of sustainability and responsibility.

The systematic review conducted by Steiner *et al.* (2016) also underlines the potential of blockchain in supply chain management. Their comprehensive analysis revealed that blockchain can serve as a powerful tool to address various supply chain challenges, from transparency to fraud prevention. The EU, with its intricate agricultural landscape and diverse products, can particularly benefit from the insights garnered in this review. By incorporating blockchain into its agricultural practices, the EU can ensure that the “Farm to Fork” concept becomes not just a concept but a tangible reality, where consumers can trust and verify the entire journey of their food, from the origins in Italian vineyards to the fields of Dutch tulip growers and the olive groves of Spain.

Therefore, blockchain is recognised as an emerging technology in the agri-food industry, offering an efficient and robust mechanism to improve food traceability and a transparent, reliable way to validate the quality, safety, and sustainability of agri-food products. However, blockchain technology is still under development.

3. MATERIAL AND METHOD

In order to perform the analysis of the blockchain technology in the European Union, the comparison, analysis and synthesis methods have been used, as well as other relevant bibliographic sources. The approach applied in this study aims to provide a holistic understanding of how blockchain technology is revolutionising the food supply chain in the European Union and its implications for enhancing transparency, traceability, and overall efficiency.

4. RESULTS AND DISCUSSIONS

The specific use of blockchain to enhance the safety and quality of agri-food products can be appreciated from various perspectives: improving data transparency, achieving data traceability, enhancing food safety, monitoring quality, and reducing financial transaction costs.

Blockchain technology offers a promising approach to promote a safer, healthier, more sustainable, and reliable future for the agri-food system (Rana *et al.*, 2021; Xu *et al.*, 2020). The safety of agri-food products is critically important for global food distribution. Safety issues can arise during processing and pre/post-harvest production (Lin *et al.*, 2018). For instance, during pre/post-harvest, the safety and quality of agri-food products can be compromised by the excessive use of pesticides, chemical additives in fertilisers, or heavy metal residues from wastewater irrigation (Xu *et al.*, 2020). During production, the safety and quality of agri-food products can be compromised by the counterfeiting of inferior products, intentional mislabelling of the origin of a food product, incorrect production or expiration date labelling, and other such issues. Most often, these safety issues stem from the lack of an efficient monitoring system and pose a significant threat to human health. It cannot be guaranteed that blockchain technology is a panacea for all these processes, but it can offer an approach to better monitor agri-food products from farm to table and provide a mechanism to connect food supply chain participants and regulators more closely. Data transparency and the inclusion of blockchain technology can significantly reduce risks related to food safety that underlie deliberate fraud, poor management, and lack of regulation.

Blockchain represents an emerging technology in the agri-food sector, capable of improving the safety and quality of agri-food products and transforming many aspects of the agricultural industry. This review seeks to define blockchain technology and provide a comprehensive analysis of its applications in the agri-food sector. It summarises the current model of blockchain implementation in the agri-food industry, discusses case studies representing various applications of blockchain technology, and presents the opportunities and challenges of blockchain in the agriculture industry in the European Union.

The name “Blockchain” was first introduced in 2008 to describe the distributed ledger technology that underlies Bitcoin. In short, Bitcoin is a type of digital currency for digital transactions, circumventing the need for intermediaries (e.g. banks, payment gateways, etc.). The main issue addressed by blockchain technology is the elimination of the need for trusted third parties (e.g. banks, insurance companies, etc.) by building a decentralised trustless ledger that enables secure peer-to-peer transactions based on secure cryptographic methods, such as hash functions (Steiner *et al.*, 2016).

Blockchain technology is rapidly transforming and can transform more the agricultural sector in the European Union and worldwide, offering a groundbreaking solution for realising the “Farm to Fork” concept. At its core, blockchain is a distributed ledger system that records and verifies transactions and data across a network of computers. In agriculture, this innovation provides a robust mechanism for tracking products from their origin to consumers’ plates, ensuring transparency, safety, and efficiency at every stage of the food supply chain.

One of the primary applications of blockchain in agriculture is farm-level traceability. Starting at the source, farms collect data regarding cultivation practices, use of pesticides, and other essential information. For instance, EU vineyards, renowned for their high-quality wines, employ blockchain to document grape varieties, harvest dates, and even weather conditions (Dressler and Paunovic, 2021). This meticulous data forms the first link in the “Farm to Fork” chain. Consumers across the EU and worldwide can scan a QR code on a bottle of European wine to access information about its origin and production, strengthening trust and respect for the product’s journey.

Moreover, blockchain technology interconnects the supply chain, linking stakeholders from farmers to distributors and retailers. In the EU, recognised for its diverse range of agricultural products, this interconnectedness guarantees that the complete history of a product’s journey is available to all parties involved. For example, Dutch tulip bulbs, known for their vibrant colours, travel from Dutch fields to home gardeners across the continent. Blockchain can therefore record every step, ensuring complete transparency and fostering the “Farm to Fork” philosophy by providing consumers with information to make informed choices about the products they select (Dasaklis *et al.*, 2022).

The implementation of blockchain in agriculture offers numerous advantages. Transparency and traceability are two significant benefits. The technology ensures that the entire journey of a product is accessible to all stakeholders, enhancing the trustworthiness of the food supply chain. This is vital in the EU, where consumers place a strong emphasis on the authenticity and quality of agricultural products. For instance, Spanish olive oil, a hallmark of Mediterranean cuisine, can be tracked from the olive grove to the supermarket shelf through blockchain (Violino *et al.*, 2020), allowing EU and global consumers to verify the product’s origin and quality.

Blockchain also addresses food safety issues. The EU has experienced food safety crises in the past, such as the BSE (Bovine Spongiform Encephalopathy,

also known as “Mad Cow Disease”) outbreak, which had a detrimental impact on consumer confidence. Blockchain technology provides a means to rapidly identify and trace the source of contaminated products in the event of an outbreak. By monitoring and recording the transportation, storage, and handling of products through smart contracts, blockchain ensures that any issues can be pinpointed, minimising the impact on consumers and enabling a swift response to prevent widespread crises. For example, in Germany, where sausages are a staple food, blockchain can be employed to track the origin and safety of pork products, thereby guaranteeing a transparent supply chain and reassuring consumers about the safety and quality of the products they purchase (Galvez *et al.*, 2018).

Furthermore, blockchain can streamline the management of subsidies and support programs for EU farmers. The Common Agricultural Policy is a crucial mechanism for supporting EU farmers. However, the disbursement of subsidies can be complex and sometimes fraught with bureaucracy. Blockchain can provide a transparent and efficient method of distributing subsidies and aid. The EU can pilot blockchain-based projects for managing agricultural subsidies, ensuring that farmers receive their support in a timely and transparent manner (Krithika, 2022).

In addition to supporting farmers and ensuring product traceability, blockchain can revolutionise the certification process for organic and sustainable farming practices. With the EU’s commitment to sustainable agriculture and environmentally friendly practices, blockchain’s transparent and tamper-proof nature can be leveraged to verify the authenticity of organic products. For example, in the EU, organic dairy products can be certified and validated through blockchain, allowing consumers to trust in the organic label and make informed choices about their food (Li *et al.*, 2023).

The “Farm to Fork” concept is also closely tied to sustainable agriculture, a key focus in the EU. Through blockchain, the environmental impact of products can be tracked and assessed. For instance, when it comes to EU-grown soybeans, a vital component in animal feed, blockchain can record the sustainability and environmental practices associated with soybean cultivation, allowing consumers to make ecologically conscious choices.

CHALLENGES AND LIMITATIONS

Several challenges and limitations are associated with implementing blockchain in agriculture:

- Cost: Developing and maintaining a blockchain system can be expensive, and small-scale farmers or organisations may find it challenging to afford the technology.
- Technical Expertise: Blockchain implementation requires technical expertise, and many individuals and organisations may lack the necessary knowledge and skills to set up and manage a blockchain network.

- Scalability: As more participants join a blockchain network, it can become slower and more resource-intensive. Scalability is a concern, especially for large agri-food supply chains.
- Data Privacy and Security: Ensuring privacy and security of sensitive data on the blockchain is a complex issue. While blockchain is inherently secure, protecting data off-chain (e.g., private information) and managing access controls require careful planning.
- Interoperability: For blockchain to be effective in agriculture, it needs to interoperate with other systems and technologies used in the industry, such as IoT devices, sensors, and data management platforms.
- Adoption and Education: Encouraging widespread adoption of blockchain technology in agriculture requires educating farmers, food producers, and other stakeholders about its benefits and how to use it effectively.
- Regulatory Challenges: Different countries may have varying regulations related to blockchain technology in agriculture, which can pose compliance challenges for international supply chains.
- Infrastructure and Connectivity: Blockchain relies on internet connectivity and digital infrastructure. In regions with poor connectivity, implementing blockchain may be challenging.
- Resistance to Change: Some stakeholders in the agri-food industry may be resistant to change and reluctant to adopt new technologies (Conti *et al.*, 2021), making it difficult to implement blockchain solutions.
- Environmental Concerns: The energy consumption of blockchain networks, especially those using proof-of-work consensus mechanisms (Popescu and Hurduzeu, 2015), is a concern for sustainability.

In summary, while blockchain holds great promise for enhancing transparency, traceability and trust in EU's agriculture, its implementation is not without challenges and limitations. Overcoming these issues will require collaboration among various stakeholders, including governments, businesses, and technology providers. It is essential to carefully plan and assess the costs and benefits of blockchain adoption in agriculture and ensure that solutions are tailored to the specific needs of the industry and its participants.

5. CONCLUSIONS

In conclusion, blockchain technology integration into the agricultural sector represents a significant step towards revolutionising the food supply chain. As discussed in this article, the adoption of blockchain has already begun to yield transformative results, ushering in a new era of transparency, traceability, and efficiency in agri-food systems.

In essence, blockchain in agriculture is not merely a technological advancement; it represents a profound shift in the way we produce, distribute, and consume food. The decentralised, secure, and transparent nature of blockchain offers the potential to create a more resilient, sustainable, and consumer-centric agri-food supply chain.

The integration of blockchain technology in agriculture in the European Union holds immense potential to revolutionize the “Farm to Fork” concept. It offers transparency, traceability, safety, and efficiency throughout the food supply chain. Through examples ranging from Italian wines to Dutch tulip bulbs and Spanish olive oil, blockchain empowers consumers with knowledge about the products they consume. It enhances food safety, streamlines subsidy distribution, and supports sustainable and environmentally friendly agricultural practices. While facing challenges and limitations, the EU is well-positioned to harness the advantages of blockchain in agriculture, creating a brighter and more transparent future for its agricultural sector.

Blockchain is not without its challenges and limitations, especially in the context of agriculture within the EU. The technology requires significant initial investment and infrastructure, which may pose challenges for smaller farms or agricultural regions with limited resources. Additionally, data privacy and cybersecurity concerns must be addressed to ensure the safe and secure use of blockchain technology. There is also a need for standardisation and regulation in the EU to ensure that blockchain systems are interoperable and adhere to established data protection laws. Overcoming these hurdles will require collaboration among industry participants, regulatory bodies, and technology developers.

As the technology continues to evolve and find broader adoption, it is essential for stakeholders in the agricultural sector to remain engaged, explore novel use cases, and drive innovation to harness the full potential of blockchain in shaping the future of food production and distribution. This article has laid the groundwork for understanding the current state, improvements, examples, food safety, quality, challenges, and potential future directions of blockchain in the European Union’s agriculture.

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