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USING BLOCK CHAIN FOR SEED TRACEABILITY: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

This systematic review of the literature critically looks at the application of blockchain technology for seed traceability systems. Seed traceability is essential for assuring the authenticity and integrity of seeds. The immutable, decentralized, and transparent characteristics of blockchain technology make it a promising solution from production to consumption to the problems with conventional seed traceability techniques. This paper propose to summarise the research on block chain traceability of seeds and the industry practices through an extensive search of peer reviewed articles, academic databases , conference papers and reports published by the industry during the time period of year 2018 to 2024.

The research paper highlights the key themes, technological approaches and implementation strategies used in the blockchain implementation for seed traceability, emphasizing both the advantages and disadvantages. The study aims to address various subjects, including the architecture and design of blockchain-based seed traceability systems, consensus-building techniques, data security and integrity protocols, regulatory frameworks, and obstacles like scalability and adoption. This review attempts to identify research gaps, offer recommendations for future studies and useful implementations, and offer insights into the current state of blockchain technology in seed traceability through a critical analysis of the literature.

Keywords: Systematic Literature Review, Blockchain, Seed Traceability, Seed Supply Chain, Seed Quality

1. INTRODUCTION

1.1. BACKGROUND AND SIGNIFICANCE OF SEED TRACEABILITY

Seed traceability is the ability to trace and track seeds' source, quality, and distribution throughout the supply chain, safeguarding transparency and dependability for farmers and consumers. This process uses technologies such as blockchain, RFID, and deep learning to assess seed quality, classify seeds, and offer data regarding seed origins [1][2][3]. Implementing seed screening and casing traceability systems improves seed sorting accuracy and precision while also allowing for seed source tracing [4]. Furthermore, a method for coding plant seed information allows for the tracing of parental generations of experimental seeds used in plant genetics and breeding experiments, resulting in comprehensive data on seed origin and features [5].

Seed traceability has become increasingly important in agricultural sectors due to a variety of factors. Grain producers and handlers have adopted traceability systems to guarantee quality, safety, and global market business competitiveness [1]. These systems include evidence that traces raw materials back to the farm, allowing for the

identification of sources and the tracking goods throughout the production and distribution chains [6]. The use of technologies such as blockchain, deep learning, and digital labeling has transformed seed traceability, enabling seed quality monitoring, origin verification, and effective seed information management in both production and distribution processes [2][5][7]. The adoption of traceability systems by food producers and operators, driven by global market competitiveness and food safety concerns, points out the importance of monitoring raw materials back to the farm, as mandated by regulations such as US Food Safety Modernization Act [5] and EC regulation 178/2002 . Integrating RFID and handheld devices for agricultural traceability enables vendors to monitor seed usage, convey feedback to cultivators, and analyze data to improve customer networks [7].

1.2. BLOCK CHAIN TECHNOLOGY

Blockchain technology is an innovation that has drawn a lot of interest from a variety of industries because of its potential to change how businesses operate and interact [8][9][10]. It works as a distributed system of ledgers that applies cryptography to guarantee safe, open, and decentralized transactions, doing away with the need for middlemen. The technology makes it possible for transactions to be documented as a series of blocks, resulting in an unchangeable and private network for data exchange. Blockchain has advantages, but before it is widely used, to determine issues like security and scalability. Applications of the technology can be seen in financial services, reputation systems, Internet of Things (IoT), and other areas, demonstrating its adaptability and potential to completely transform a number of industries. People and organizations with an interest in utilizing blockchain technology must comprehend its architecture, protocol for consensus, and emerging trends.

1.3. RATIONALE OF IMPLEMENTING BLOCKCHAIN FOR SEED TRACEABILITY

According to several research studies, the decentralized, transparent, and tamper-proof features of blockchain technology make it an attractive option for seed traceability. Data loss, tampering, and privacy flaws are common with traditional centrally managed traceability systems [11][12]. The quality and safety of agricultural products can be guaranteed by significantly improving the traceability results' reliability through the utilization of blockchain, a distributed and transparent platform [13]. Additionally, information islands, big companies privacy data loss vulnerabilities, and inadequate information queries can all be resolved by utilizing blockchain technology in seed traceability systems. This will ultimately result in a safe and effective way to track seeds from their point of origin to the final user [12][13].

1.4. RESEARCH GAP

Research on seed traceability identifies important gaps in the agriculture sector and highlights the necessity for open systems to track seed distribution and ensure the quality of seeds that cultivators plant [14] [15] [16]. The market is overrun with fake and inferior seeds as a result of inadequate seed quality verification procedures, which lowers farmer incomes and reduces agricultural productivity [5]. Farmers can track the provenance of seeds and validate their quality by utilizing deep learning algorithms like Convolutional Neural Networks in conjunction with blockchain technology. This improves the transparency and reliability of the seed supply chain [17]. Furthermore, the security and accuracy of tracking grain consignments from end to end of the supply chain are improved by the use of traceability codes and RFID technology in grain supply chains, guaranteeing food security.

In addition the absence of reviews concentrating on blockchain technology's utilization in the agriculture sector, specifically in seed traceability systems, represents another research gap in the use of blockchain for seeds traceability [18]. Information loss and data manipulation are two issues that plague the centralized traceability systems currently in place in agri-food supply chains, underscoring the necessity for a quick and reliable way to obtain crucial data about food items [19].

A decentralized, transparent, immutable, and dependable system can be created by integrating blockchain technology with traceability systems, improving data monitoring in real time and making decisions in seed traceability [20]. In addition to improving agri-food supply chain management, putting blockchain-based traceability systems into place helps reduce food loss, improve food safety, and align with the SDG (Sustainable Development Goals) of the UN [21].

The study of seed traceability using blockchain technology has revealed a number of gaps in the body of knowledge. A small number of reviews explicitly address the traceability on the basis of block chain for agricultural products, despite the growing number of blockchain applications in agri-food supply chains [18]. Moreover there does not exit any systematic literature review on using block chain technology for seed traceability. Therefore filling this research vacuum and gathering all pertinent study findings are imperative.

On seed traceability using block chain technology and to identify the important areas of seed traceability and block chain technology. This research combines two important areas of block chain technology and application of block chain technology for seed traceability.

The research questions or objectives addressed in the study:

- **Research Objective 1:** To study the present status of seed traceability.
- **Research Objective 2:** To arrange numerous themes for application of block chain technology for seed traceability over a conceptual framework?
- **Research Objective 3:** To identify key research areas and emerging trends for seed traceability.

2. SYSTEMATIC LITERATURE REVIEW: THE METHODOLOGY

With the goal of identifying gaps in the research study through literature and recommending scope for future research, a systematic literature review (SLR) is a technique used to provide an exhaustive and unbiased summary of the body of knowledge currently available on a given subject. [22]. Thorough planning, comprehensive data gathering, and methodical examination are required to support policy formation on the basis of evidences collected, recommend guidelines, and facilitate decision-making process in a variety of domains, including education, psychology, social sciences and healthcare. Planning, conducting, and reporting are some of the phases in the process. Bibliographic indicators, keyword analysis, and citation analysis are some of the methods used for analysis and article selection [23]. Systematic and rigorous approaches to research (SLRs) are important tools for professionals, academics, and decision-makers who are examining the current state of knowledge in a particular field. They highlight the importance of these procedures.

The five steps suggested by [24], a generally established approach, are used in this investigation. The steps (Fig. 1) which were taken on and followed in the sequence are as follows:

Step 1: Identify objectives of the Research

The purpose of this study is to provide an organized overview of the literature on the application of blockchain technology to seed traceability. The preceding section outlines and discusses the three research objectives.

Figure 1

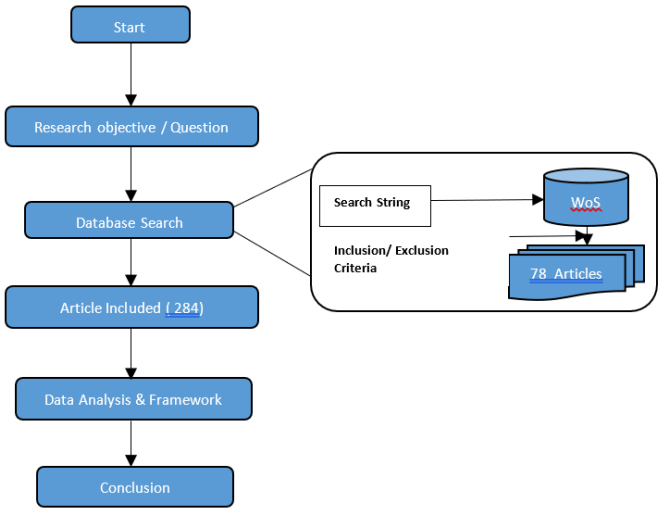

Figure 1 Flowchart for Systematic Literature Review

Step 2: Database search with a query:

Finding the database containing pertinent research papers using a search string the researcher has created is the next stage in the systematic literature review. The research on using blockchain technology for seed traceability is examined in this study. The Web of Science (WoS) database was chosen because it contains excellent research publications on a wide range of topics, particularly the emergent ones, and is appropriate for technology-related investigations. WoS is therefore frequently the primary option for research that are based on literature reviews. With the aid of the literature, search strings were created. Specifically, keywords related to seed traceability through Blockchain technology were initially determined. The string is then created as a result of the insertion of terms like "Block chain."

(Blockchain OR Block Chain) AND "Seed Traceability"

In May 2024, the databases were searched using the aforementioned string, producing 284 research articles as a result. The titles, abstract, and keywords were the only things included in the very initial search. The search in WoS database was conducted from January 2018 to May 2024.

Step 3: Inclusion / Exclusion criteria for further analysis

The abstract of each and every research article from the result of WoS database and Scopus is thoroughly viewed and assessed for relevance for getting included in the study. The research article not related to block chain and seed traceability were excluded. The book chapters, discussion articles and non-refereed research papers are also excluded as the peer reviewed research papers are considered most valid [25]. Out of 284 research article list produced by data base search, 78 articles are included for further study and analysis. By carefully following established exclusion criteria and accounting for researcher bias in selection, validity was attained. To enhance understanding, a graph representing the number of research papers related to the topic under investigation is created on the timeline of research papers. It can be noticed from Fig 2 that May 2024 has 8 contribution till the month of May.

Step 4: Analysis and Compilation

The primary objective of [36] is to ensure and validate a traceability system that is visible, secure, and auditable, enabling all supply chain participants to independently confirm the product's quality through a implementation model. [37] Examine how a blockchain-based solution might be able to assist in overcoming issues such as incentives, traceability options, trust between stakeholders, and transparent and equitable sharing of materials and know-how. It can also demonstrate how incentive mechanisms can assist in overcoming weaknesses in current intellectual property regimes that impede effective conservation, research, and innovation. The aim of study [38] is to suggest a supply-chain model for a smart agricultural production framework that is enabled by blockchain technology. Among the outcomes displayed are: a supply-chain approach that makes it easier to certify seeds, supervise and monitor the grain process, track provenance, and optionally communicate with regulatory agencies, financial services, and logistics. The top 10 most cited research papers are evaluated and shown in Table 1 along with their key conclusions from the final 78 selected articles for the literature study.

Figure 2

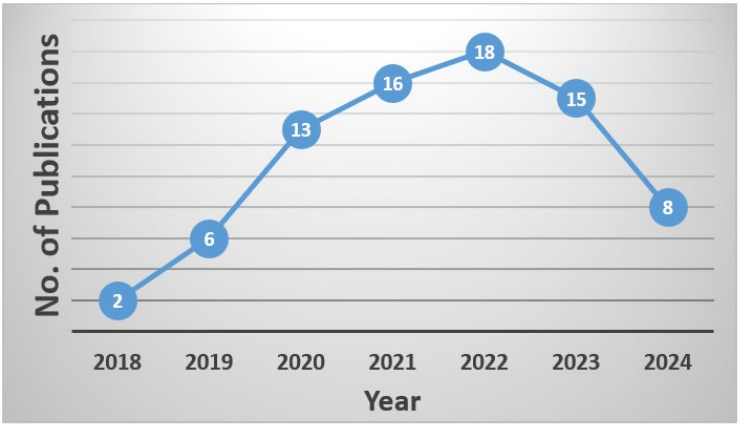

Figure 2 Year wise publications for the related study

Table 1 Compilation of top 10 most cited research papers

Year	Author (s)	Contribution and Findings
(2019)	Andreas, et al. [26]	The article describes ongoing blockchain-related food supply chain projects and activities. This article looks at how blockchain technology is affecting agriculture and the food supply chain.
(2020)	Konstantinos, el al. [27]	An overview of blockchain technology for agricultural traceability The paper examining the difficulties and potential opportunities in the agri-food supply chain
2018	Damion, M. et al. [28]	Terminology gaps and food traceability are addressed by the FoodOn ontology. FoodOn helps global food networks harmonize their data.
2021	Jamilya, et al. [29]	Six strategic Sustainable Development Goals (SDGs) can be aided by DLTs. Improve the food supply chains' sustainability, traceability, and transparency.
2020	Razi, et al. [30]	By incorporating blockchain technology into agricultural supply chain management, safe farming can be improved while maintaining increased security and transparency.
2022	Christina, et al. [31]	The study identifies the benefits and challenges of blockchain adoption for coffee growers. addressing possible design elements and distributive issues for the application of blockchain.
2022	Abdo et al., [32]	The study examines how digital technologies might improve food traceability, fight fraud, and cut down on waste. concludes that blockchain, IoT, AI, and big data are FT 4.0 enablers.
2022	Rayda, et al. [33]	The research investigates Agri-food 4.0 technologies to promote production and trade, as well as DNA traceability to authenticate olive products and guarantee their provenance and quality.
2022	Mohannad, et al. [34]	By identifying blockchain applications in operations and supply chain management and expanding knowledge of blockchain technology in agriculture and related issues, the article assesses the current and potential significance of blockchain technology in agriculture.
2021	Minh Son, et al.	The article suggests a novel approach that supports the origin traceability of agricultural products at farms by utilizing blockchain and Internet of Things technology. The parameters that affect farming processes, can be read using sensors and computational codes.

Step 5: Qualitative evaluation and suggested Framework

Every research piece was carefully examined to gain a comprehensive knowledge. In Fig. 3, the quantity of investigations is also displayed.

Figure 3

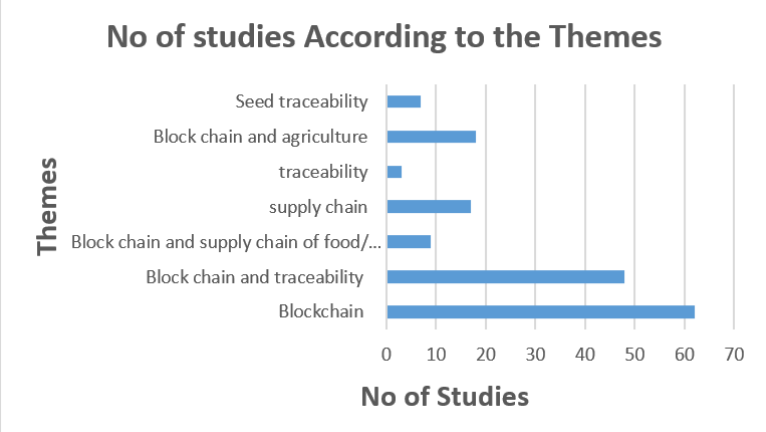

Figure 3 Number of Study on the basis of area of interest

Based on the topics covered in these papers, the following research framework is suggested and presented:

1) Foundation for Blockchain and Supply chain Management
2) Stakeholders Perspective
3) Implementation
   - Blockchain platform selection

- Data Management
- Interoperability of stakeholders

3. RESULT AND DISCUSSION

The systematic literature review on blockchain technology for seed traceability produced several significant findings, demonstrating that blockchain technology significantly improves transparency across the seed supply chain. Blockchain fosters trust by providing an immutable public ledger that allows stakeholders to see all transactions and data entries. The immutability of blockchain ensures that data cannot be altered or tampered with once entered. This feature is critical to ensuring the integrity and authenticity of seed data. Blockchain's decentralized nature makes it a secure platform for storing sensitive information, lowering the risk of data breaches and fraud. Blockchain's transparency instills confidence in farmers, seed producers, distributors, regulators, and consumers by allowing them to verify the authenticity and quality of seeds at every stage of the supply chain.

4. CONCLUSION AND FUTURE SCOPE

This study is a significant addition to the field of supply chain management research on seed traceability through block chain technology. Transparency in the seed supply chain is increased by blockchain technology's immutability and decentralization. Every transaction is recorded on a public ledger that all stakeholders can access, building trust among farmers, seed producers, distributors, regulators, and consumers. Blockchain ensures data integrity by creating immutable records that prevent tampering and fraud. This secure data management system ensures the authenticity and quality of seeds by sharing only verified information throughout the supply chain. The author has employed approach of systematic literature review to assemble the work done in this area. The compilation is shown using a framework and graphs. Given that only the Web of Science database was utilized, there are undoubtedly few restrictions (WoS). For a comprehensive analysis, additional databases like EBSCO and Scopus might be incorporated. The following concerns and research areas are identified for future study:

More research is needed to create scalable blockchain solutions capable of handling high transaction volumes efficiently.

- There is a need for standardized protocols to ensure data interoperability between blockchain systems and current agricultural databases.
- More thorough cost-benefit analyses are needed to fully comprehend the economic implications of blockchain adoption in seed traceability.
- Future research should prioritize overcoming scalability and interoperability challenges.
- Investigating the broader socioeconomic implications of blockchain adoption in agriculture.
- Developing practical guidelines for implementing blockchain technology in seed traceability.
- Encourage policy support and regulatory harmonization to make blockchain adoption easier.
- Promoting collaboration among technologists, agriculturists, policymakers, and other stakeholders to advance blockchain applications for seed traceability.

CONFLICT OF INTERESTS

None.

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