Analyzing the performance of blockchain and biotechnology (bt)-integrated food supply chains

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Abstract

Objective

The Food Supply Chain (FSC) internationalization has caused significant problems for the food system. These problems include fraud, security, dependability, and quality, all caused by a lack of fair data. Globalization makes dealing with these problems more complex and complicated, which makes FSC more successful. Blockchain (BC) has shown that it can change FSC by using its strengths. Much research is still being done on using BC in FSC, but it is still in its early stages. This work takes a close look at all the previous research that has been done on BC and Biotechnology (BT) integrated FSCs (BT-FSC).

Results

A review using well-known sources was part of the research. Publications from 2018 to 2024 were included in the study. Fifty pieces were looked at to find the things that make BC possible

and its pros and cons. Based on the facts in this study, a theoretical framework was created to help with the adoption of BC in the BT-FSC.

Conclusions

The poll found that the main things that stop people from using BC are its scalability, interaction, higher prices, inadequate knowledge, and laws. It adds to what is already known by giving helpful information about how BC is used in the BT-FSC. It provides other businesses with evidence-based advice on how to make plans for adopting BC.

Keywords: Biotechnology, Blockchain, Food Supply Chains

Introduction

Food Supply Chains (FSCs) are groups of businesses that work together to move agricultural and food products as quickly as possible to give customers the best value for their money (Katsikouli et al. 2021). The FSC is a complicated system with many parts, such as customers, farmers, producers, retailers, distributors, and the governing group. Individuals involved in the FSC have different roles to play in the organization's work, which includes growing crops and using goods.

Blockchain (BC), a new technology that solves several supply chain problems (Krichen et al. 2022), is rising. BC makes the FSC more effective by being more open, accountable, and good at running the business (Obeidat & Yaqbeh 2023). BC is often seen as a vital tool that can rebuild trust between FSC and customers by making sharing and checking information easier. As an add-on to FSC systems, it lets precise and reliable data be sent in a safe way that can be trusted.

Because of its possible benefits and advantages, BC has changed the FSC industry (Rana et al. 2021). It could improve traditional supply chain processes, which tend to be more organized (Kioskli et al. 2022). It was found that the BC can be used in finance (Oleksandr et al. 2024). BC has garnered significant attention in recent years, particularly in FSC management, due to its ability to enhance transparency and foster trust between partners in the Biotechnology (BT) integrated FSC (BT-FSC) (Nabeesab Mamdapur et al. 2019). Among other significant corporations, Walmart has investigated BC to tackle food monitoring and safety concerns and to improve food reliability through the FSC.

The FSC comprises diverse stakeholders, including farmers, shipping companies, wholesalers, retailers, suppliers, and grocery shops, and it is widely distributed worldwide. These several actors should be executed collaboratively to generate optimal value. Accurate and timely data could enhance the cooperation among FSC stakeholders (Zoran et al. 2022). This data can be managed by implementing the newly developed technology known as BC.

Several studies regarding incorporating BC in the BT-FSC can be found in the existing literature. Tayal et al. (2021) examine the efficacy of BC in guaranteeing the authenticity and validity of FSC (Tayal et al. 2021). They examine the different security features of BC and the benefits of implementing them in the FSC. Bosona et al. describe implementing BC in a firm's production and FSC delivery network (Bosona & Gebresenbet 2023). The authors examine the utilization and implementation of BC in global sup FSC to enhance the efficiency and transparency of commodities transportation. They specifically focus on egg manufacturing. Najmi et al. introduced a BC paradigm for a halal FSC (Najmi et al. 2023).

They highlighted the significance of integrating the BT-FSC and implementing food standards inside the halal FSC as crucial factors enabling BC achievement. Brandín et al. provide an overview of the characteristics and capacities of BC, examine the use of BC for resolving problems related to food accountability, and emphasize the potential advantages and obstacles associated with deploying BC-based traceability platforms (Brandín & Abrishami 2021). Ardra et al. examined the primary barriers to adopting BC to simulate the agricultural BT-FSC in Nepal (Ardra & Barua 2023). The study's findings show that two big problems with implementation are that the government is too involved and Agri-stakeholders don't trust BC (Surendar et al. 2024). Yap et al. analyzed how BC affects the ecological viability of the food and agriculture business

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and how BC is used in the agri-FSC (Yap & Al-Mutairi 2024). Xu et al. provided a concise overview of the operational concept of the BC for data collecting and tracking (Wu et al. 2022). The current applications of BC in the agri-food industry are described as collaborative approaches. The application of BC is examined in four ways to enhance the security and excellence of agri-foods: improving the visibility of data, ensuring the ability to track data, enhancing the tracking of food safety and excellence, and reducing the costs associated with financial transactions. Moreover, data generation in agriculture and biotechnology has greatly increased in recent years due to the very rapid development of high-performance technologies (Mohammadabadi et al. 2024). These data are obtained from studying products, foods, and biological molecules, such as metabolites, proteins, RNA, and DNA, to understand the role of these products and molecules in determining the structure, function, and dynamics of living systems (Pour Hamidi et al. 2017). Functional genomics is a field of research that aims to characterize the function and interaction of all the major components (DNA, RNA, proteins, and metabolites, along with their modifications) that contribute to the set of observable characteristics of a cell or individual (i.e., phenotype). Artificial neural networks have been proposed to alleviate this limitation of traditional regression methods and can be used to handle nonlinear and complex data, even when the data is imprecise and noisy (Pour Hamidi et al. 2017). Agricultural data can be too large and complex to handle through visual analysis or statistical correlations. This has encouraged the use of machine intelligence or artificial intelligence (Ghotbaldini et al. 2019). Thus, this review aimed to Ai in agriculture applications.

Systematic Analysis

The research conducted a methodical examination to address the research inquiries, adhering to the guidelines set forth by the Preferred Reporting Items for Systemic Ratings and Meta-Analyses (PRISMA).

Materials: PRISMA is a methodology for reporting systematic reviews that is based on evidence. The search was conducted from January 2018 to May 2024, as this period encompasses the articles available on BC for agriculture. At first, 152 papers were deemed suitable for examination out of a large group of 322 articles sourced from several databases. One hundred ninety-seven papers have been eliminated based on causes, outcomes, non-BC, and non-smart farming criteria. A total of 50 publications have been selected for this investigation. A meticulous content evaluation has been conducted after comprehensively examining the pertinent articles.

Inclusion and exclusion conditions: The primary objective of this review is to gather material that possesses characteristics that will enable the achievement of the ongoing study's

objectives. A comprehensive set of inclusion or exclusion criteria establishes the analysis's parameters and serves as the foundation for achieving the objective. Establishing a precise standard enhances the probability of generating dependable and replicable outcomes, reduces prejudice, and safeguards against making weak deductions. To accomplish the aim of this research, various aspects are employed to establish the criterion.

Quality analysis: A quality evaluation checklist was employed to evaluate the pertinence of the papers in this research.

Search findings: The initial search was restricted to the titles and summaries. Three hundred twenty-two articles were chosen from the two libraries based on the search criteria. After identifying and removing 170 duplicate documents, the remaining number of papers was reduced to 152. The researchers examined the titles and abstracts of articles to find those that specifically addressed the use of BC in BT-FSC. The outcome was 85. The authors subsequently examined the complete articles to ascertain their relevance or in cases where complete texts were not accessible. As a consequence, there were 41 papers produced. Nine (9) papers were included in the study using snowballing methods, resulting in a final sample size of 50 documents for further examination. Figure 1 displays the flowchart of PRISMA.
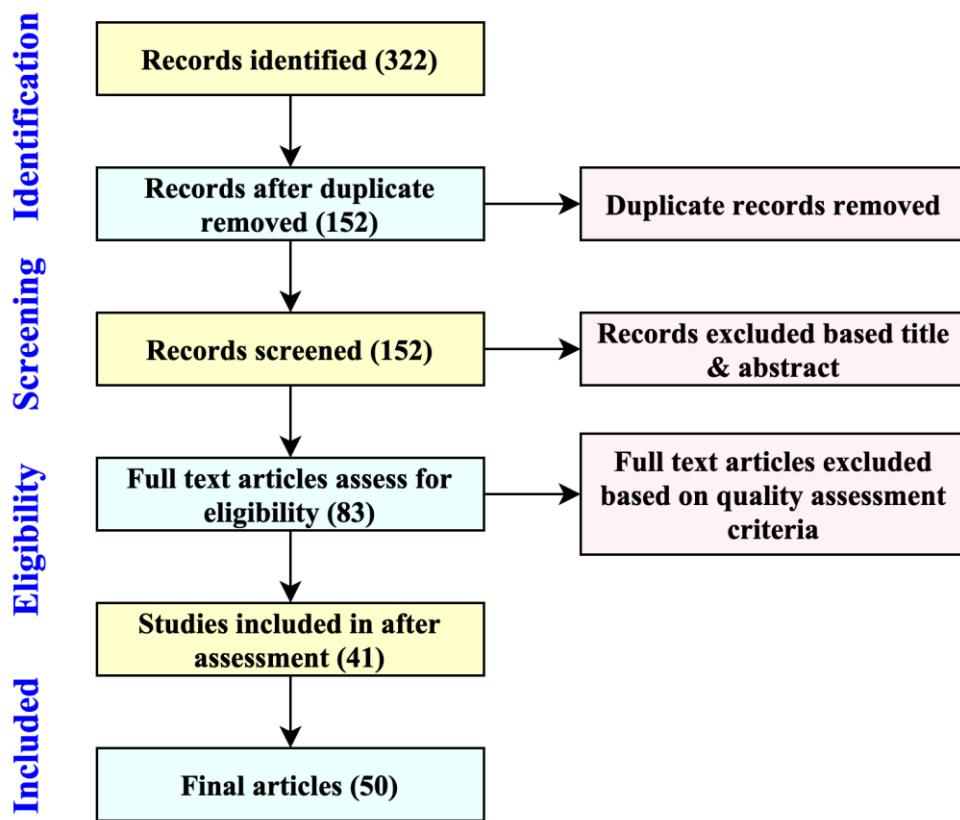

Figure 1. Flowchart of the PRISMA for FSC and BC using BT

Analysis of BC in BT-FSC

Enablers: The literature has identified the factors that facilitate the implementation of BC in FSC. The following facilitators are thoroughly explored below.

Traceability: Food traceability functions as a form of logistical management—monitoring and following the various stages of food production throughout the entire FSC. Internet of Things (IoT) gadgets, such as QR numbers, Wireless Sensor Networks (WSN), and Radio Frequency Identifiers (RFIDs), can track and organize data. BC has the potential to enhance the traceability of the BT-FSC. This demonstrates how BC bolsters the security and excellence of the agri-food industry. Scientists have suggested traceability solutions that utilize BC and other technological advances.

Transparency: Transparency can facilitate BC in a FSC. Insufficient disclosure can impact food quality, and implementing BC in BT-FSC can enhance transparency. Although still in its early stages, BC is a revolutionary innovation that has the potential to improve FSC by promoting transparency, trustworthiness, and reliability.

Decentralized records: The metadata utilized to communicate inside a BC is distributed throughout the ledger and cannot be consolidated in a single location. This indicates that the BC ledger is decentralized. The data were distributed across multiple servers. Instead, it is saved in parallel on various computers, called "nodes." BC members can establish a higher level of confidence among themselves due to the decentralized nature of the database.

Immutability: Immutability denotes the characteristic of remaining unchanged over time. Immutability enables the creation of a comprehensive record of all actions executed on the database. This allows the tracking of any documentation at any given moment. BC offers an immutable audit trail, and its distributed structure makes it more challenging for attackers to manipulate or fabricate data within the BC system.

Provenance: BC enhances traceability in the BT-FSC by facilitating the identification of the origin of products. Many industries derive the worth of their items from their source.

Smart agreement: Stakeholders must consent to digital BT-FSC activities and record any modifications. Intelligent contracts are beneficial because they encompass mutually agreed-upon terms of all parties, leading to desirable outcomes. The implementation of digital agreements has had a substantial influence on corporate operations. An intelligent agreement facilitates the digital transmission of a commodity or currency to a BC service.

Benefits

Enhanced food safety: BC can address significant BT-FSC challenges, including food waste, recalls, inefficiencies, accountability, and fraud. BC's inherent openness and traceability enable precise identification of food's origin, enhancing its safety and quality. As an illustration, Wal-Mart utilizes a BC to monitor the shipment of sliced mangoes. Surveillance was carried out within the borders of Mexico. Nestlé monitors the movement of milk from fields and manufacturing facilities to factories. Enhanced familiarity with the product and manufacturing process leads to a more comprehensive comprehension of quality, elevating the quality of the food.

Enhanced data security: BC can expedite transactions inside the BT-FSC. Preserving every online transaction document can effectively remove errors that arise from traditional paper-based documentation. The decentralized structure of the database, the process for consensus, and the encryption components of the BC collectively render it infeasible for any individual to alter the information in it.

Enhanced performance: Improving the alignment between FSC and need can boost the efficiency of the FSC. BC provides up-to-date information on the current operations of FSC, including data on inventory, customer demand, available supplies, the amount of time goods spend in storage, and the manufacturing dates. It facilitates the monitoring of inventories in BT-FSC. BC enhances the sustainability of FSC for the surroundings, the finances, and the community.

Enhanced efficiency: BC could enhance the efficiency of FSCs in their operations. BC enables immediate and continuous access to information about food goods. Walmart gathered up-to-the-minute data to oversee the entire BT-FSC, including cultivation, manufacturing, processing, and marketing. This implies that the source and standard of food are always visible. By employing this approach, Walmart can detect any mishandling or expiration of food items before their delivery to the client. Food waste is present at every stage, from delivery centers to logistical operations to retailers. According to Walmart's 2018 Worldwide Responsibility Assessment, the firm intends to decrease or eradicate food waste. Implementing BC in food recall procedures across multi-party BT-FSC can save costs because of the intricate detail captured in the recorded transactions. Food corporations can evade the sale of damaged or hazardous items, averting any potential financial or reputational harm.

Enhanced trust: Implementing BC is an exemplary strategy for Walmart to attain the beneficial impact of strategic partnerships by fostering cooperation in the food business. BC can enhance trust and collaboration among FSC participants.

Barriers

While BC offers BT-FSC advantages, several issues must be resolved. These include scalability, complexities, limited knowledge, high expenses, and regulatory concerns.

Scalability: BC has experienced a surge in prominence in the last decade. As a result of the rapid adoption of technology, the amount of transactions inside a network is growing. The block size is limited due to the growing significance of the interactions. When the number of clients and activities grows, the number of nodes needed to handle them grows. Insufficient scalability can result in a high volume of transactions, which might cause the system to slow down.

Compatibility: Compatibility refers to the ability of distinct BC to establish connections and exchange information. Multiple BC initiatives are presently in progress. These initiatives were developed using various programming tools and executed on diverse platforms. Different BC systems cannot establish connections due to their inability to communicate. This results in the segregation of networks and a lack of equal access to information.

High cost: Implementing BC faces obstacles because of the expenses involved in acquiring, customizing, and learning how to use it, especially for small and medium-sized companies in the BT-FSC. Developing the necessary facilities and managerial skills for BC necessitates substantial capital expenditures.

Inadequate Expertise: Most people intrigued by the area of BC need to learn more about it and how it impacts the business. Many companies worry they must learn more about BC or comprehend it well enough. Companies need to have appropriate technological know-how and tools to install BC, which is a complex and time-consuming procedure.

Regulations: Setting up rules and creating a regulatory system are other important parts of implementing BC. Policymakers and scientific experts have different opinions on the subject of BC use. Regulatory problems have made it harder to adopt BC fully. For BC to be used in BT-FSC, more specific requirements and standards must be met. Setting up laws and rules to implement BC in BT-FSC is essential. It is necessary to do a complete study into how BC affects governance.

Discussion

This study summarizes the things that make BC possible, as well as the pros and cons of it in the financial services industry. The results make BC's importance in FSC clear. Based on the review results, BC looks like an exciting technology that could change FS and help with some problems in FSCs. BC could make it easier to keep track of goods and find the source of items that have been recalled because of issues about pollution, fraud, or other violations of food safety

standards. BC makes it possible to keep track of your inventory, making it easier to keep an eye on food things across the whole BT-FSC. The study shows that traceability, openness, distributed records, sources, and smart contracts are the main things that encourage BC adoption. The results look into the benefits of BC and how it can make FS activities more reliable, secure, and private, as well as boost trust, teamwork, performance, and environmental sustainability. The findings show that BC works to make it easier for BT and FSC to work together. BC helps the FSC stakeholders work together better and more quickly. The findings indicate that implementing this could enhance FSC efficiency and long-term viability. This study presented a theoretical basis for implementing BCs in a BT-FSC. This framework incorporates the factors that facilitate, advantages, and obstacles to adopting BCs. The model can be utilized further to investigate the mainstreaming of BC in various industry environments and comprehend its effects and benefits.

Limitations

While this analysis offers information on implementing BC within the FSC, it is important to acknowledge several limitations that must be considered for additional studies. This review focuses explicitly on FSC. The selection criteria were restricted exclusively to scholarly works that have undergone peer review. The research indicates a need for more journal papers in the existing literature. The authors propose the inclusion of proceedings, white papers, reports, publications, and similar sources to prevent the oversight of accessible information. The research uncovered a limited quantity of printed publications on the widespread use of BC.

Future Studies

This study indicates that although BC has potential advantages, several obstacles must be overcome, including scalability, higher cost, lack of knowledge, and regulations. The administration should have a clear understanding of the additional challenges and pressures that arise from the implementation of BC. The review has analyzed the factors that facilitate BC and the advantages and obstacles of BC in BT-FSC. The following further study is proposed:

- Subsequent research should focus on devising tangible remedies to overcome organizational and technological obstacles.
- Investigators must ascertain the reasons for BC's utilization in the food industry.
- Investigators should furnish illustrations of the impact of BC on individuals' lives and their perceptions of it.
- Subsequent investigations should explore the potential synergies between forensic examinations and BC to guarantee food products' safety, origin, and accuracy.
- Subsequent research should explore the possible uses of BC in the financial services sector.

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Conclusions: Based on the analysis of previous research, the use of BC in the financial services sector is still developing and in its early stages. Like numerous other technical advancements, the excessive excitement around BC has surpassed its advantages and possibilities. This study compiles the critical features of BC, various platforms used for BC, BC's role in the BT-FSC, and the obstacles encountered in the BT-FSC. The primary results of the review identified apparent factors that facilitate, advantages gained and barriers faced in adopting BC in the BT-FSC. These findings contributed to developing a theoretical framework for using BC in the BT-FSC, which will serve as a valuable foundation for further study in this field.

Conflict of Interest: There is no conflict of Interest.

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تجزیه و تحلیل عملکرد زنجیره تامین مواد غذایی یکپارچه با زنجیره بلوکی و بیوتکنولوژی

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چکیده

هدف: بین المللی شدن زنجیره تامین مواد غذایی (FSC) مشکلات قابل توجهی را برای سیستم غذایی ایجاد کرده است. این مشکلات شامل تقلب، امنیت، قابلیت اطمینان و کیفیت است که همگی ناشی از فقدان داده‌های منصفانه است. جهانی شدن، برخورد با این مشکلات را پیچیده‌تر و مشکل‌تر می‌کند، که باعث موفقیت بیشتر FSC می‌شود. بلاک چین (BC) نشان داده است که می‌تواند FSC را با استفاده از نقاط قوت خود تغییر دهد. تحقیقات زیادی هنوز در مورد استفاده از BC در FSC در حال انجام است، اما هنوز در مراحل اولیه است. این کار نگاهی دقیق به تمام تحقیقات قبلی دارد که در BC و FSCهای یکپارچه بیوتکنولوژی (-BT FSC) انجام شده است.

نتایج: بررسی منابع شناخته شده بخشی از این تحقیق بود. انتشارات از سال ۲۰۱۸ تا ۲۰۲۴ در این مطالعه گنجانده شد. پنجاه قطعه مورد بررسی قرار گرفت تا چیزهایی که BC را ممکن می‌سازد و جوانب مثبت و منفی آن را بیابند. بر اساس حقایق در این مطالعه، یک چارچوب نظری برای کمک به پذیرش BC در BT-FSC ایجاد شد.

نتیجه‌گیری: این بررسی نشان داد که مهم‌ترین چیزهایی که مردم را از استفاده از BC باز می دارد، مقیاس پذیری، تعامل، قیمت‌های بالاتر، دانش ناکافی و قوانین آن است. با ارائه اطلاعات مفید در مورد نحوه استفاده از BC در BT-FSC به آنچه قبلاً شناخته شده است اضافه می‌کند. این امر به سایر مشاغل مشاوره مبتنی بر شواهد در مورد چگونگی برنامه ریزی برای پذیرش BC ارائه می‌دهد.