Operations Management Research (2023) 16:1594–1618
https://doi.org/10.1007/s12063-023-00363-2

# Blockchain enabled food supply chain management: A systematic literature review and bibliometric analysis

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Received: 10 September 2021 / Revised: 21 January 2023 / Accepted: 18 March 2023 / Published online: 5 May 2023


**Abstract**
With the rapid developments in the field of blockchain technology, the food supply chain has entered the era of blockchain applications for the past few years. Although many publications related to blockchain technology have shown a remarkable impact on the food supply chain, there is no bibliometric report that considers this research trend. The research for this study was carried out from the years 2008 to 2021, with the first paper in this field being published in the year 2016. The research uses multiple databases for data analysis, studying approximately 2637 records to enlighten scholars around the world, and 150 records are finalized for the study. The primary purpose of this study is to conduct a systematic literature review to understand the current research status of blockchain technology in managing and transforming food supply chains and fill the gap. Additionally, bibliometric analysis is utilised with the VOS viewer to visualise, comprehend, and simulate the diverse range of findings in terms of essential authors, authorship pattern, keyword analysis, and blockchain usage pattern in food supply chains. Additionally, the literature also examines the advantages, difficulties and applied blockchain-based models in the food supply chain. The study concludes by outlining research gaps, implications, and future research opportunities. This research will help the students, academicians, and experts to get a complete idea of the development of blockchain in the food supply chain area. The highly cited implementation papers existing in the literature have demonstrated that blockchain could improve transparency, traceability, food safety, and food quality. It is a promising technology to build trust among food supply chain actors. Furthermore, it revealed that blockchain is moving from its nascent stage to maturity stage.

**Keywords** Blockchain · Systematic literature review · Bibliometric analysis · Citation analysis · Food supply chain

## 1 Introduction

The financial industry has given a lot of attention to blockchain technology over the past few years, and now it has started diversifying the health sector, real estate sector, government services, and supply chain sector. It is undoubtedly increasing security, providing traceability and transparent platforms (Iyenger et al. 2022; Babich and Hilary 2019), and avoiding the centralizing system with the principle of decreasing intermediaries where each actor in the supply chain can prove their legitimacy/authority. Blockchain technology helps detect fraud by tracing its components from harvesting to end-user in the market and phroviding transparency to create trust among stakeholders. The collaboration of distributed ledger platforms with supply chain management can significantly advance the food supply chain management system (Katsikouli et al. 2021). Many businesses are implementing blockchain technology for tracking and tracing to increase the agility of the supply chain and boost employee productivity by paying workers and farmers

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fairly. For example, the company of Denver's Coda Coffee partnered with bext360 used blockchain platform to trace coffee operations and also at the time of collection of payment to farmers regardless of gender (Sodhi and Tang 2021; Tang 2022). The traditional food supply chain's intricate structure faced a number of difficulties, including those related to animal welfare, environmental impact, fair trade, food safety, authenticity, fraud, and ineffective procedures (Marucheck et al. 2011; Kumari et al. 2022). Blockchain technology seems to be an attractive tool for overcoming most of these issues (Katsikouli et al. 2021) and is being one of the most well-known disruptive technologies for supply chain adoption (Tokkozhina et al. 2022). IoT devices could also monitor and store the information at all stages in the food supply chain, but the platform relied on a centralized system. Consumers are not sure about the security and privacy of data maintained on a centralized platform, so they cannot build trust among participants (Chod et al. 2020; Feng et al. 2020; Gregory et al. 2022). Traceability is an essential tool in the food supply chain to guarantee food safety, quality, and transparency of the food products. It helps to optimize the production process. In the modern food supply chain, traceability is an important component to adopt at the initial stages to get over various issues in the conventional system (Dasaklis et al. 2019). Traceability retrieves data, stores, and traces the food supply chain information at all stages so that the quality, safety, and tracing capability are maintained throughout the food supply chain. For example, the traceability mechanism can be used with the help of blockchain technology in the plant production chain (Matzembacher et al. 2018) and traceability of poultry products (Feng et al. 2020), which helps build trust among consumers and provide transparency. Therefore, food traceability is a new topic among researchers, and blockchain food traceability in the agriculture sector is less explored (Mirabelli and Solina 2020). Digitalization in the food industry is not a new phenomenon as it is a crucial factor in making the food supply chain into a new era of the world (Lin et al. 2018) and reshaping the food supply chain in terms of operational processes and business perspective (Casino et al. 2021). Digital platforms cause fewer mistakes arising along supply chains and make them more cost-effective (Kittipanya-Ngam and Tan 2020; Dewett and Jones 2001). The five main dimensions of the digital food supply chain are efficiency, transparency, traceability, and environmental and social impacts to make it more reliable.

Legal liability and e-market/supply accessibility issues plagued the digital food supply chain. These dimensions support some technological platforms, making food supply chains valuable. It was identified that blockchain and IoT are the two leading platforms for digitalizing food supply chains in the upcoming era (Kittipanya-Ngam and Tan 2020). For example, Australia has recently run blockchain technology pilot use cases in Australian wheat growers. Using blockchain technology, an Australian wheat grower sent a shipment of wheat to New Zealand in 2016, and an Australian grain grower cooperative delivered oats in 2017. In both cases, blockchain technology was used for the transaction process, reducing the intermediaries and transaction costs (Gunasekera and Valenzuela 2020). Figure 1 describes the role of blockchain technology in the food supply chain. Stakeholders are comprised of growers & producers, manufacturers, distributors, retailers and wholesalers who deliver the end product to the customers. Barcodes are assigned to each product. All the information about the product and transactions that occurred among various stakeholders are stored in the form of a chain of blocks. Furthermore, distributed ledger technology shares the information in the blockchain network. The admin portal provides each product's information transparently and the transactions information among various stakeholders using their own private keys.

Blockchain technology is used for fair trade among stakeholders and strengthens their position in the market. Blockchain technology is the innovative technology for sharing information from one place to another. The distributed ledger technology provides trust and forward and backward control to the end consumer (Dasaklis et al. 2019). The mathematical solution was given by (Fan et al. 2020) to explain the pricing strategies of the food supply chain with and without the adoption of blockchain technology. Furthermore, the authors found that blockchain technology maximizes the profits of the whole supply chain by creating a traceability mechanism for each stakeholder. Blockchain technology also provides a feasible coordination analysis for the supply chain stakeholders. It provides a practical solution and a more comprehensive and exclusive framework for data exchanged among food supply chain (FSC) partners and increases the visibility and transparency of the shared data (Keogh et al. 2020). Though the study of blockchain technology in the food supply chain has shown tremendous growth in the past few years, it is still in the early phases of development. It is a relatively new concept and actual case studies are absent in the literature. This is an unclear phenomenon of how blockchain technology could benefit the agriculture food supply chain in the future (Mirabelli and Solina 2020).

The aforementioned characteristics of blockchain technology, as well as ongoing research into its applications, difficulties, and environmental problems (Moretto and Macchion 2022), as well as how it can benefit the food supply chain industry, have garnered a lot of interest. In order to close this gap and address the following research questions, this paper:

RQ1. What is the current status of integrating blockchain technology into food supply chain management?
RQ2. What experimental studies and models are currently explored in blockchain enabled-agri food supply chain area?

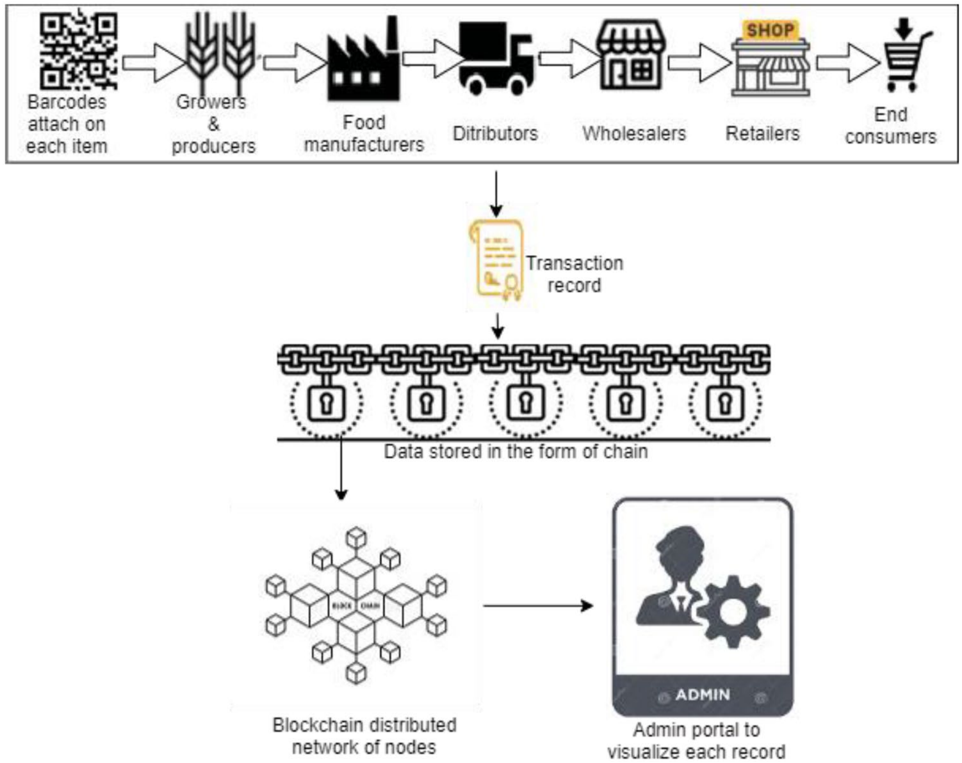



**Fig. 1** Transforming food supply chain with blockchain technology (source: authors)

RQ3. What are the current issues with using blockchain technology in the management of the food supply chain that are documented in the literature and research gaps?

To answer the questions, the systematic literature review (SLR) approach (Taylor et al. 2020) is used to map the existing literature and address the knowledge in the scope of using blockchain technology in food supply chain management.

### 1.1 Motivation

The increasing interest of researchers has led to an increasing number of studies in this field. However, a bibliometric analysis of blockchain technology in the food supply chain was not carried out so far. The bibliometric analysis was used to describe the role of blockchain in logistic and supply chain management (Mirabelli and Solina 2020; Muessigmann et al. 2020; Xu et al. 2022; Bermeo-Almeida et al. 2018, Zhao et al. 2019), agri-food sector (Antonucci et al. 2019) and food agriculture industry (Niknejad et al. 2021). The existing studies are based upon the general supply chain sector using content analysis (Queiroz et al. 2019) and SLR (Wang et al. 2018) until 2018. However, this study narrows down the research from general supply chains to food supply chains from the year 2008 to 2021. Most of the existing studies used a single database for performing bibliometric analysis, such as Scopus (Mirabelli and Solina 2020; Antonucci et al. 2019; Niknejad et al. 2021) or Web of Science (WoS) (Xu et al. 2022). Very few studies are based on multiple databases (Muessigmann et al. 2020; Bermeo-Almeida et al. 2018; Zhao et al. 2019; Queiroz et al. 2019; Wang et al. 2018) on the general supply chain. Furthermore, none of the existing studies particularly explore the use of blockchain in food supply chain management. Therefore, to address this gap, the SLR and bibliometric analysis was applied to identify the status and future challenges of using blockchain technology in the food supply chain. To the best of our knowledge, this is the first study that explores blockchain application in the food supply chain instead of general supply chain using both SLR and bibliometric analysis. The data analysis was obtained in three parts: descriptive analysis, bibliometric analysis, and comparative analysis.

The remainder of this article is divided into the following sections: Blockchain technology and its use in managing the food supply chain are covered in Section 2. The SLR methodology is presented in Section 3. In the form of descriptive analysis, bibliometric analysis, and comparative analysis, Section 4 presents the findings and interpretations. The difficulties and potential directions for future research in using blockchain technology in the food supply chain management are discussed in Section 5. Finally, Section 7 brings the paper to a close. Section 6 presents the discussion.

## 2 Background

The literature review explicates the relation between blockchain technology and the food supply chain.

### 2.1 Blockchain technology

The emergence of blockchain technology was founded in 2008 by Satoshi Nakamoto to create Bitcoin. Since then, blockchain use cases have gone far beyond cryptocurrency to food traceability, ballot tracking, identify verification, real estate processing, supply chain management, etc. Blockchain technology is an information and communication tool based on cryptography to secure transactions between two parties. It comprises a chain of blocks in which many transactions are recorded, executed, and shared among involved parties (Bermeo-Almeida et al. 2018; Cheng et al. 2019; Roozkhosh et al. 2022). The blockchain is a technology that allows for the creation of digital platforms that do not require centralized task assignment and resource allocation from the top down (Hsieh and Vergne 2022). Blockchain transactions are executed using smart contracts that run automatically when any contract or deal between two parties is executed. All the transactions in the blockchain are cryptographically hashed and transparent to the users involved in the transaction process. The cryptographic hash of each block contains the hash value of previous blocks to maintain the chain of the blockchain. It also offers several opportunities such as transparency, trust, traceability, and security across the whole food supply chain. It is a promising technology for building a more trusted environment and solving transparency and security issues in the food supply chain (Feng et al. 2020; Gunasekera and Valenzuela 2020, Keogh et al. 2020).

### 2.2 Blockchain in food supply chains

The food industry has four pillars, namely food safety, food quality, food authenticity and food defence and security. The fabrication of these pillars would create distrust among consumers and stakeholders. So, much emphasis was placed on improving information sharing among stakeholders, increasing transparency, reducing information symmetry, and enhancing trust among consumers (Keogh et al. 2020; Gray et al. 2022). Katsikouli et al. (2021) discussed the issues and challenges in the traditional food supply chain and explained how blockchain technology helps to resolve those issues. The authors explained the use cases of Denmark-related companies, namely Twisted Leaf, Centrarogeriet, Eskelyst and Einar Willumsen. The challenges that occurred in the food supply chain of these companies were recognized, and the potential of blockchain solutions was explained to solve those issues. The interviews were conducted with various company employees, and it was found that the industry is not ready to adopt blockchain technology as there is a lack of knowledge and education regarding blockchain. And secondly, the standards are not defined until now. Keogh et al. (2020) systematically reviewed the usage of blockchain technology with GS1 standards in the food supply chain. This integration of GS1 standards with blockchain technology offers interoperability of data shared among global FSC stakeholders, and it is far better than the traditional or linear supply chains with limited data sharing. It facilitates the FSC, increases food traceability, provides multidimensional data sharing and optimizes food chain processes. Chod et al. (2020) developed the prototype having low-cost, open-source, lightweight, and flexible protocol to securely record and verify transactions on an immutable distributed ledger and provide transparency in the supply chains through blockchain technology. Further the protocol was tested on the agriculture warehouse implementation for the farmers to deposit or withdraw produce. Mirabelli and Solina (2020) explored the application of blockchain technology in the agriculture sector for traceability issues to determine the current research trends, issues, and challenges that blockchain could solve in the agriculture sector and some open research questions find out the challenges faced by blockchain. This study revealed that blockchain usage in the agriculture sector reduces fraud and errors, increasing the quality and safety of products. Some of the research questions include the economic and environmental impact of blockchain on the actual agriculture supply chain, the relationship between IoT and blockchain, how stakeholders could adopt a blockchain in the agriculture sector, and whether blockchain guarantees data integrity and authenticity need to be answered. Gunasekera and Valenzuela (2020) quantified the economic effect of blockchain technology in the Australian grain sector. The Global trade analysis project (GTAP) model analyzed the economic effect. GTAP is an economy-wide global market analysis to analyze the decrease and increase of the global economy. The simulation results indicate that the model growth of productivity in the Australian grain sector was increased by 5% due to the adoption of blockchain technology. Wang et al. (2021a, b) implemented blockchain-enabled data-sharing system to facilitate a trustable information sharing system in a supply chain. The system mitigates the several challenges of the supply chain, such as data sharing, including privacy breaches, data leakage, improper valuation of data, and unfair compensation. The results indicate that the proposed usage-based data valuation mechanism using blockchain technology can achieve transparency, security, fairness, and accountability.

Moreover, the Australian finance sector was also raised to 9.7% for the trading of grains due to the reduction of transaction costs between two parties. Feng et al. (2020) explored the use case of blockchain technology in the food supply chain traceability system. They addressed how blockchain can provide a better solution to food traceability systems by providing complete transparency and security issues. The operational framework and mechanism were designed to address blockchain-based IoT traceability systems in the food traceability system. The flowchart was proposed to check the suitability and sustainability application analysis for blockchain-based food traceability systems. The benefits and challenges of using blockchain technology in food traceability systems were also mentioned.

## 3 Methodology

To explore the full potential of existing literature on the food supply chain using blockchain technology, an SLR method was used (Tranfield et al. 2003). It is a systematic method to locate, analyze, explore and synthesize peer-reviewed publications. It helps the researcher to carry out the latest topics, challenges, and future research gaps from the existing literature related to that area (Taylor et al. 2020). The methodology adopted for carrying out this SLR of blockchain technology in food supply chains used Preferred Reporting Items for Systematic review and Meta-Analyses (PRISMA) guidelines (Moher et al. 2009), as shown in Fig. 2. The literature analysis and inclusion and exclusion criteria at every stage are provided using the PRISMA framework. The explanation of using the PRISMA framework is discussed below.

### 3.1 Search strategy

The SLR developed a search strategy to find the relevant literature. We identified that no single database could cover all the papers related to blockchain technology and the food

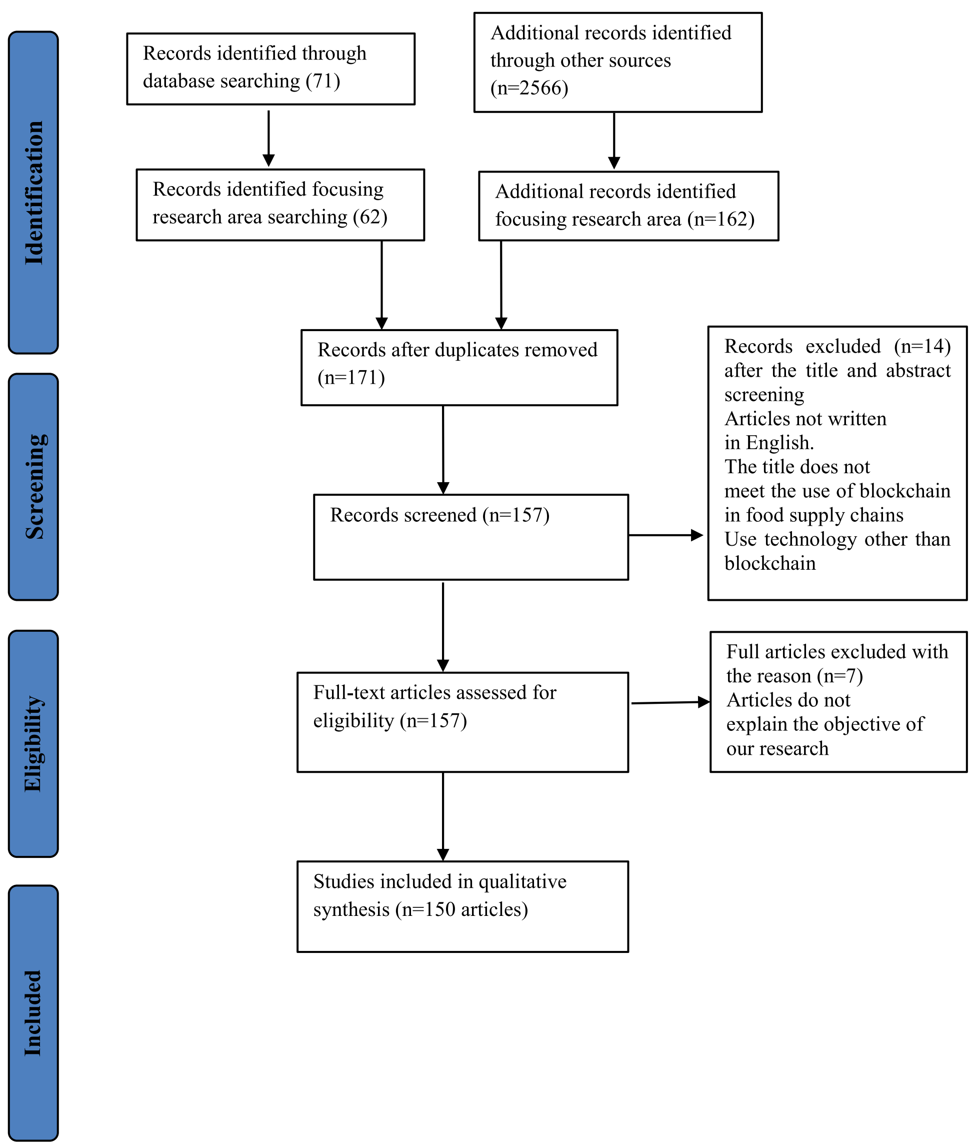



**Fig. 2** SLR using PRISMA framework

supply chain during the literature. Most of the researchers conducting SLR were focused on a single database such as Scopus, Web of Science, or EBSCO host (Fahimnia et al. 2015; Astarita et al. 2019). This systematic literature review strategy was tailored to seven databases: WoS, Wiley, IEEE Explore, ACM digital library, Science Direct (Elsevier), Springer link & Taylor and Francis. Initially, the total number of articles extracted from these databases was 2637. Then we refined the article based on our research area, and a total of 228 articles came under the study. The number of articles extracted after removing duplicates from the databases is listed in Table 1.

We intend to achieve maximum collection of the use of blockchain in food supply chain management. Initially, we searched the term "Blockchain" AND "Supply chain management," and we collected a total of 3000+. After that, we focused on the food supply chains only. So, after the refinement of our study, we combined research terms using AND, OR connectors such as "Blockchain" AND "food Supply Chain" OR "Agri-food supply chain" OR "Agriculture food supply chain" OR "food traceability" OR "food transparency." Finally, 228 articles were extracted at the end. Many researchers commonly use this procedure in their previous work (Muessigmann et al. 2020; Hohenstein et al. 2014). All searches spanned from the period 2008 to 2021 and included journal articles, book chapters, and conference papers published in English only.

## 3.2 Selection criteria

The criteria used in this SLR are based on the PRISMA framework (Moher et al. 2009). The search is mapping the existing literature on blockchain usage in food supply chain management in the field of social sciences, computer sciences, environmental sciences, and engineering. During our initial data collection phase, we identified that no single database could contain all the articles related to the study. The search is narrowed from supply chain management to food supply chain management. We take the period of the year from 2008-to 2021. All articles before 2008 are not included in this research. Finally, 228 articles were extracted at this stage.

## 3.3 Quality assessment

This study is based on original research articles, review papers, book chapters, and conference papers. To preserve the review's quality, all duplicate entries, around 59, were removed and checked thoroughly. The abstract of the articles was checked deeply to analyze and ensure the relevance of this review search. The inclusion and exclusion criteria are explained in Table 2. There was only one non-English paper that was excluded from the search. Furthermore, after the filtration of duplicate records, 171 articles were selected for applying inclusion and exclusion criteria. Each review is deeply analyzed at a later stage.

## 3.4 Data extraction

In the data extraction phase, 150 articles were selected for the review, and the characteristic extracted were:

1. Articles must be original papers, review papers, conference papers, and book chapters. The published reports and case studies were excluded.
2. The articles must be written in the English language.
3. The published articles were from social sciences, computer sciences, electronics, and multidisciplinary research sciences.
4. The extracted articles selected for the review were published from 2008-to 2021.

**Table 1** List of databases used in the systematic literature review process ad their contribution

| Database | Papers after removing duplicates | Reduced papers after title, abstract & full reading | Full-text reading | Contribution (%) |
|---|---|---|---|---|
| Web of Science (WoS) | 58 | 2 | 56 | 37.3% |
| Wiley Library | 6 | 2 | 4 | 2.6% |
| IEEE Explore | 38 | 1 | 37 | 24.6% |
| ACM digital library | 5 | 2 | 3 | 2% |
| Science Direct (Elsevier) | 19 | 3 | 16 | 10.6% |
| Springer link | 41 | 10 | 31 | 20.6% |
| Taylor and Francis | 4 | 1 | 3 | 2% |
| Total | 171 | 21 | 150 | |

**Table 2** Inclusion and exclusion criteria followed in this process

| Sr.no | Inclusion criteria | Exclusion |
|---|---|---|
| 1 | The paper is written in English only | Paper is written in some other language |
| 2 | Articles published between 2008–2021 | Articles published before 2008 and after 2021 are not included |
| 3 | Articles that contain the content of blockchain and food supply chain | Articles that contain the content of using blockchain in the general supply chain, excluding food supply chain |
| 4 | The paper must contain empirical data related to the application of blockchain in the food supply chain | Papers focusing on financial, business, the economic impact of blockchain |

# 4 Results and interpretations

## 4.1 Descriptive analysis

Descriptive analysis is a statistic that quantitively summarizes the valuable information from the collection of data. In this study, Fig. 3 shows the yearly published documents in the field of blockchain in the food supply chain from the year 2008–2021. The emerging nature of blockchain technology indicates that before 2016 no research was focused on blockchain in food supply chains, but in 2016 the research started exploring. The bar graph in Fig. 3 clearly shows the rise of publications till 2020, with the highest peak of publications in 2020. Figure 4 depicts the relationship between the average citation per year and the number of publications in a given year. The average citation per year can be measured by dividing the total number of citations of papers by the number of papers in a given year. Moreover, 4496 citations were found in this study, with the average citation per article being 29.97. However, 30 publications published in a year between 2019 and 2021 have obtained no citations to date, so they cannot be included in this bar chart, and they may receive citations in the future.

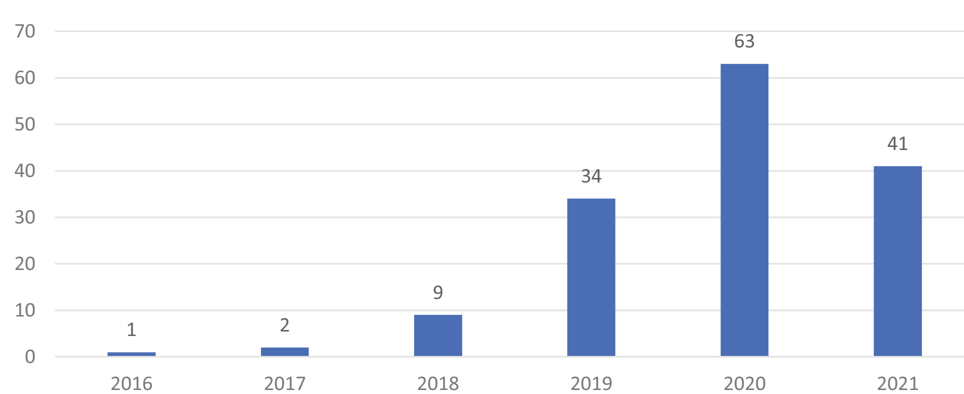
### 4.1.1 Record distribution of journals and databases

A comprehensive result in the initial phase of SLR shows the high number of studies provided by WoS (37.6%) following IEEE Explorer (26.5%), Springer (26.5%), and Science Direct (Elsevier) (4.3%) as shown in Fig. 5. The increasing interest of researchers in blockchain applications in the food supply chain leads to publications in many journals. The results of many journals' pioneering role in this field and the top leading journals by publications from the year 2016 to 2021with their impact factor working in the area are listed in Table 3. The impact factor describes the importance or rank of a journal by calculating the times its articles are cited. The table summarises the top 13 contributing journals with a maximum of 9 and a minimum of 2 publications. The rest of all journals contribute one article each.

### 4.1.2 Highly cited journals and publications

Through the SLR, we extracted the ten most highly cited journals listed in Table 4, which describe the total citations of the journal, citation per year, h-index, g-index and the number of publications in the field of the food supply chain. It is shown that the most influential journal is the IEEE Access, whose citation count is 342 and has a maximum number of publications as well. It is possible to assume that the journal has great potential in the food supply chain and the quality of the publication is also high. The top leading conferences are also listed in Table 5 with their citations count. Further, the top ten highly cited publications are listed in Table 6, with their associated author and year, total citations, and citations per year. In addition, the detailed description of these ten publications is shown in Table 7 to understand their objectives and blockchain contribution in the food supply chain area.

**Fig. 3** Records distribution of articles over the year 2008–2021



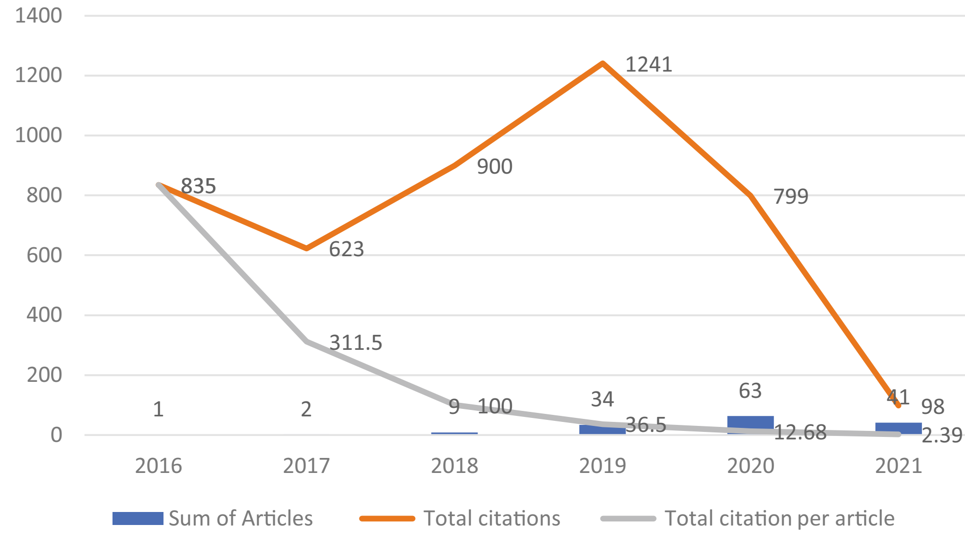



**Fig. 4** Number of articles per year with an average citation

#### 4.1.3 Type of articles

In SLR, the information regarding the distribution of reviewed papers based on their type of articles from the various databases is shown in Fig. 6. A total of 150 papers are analyzed in detail and in which 52% of papers are found to be Journal articles, 41% are conference papers and only 7% papers are book chapters. The number of journal papers is higher than the number of conference papers and the number of book chapters is the lowest among them. Further, the papers are classified into four categories: management-based, Survey-based, Framework-based and implementation-based, as shown in Fig. 7. The Management paper constitutes 13% of the total publications, 21% are Survey-based papers, 28% are Framework-based papers and 38% are implementation papers. Survey-based articles are those which explain the existing studies, current challenges and future research gaps in detail. Management-based articles belong to the social sciences studies to analyze the adoption models based on surveys, questionnaires, interviews, etc., in which the most prominent factors responsible for the adoption of technology can be predicted. Framework-based articles belong to the conceptual research by the authors to design the theoretical framework. Moreover, the implementation articles defined the experimental and simulation-based research in this area on Ethereum, hyperledger, etc., blockchain platforms. The pie chart illustrates the percentage of articles involved in these categories, which depicts that the blockchain technology is moving in its maturity phase with the increase in implementation papers and management studies are still very few. Hence, the study encourages the researchers to develop and analyze adoption models to understand the behavior of individuals towards adopting blockchain technology in the food supply chain.

Moreover, Fig. 8 depicts the country-wise distribution of articles that analyzed the user adoption behavior towards blockchain technology. It shows that China has the highest number of publications in the management study, followed by Australia and Europe. Citizens of these countries are more willing to adopt blockchain technology than other

**Table 3** Top contributing academic Journals in the field of food supply chain management

| Journals | 2018 | 2019 | 2020 | 2021 | Total | Impact factor |
|---|---|---|---|---|---|---|
| IEEE Access | | 3 | 3 | 3 | 9 | 3.745 |
| Journal of cleaner production | | 1 | 3 | 5 | 9 | 7.246 |
| International Journal of Environmental Research and Public Health | 1 | | 2 | 1 | 4 | 2.849 |
| Sustainability | | | 1 | 2 | 3 | 2.576 |
| Food control | | 1 | | 2 | 3 | 4.258 |
| Artificial Intelligence and Security | | 1 | 2 | | 3 | 6.628 |
| Applied Economic Perspectives and Policy | | | | 3 | 3 | 2.779 |
| Journal of the Science of Food and Agriculture | | 1 | 1 | | 2 | 2.614 |
| Computers and Electronics in Agriculture | | | 1 | 1 | 2 | 3.858 |
| Supply Chain Management-An International Journal | | | 2 | | 2 | 4.725 |
| International Journal of Information Management | | | 2 | | 2 | 8.210 |
| Computers & Industrial Engineering | | | | 2 | 2 | 4.135 |

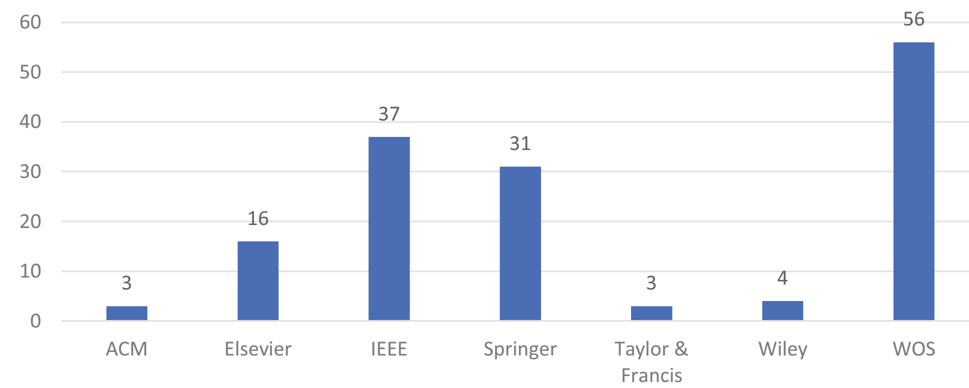



**Fig. 5** Record distribution of articles based on databases

countries. Moreover, China has already adopted blockchain technology in different areas of the food supply chain such as finance, medicine, energy and supply chain.

## 4.2 Bibliometric analysis

The bibliometric analysis technique is used to support the systematic analysis of this research article. The bibliometric analysis is a quantitative method to evaluate scientific publications, analyze publications content and network, and create maps based on available data (Moosavi et al. 2021). The data was collected from various databases, and Publish or Perish software was used to extract the data statistic of 150 articles for bibliometric analysis. The bibliometric analysis was conducted using Publish or Perish software to directly extract the data statistic from google scholar. The data statistics include author, journal, citation, and keyword statistics. Moreover, this software has a limitation of the confined bibliographic analysis. Several tools have been created for bibliographic analysis with their advantages and limitations. Based on our research, the VOS viewer is suitable for the analysis. It is practical software to provide visualization of analysis (Van Eck and Waltman 2010). The following sections describe the statistics drawn from the bibliometric analysis.

### 4.2.1 Authorship pattern and statistic

The authorship pattern explains the study of the collaboration of various authors, which leads to the maximum contribution to the literature is presented in Table 8. It has been done by single authors, followed by papers having two authors, three authors, four authors, five authors, and more than five authors.

The degree of collaboration has been calculated using Subramanyam (1983) formula:

$$C = 1 - \left(\frac{f_1}{N}\right)$$

Where, $f_1$ = *Papers having one author*

$N$ = *Total papers published in a year*

The collaboration index (CI) is calculated as (Lawani 1980):

$$CI = \frac{\sum_{j=1}^{A} \left(j * f_j\right)}{N}$$

Where, $j$ = *number of authors in a paper*

**Table 4** The top 10 most highly cited sources/ Journals based on publications related to blockchain in the food supply chain

| Journals | Citations | Citations per year | No of publications | h-index | g-index |
|---|---|---|---|---|---|
| IEEE Access | 342 | 195 | 9 | 198 | 300 |
| Trac-trends in analytical chemistry | 266 | 88.67 | 1 | 232 | 346 |
| International Journal of Information Management | 238 | 238 | 2 | 227 | 360 |
| Trends in Food Science & Technology | 238 | 119 | 1 | 295 | 455 |
| Journal of Cleaner Production | 155 | 128 | 9 | 263 | 310 |
| International Journal of Environmental Research and Public Health | 136 | 76 | 4 | 160 | 200 |
| Computers in Industry | 122 | 61 | 1 | 158 | 252 |
| IEEE Internet of things journal | 81 | 40.5 | 1 | 154 | 284 |
| Journal of the science of food and agriculture | 71 | 37.5 | 2 | 247 | 385 |
| Global food security-agriculture policy economics and environment | 64 | 32 | 1 | 1 | 1 |

**Table 5** Top highly cited conferences in the field of blockchain in food supply chain

| Journals | Citations | Citations per year | No of publications |
|---|---|---|---|
| 2016 13th International Conference on Service Systems and Service Management (ICSSSM) | 835 | 167 | 1 |
| 2017 International Conference on Service Systems and Service Management | 449 | 112.5 | 1 |
| 2018 IoT Vertical and Topical Summit on Agriculture—Tuscany (IOT Tuscany) | 244 | 81.3 | 1 |
| 2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM) | 174 | 43.5 | 1 |
| Proceedings of the 3rd International Conference on Crowd Science and Engineering | 117 | 39 | 1 |

$$f_j = number\ of\ j\ authors\ in\ a\ paper$$
$$N = Total\ papers\ published\ in\ year$$
$$A = Total\ number\ of\ authors\ per\ paper$$

The collaboration coefficient (CC) is calculated using Ajiferuke et al. (1988) formula:

$$CC = 1 - \frac{\sum_{j=1}^{A}\left(\frac{1}{j} * fj\right)}{N}$$

Where, $j = number\ of\ authors\ in\ a\ paper$

$$f_j = number\ of\ j\ authors\ in\ a\ paper$$
$$N = Total\ papers\ published\ in\ year$$
$$A = Total\ number\ of\ authors\ per\ paper$$

The value of the collaboration coefficient indicates higher the value, the better the collaboration rate. If the value is nearer to 0 indicates a weak collaboration among authors (Elango and Rajendran 2012).

Researchers play an essential role in leading blockchain technology research and exploring their applications in various fields. A total of 424 authors are involved in the publication under this domain. The most influential ten authors with their link strength having multiple publications in using blockchain technology in the food supply chain are listed in Table 9 with a total number of citations of all articles, number of articles, average citations per article by the author and total link strength between these authors. Fran casino, a postdoctoral researcher in Athena Research at Piraeus University, Greece, published maximum documents in 2019. His broader areas of publication include pattern recognition, recommender systems privacy, smart health and blockchain. Further, Thomas K. Dasaklis having their first publication in year 2019, studied supply chain management, smart logistics, blockchain, IoT, and humanitarian logistics.

The co-authorship between these publications is also conducted using VOS viewer software in which the strength of the co-authorship link with another author is calculated. The co-authorship analysis defines the involvement of two or more than two authors in a publication. It is a powerful tool to examine the group of researchers working together in the same field (Moosavi et al. 2021). From Fig. 9, it is observed that seven clusters are developed for the analysis. It provides

**Table 6** Top highly cited research articles

| Publications | Reference | Year | Citations | Citations per year |
|---|---|---|---|---|
| An agri-food supply chain traceability system for China based on RFID & blockchain technology | Tian (2016) | 2016 | 1135 | 189.17 |
| A supply chain traceability system for food safety based on HACCP, Blockchain & Internet of things | Tian (2017) | 2017 | 617 | 123.40 |
| Future challenges to the use of blockchain for food traceability analysis | Galvez et al. (2018) | 2018 | 410 | 102.50 |
| Blockchain-based traceability in Agri-Food supply chain management: A practical implementation based | Caro et al. (2018) | 2018 | 437 | 109.25 |
| The rise of blockchain technology in agriculture and food supply chains | Kamilaris et al. (2019) | 2019 | 427 | 142.33 |
| Blockchain application in food supply information security | Tse et al. (2017) | 2017 | 240 | 48 |
| Boundary conditions for traceability in food supply chains using blockchain technology | Behnke and Janssen (2020) | 2020 | 265 | 132.50 |
| Blockchain-Based Soybean Traceability in Agricultural Supply Chain | Salah et al. (2019) | 2019 | 258 | 56 |
| Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions | Zhao et al. (2019) | 2019 | 239 | 79.67 |
| Blockchain and IoT Based Food Traceability for Smart Agriculture | Lin et al. (2018) | 2018 | 215 | 53.75 |
| Food Safety Traceability System Based on Blockchain and EPCIS | Lin et al. (2019) | 2019 | 174 | 58 |

**Table 7** Description of the top highly cited publications associated with a food supply chain using blockchain technology

| Author (year) | Type of research | Objective | Technologies integrated | Blockchain contribution | Limitations |
|---|---|---|---|---|---|
| Tian (2016) | Descriptive research | Food safety | RFID & Blockchain | An Agri-food supply chain traceability system was developed | No experimental research, development cost is still high |
| Tian (2017) | Descriptive research | Food safety | Blockchain & IoT | Food supply chain traceability system for tracing food | Have not considered the scalability factor |
| Galvez et al. (2018) | Descriptive use case | Food falsification & trust | Blockchain technology | Plant food case and animal food case were described | No verification mechanism was introduced to check the authenticity of data and did not observe the implementation cost of blockchain |
| Caro et al. (2018) | Experimental research | Data integrity, tampering, and single point failure of centralized IoT system, | Blockchain and IoT | AgriBlockIoT system was compared on Hyperledger sawtooth and Ethereum platform | Have not analyzed the performance of the system using more constrained hardware |
| Kamilaris et al. (2019) | Descriptive use cases research | Impact of blockchain on agriculture and food supply chain | Blockchain | Food supply chain model was developed | Accessibility, privacy, and technical issues were not taken into consideration |
| Tse et al. (2017) | Descriptive research | Food safety and quality of life | Blockchain | Decentralized Food Supply Chain authentication model | No experimental research was done |
| Behnke and Janssenl (2020) | Exploratory research | Traceability | Blockchain | Boundary conditions for a blockchain traceability system | Lack of organizational standards |
| Salah et al. (2019) | Experimental research | Food safety and traceability | Interplanetary file system (IPFS) & blockchain | Soybean traceability system | Lack of automated payments and proof of a delivery system |
| Zhao et al. (2019) | Descriptive research | Sustainability, affordability, and food safety | Blockchain | Description of using traceability, information security, manufacturing, and sustainable water management through blockchain technology | Lack of experimental research |
| Lin et al. (2018) | Descriptive research | Food safety and traceability | IoT & Blockchain | Blockchain and IoT-based smart agriculture ecosystem framework | Smart contracts were not used for automation |

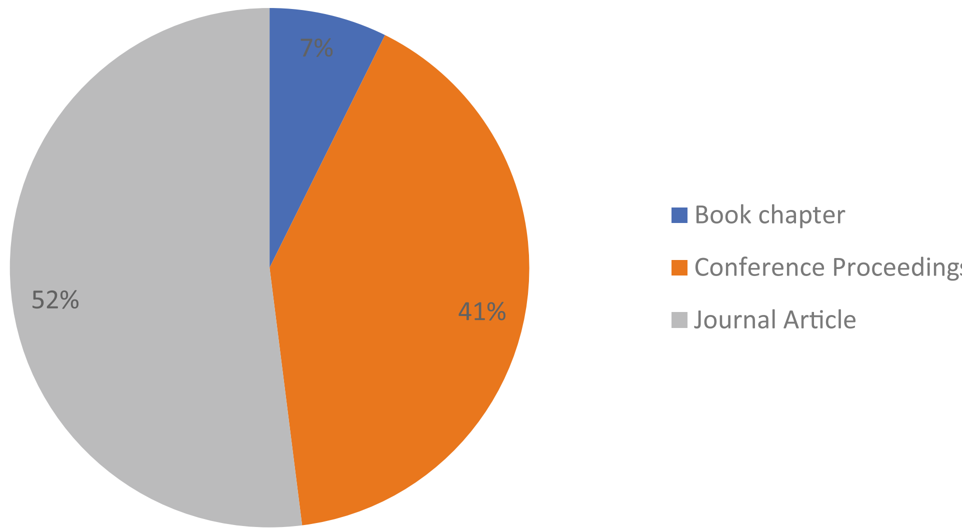



**Fig. 6** Distribution of reviewed papers based on paper types

the information of only 38 authors out of 424 authors, who are working together in the same field, the rest of them are not linked with each other. The nodes in the cluster explain the link between the authors. The papers that are not linked are not presented here. Table 10 demonstrates the number of clusters, including their co-authors and focused research area.

#### 4.2.2 Text statistics

The test statistics are also conducted using VOS viewer software, and it extracts the title and abstract field keywords. In the keyword statistic, a total number of 1782 keywords are collected out of a total of 150 papers. After selecting the "all keywords," the software recommends selecting the occurrence of a minimum number of keywords. The 103 keywords are selected to examine the occurrence of keywords with a minimum repetition of five. Table 11 demonstrates the occurrence of the most popular keywords with their respective frequencies. The most frequently repeated keywords are "blockchain" and "food supply chain," having frequencies of 0.0716 and 0.1752, respectively. This shows how these terms are interconnected with each other to attract researchers for future work. The main contributing keywords in this domain are blockchain, food supply chain, traceability, transparency, food safety and many more. Therefore, blockchain technology comes out to build trust among consumers in food safety (Xu et al. 2022).

The representation of text analysis is shown in Fig. 10. The visualization of co-occurrence analysis made 6 clusters with different colors. The size of each bubble depicts the frequency of occurrence of a keyword. The same color was depicted together to form a cluster. The blockchain, food traceability system and food supply chain are the most

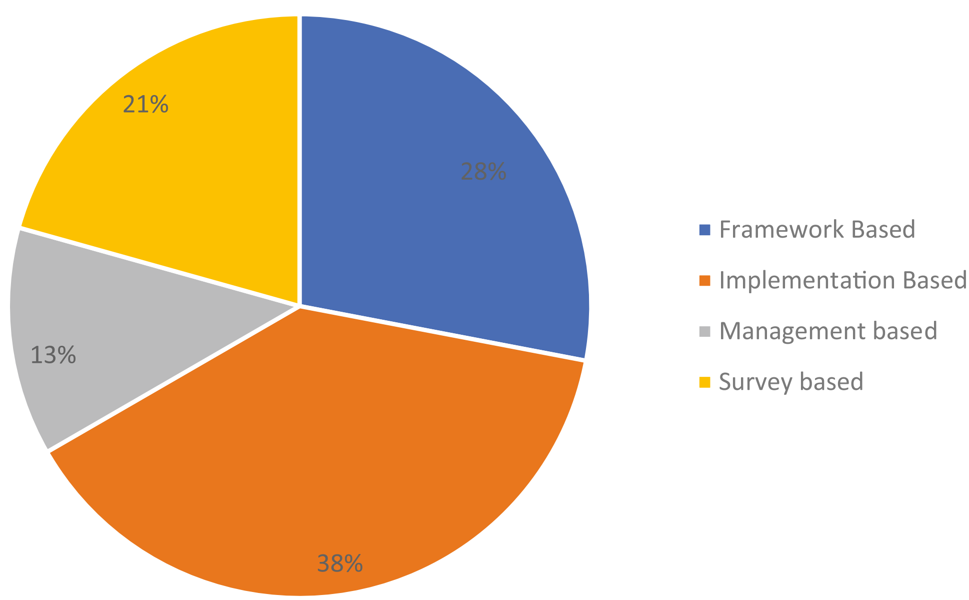
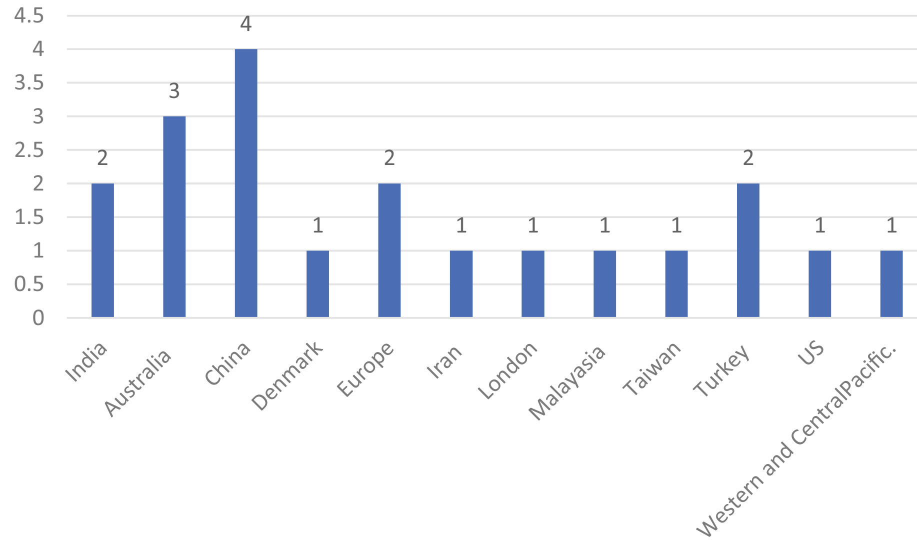



**Fig. 7** Classification of papers involved in SLR

**Fig. 8** Countries associated with management-based papers in SLR




significant nodes and are closely related to each other. Furthermore, the results show the connectivity of keywords such as "blockchain", "food supply chain" and "food traceability system" to define the directions to explore the existing literature. It would also help increase scholars' interest in adopting blockchain technology in the food supply chain.

### 4.3 Comparative analysis

Blockchain technology is coming into its maturity phase to provide value to the supply chain operations and promote optimization processes to remove the conventional challenges (Bechtsis et al. 2019). The comparative analysis addresses the second research question, RQ2, "What are the existing models and experimental studies for the blockchain-enabled in food supply chain?". During the systematic mapping of existing studies, 38% of experimental studies were extracted to answer this research question. Most of the studies were based on implementation, which indicates blockchain technology is moving from its nascent phase to a maturity phase. Researchers are exploring use-cases and applications of this revolutionary technology in streamlining the food supply chain by developing apps and solutions based on existing platforms such as Ethereum, Hyperledger Fabric, Hyperledger sawtooth etc. as shown in Fig. 11. Out of 38% of software-based implementations papers, 21.37% use Ethereum, 16.28% use Hyperledger Fabric, 2.3% use Hyperledger saw tooth, 1.3% use both Ethereum and Hyperledger sawtooth and 18.32% comes under the category of Others which involve comparison of Ethereum and Hyperledger saw tooth platforms and mathematical solutions. As per Fig. 11 mostly Ethereum platform is used for applying blockchain in food supply chain followed by Hyperledger and it would help the readers to select the platform for the upcoming implementation of blockchain technology. Moreover, this study extracted the ten most highly cited publications from highly cited journals that are based on the implementation of blockchain technology, as described in Table 12. This study also examines the particular use-case or application of existing implementation articles in the food supply chain as shown in Fig. 12. As per Fig. 12 depicts that out of total 57 implementation articles, 29 focused on traceability followed by 9 focused on transparency. The study indicates that most of the applications focused on the traceability and transparency as also shown in Text analysis that traceability and transparency are the most popular keywords.

**Table 8** Authorship pattern of papers published

| Year | Single author paper | Two author papers | Three author papers | Four author papers | Five author papers | More than five author papers | Total papers | Degree of collaboration | Collaboration index | Collaboration coefficient |
|---|---|---|---|---|---|---|---|---|---|---|
| 2016 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 2017 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 0.5 | 3 | 0.4 |
| 2018 | 1 | 1 | 1 | 4 | 1 | 1 | 9 | 0.89 | 3 | 0.67 |
| 2019 | 1 | 3 | 11 | 11 | 3 | 5 | 34 | 0.971 | 2.912 | 0.74 |
| 2020 | 1 | 11 | 17 | 14 | 9 | 11 | 63 | 0.984 | 2.77 | 0.72 |
| 2021 | 0 | 8 | 5 | 15 | 7 | 6 | 41 | 0 | 3.317 | 0.73 |

**Table 9** Top leading authors (sorted on the publication count)

| Author | Affiliation of author | No of citations | Average citations per article | Number of documents | Total link strength |
|---|---|---|---|---|---|
| wang, x | China agriculture university, Beijing, China | 253 | 63.25 | 4 | 14 |
| li, x | College of Information Science and Technology Zhongkai University of Agriculture and Engineering Guangzhou, China | 273 | 68.25 | 4 | 14 |
| casino, f | Department of Informatics, University of Piraeus, Piraeus, Greece | 137 | 45.6 | 3 | 9 |
| dasaklis, tk | Department of Informatics, University of Piraeus, Piraeus, Greece | 119 | 39.6 | 3 | 9 |
| barilla, g | Department of Mathematics and Computer Science, University of Cagliari, Cagliari, Italy | 141 | 47 | 3 | 7 |
| hao, z | University of Waterloo | 216 | 72 | 3 | 10 |
| Liu, x | School of Information Management, Nanjing University | 105 | 35 | 3 | 9 |
| mao, d | Chinese Academy of Sciences, Beijing, P.R. China | 225 | 75 | 3 | 10 |
| Tonelli, r | Department of Mathematics and Computer Science, University of Cagliari, Cagliari, Italy | 89 | 29.6 | 3 | 10 |
| yan, j | School of Information Management, Nanjing University | 119 | 39.6 | 3 | 9 |

Experimental studies belong to the real-time implementation of blockchain technology in the food supply chain sector. For example, Longo et al. (2020) proposed a food processing industry design to evaluate the amount of data stored, functionalities, reliability, and cost of using blockchain in the food industry to create transparency and provide

**Table 10** Table for clusters

| Cluster 1 | | | Cluster 2 | | |
|---|---|---|---|---|---|
| **Authors** | **Total documents** | **Research area focused** | **Authors** | **Total documents** | **Research area focused** |
| duan, j | 1 | Food supply chain, agri-food supply chain, grain supply chain, and food safety traceability supply chain | cheng, c | 2 | Agri-food supply chain and food supply chain |
| Feng, h | 1 | | fu, h | 1 | |
| sun, p | 1 | | ma, m | 1 | |
| wang, x | 4 | | tse, d | 1 | |
| xu, j | 1 | | yang, y | 1 | |
| yu, j | 1 | | zhang, b | 2 | |
| zhang, j | 1 | | Zhao, c | 1 | |
| zhang, x | 2 | | | | |
| Zhao, z | 2 | | | | |
| Cluster 3 | | | Cluster 4 | | |
| Zhao, c | 1 | Agri-food value chain, food supply chain information security, agriculture system, | fang, h | 1 | Blockchain in agriculture system and grain supply chain |
| Chen, q | 1 | | Hua, y | 1 | |
| ding, h | 1 | | lin, w | 1 | |
| Huang, x | 2 | | wang, j | 2 | |
| tao, q | 1 | | wang, v | 1 | |
| Cluster 5 | | | Cluster 6 | | |
| hua, j | 1 | Blockchain in agriculture and food safety traceability system | hao, z | 3 | Food supply chain and food safety risk traceability system |
| Kang, m | 1 | | li, h | 2 | |
| lin, q | 1 | | mao, d | 3 | |
| Pei, x | 1 | | wang, f | 2 | |
| wang, h | 2 | | zuo, m | 1 | |
| Cluster 7 | | | | | |
| merveille, n | 1 | E-agriculture blockchain | | | |
| song, l | 1 | | | | |

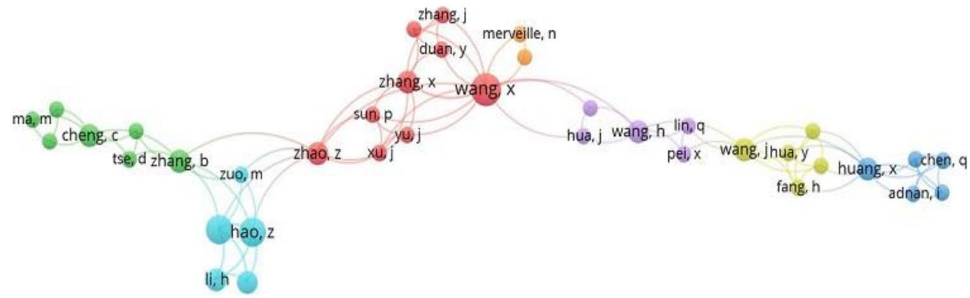



**Fig. 9** Author analysis of all authors involved in the 150 selected articles

trust to each member of the supply chain using blockchain technology. This study indicates that the transaction fees were increased as we move down the stages of the supply chain and there is no implementation cost required by the actors, as transactions run automatically. Similarly, Bumblauskas et al. (2020) designed the use case of Bytable Inc. company based on blockchain food traceability in the Midwestern USA for tracking eggs. The tracking was done transparently in the supply chain to build trust and relationships with customers. Therefore, the use of blockchain in business would transform the world's food system.

## 5 Challenges of blockchain-enabled food supply chain

Besides the benefits of using blockchain technology, various challenges also exist which has to address to reap the full benefit of this technology. Therefore, this research addresses the question, "What are the existing challenges in the literature and research gaps in using blockchain technology in food supply chain management?". The identified challenges and future research gaps that were not addressed by the research studies in the literature are depicted in Fig. 12 and discussed as follows:

**Table 11** Keyword statistic

| Title keyword | Occurrences | Frequency |
|---|---|---|
| Blockchain | 117 | 0.0716 |
| Food supply chain | 50 | 0.1752 |
| Blockchain technology | 55 | 0.1358 |
| Traceability | 49 | 0.1199 |
| Transparency | 35 | 0.2604 |
| Food safety | 26 | 0.7995 |
| Trust | 18 | 0.5849 |
| Agriculture | 17 | 0.7122 |
| Food industry | 13 | 0.6158 |
| Food traceability system | 13 | 1.2541 |
| Smart contract | 10 | 1.0009 |
| Blockchain application | 8 | 0.8275 |

1. **Integrity of data**: Many practical challenges still exist in the blockchain system. Trusted data collection is one of the biggest concerns of researchers (Modgil et al. 2022; Zhang et al. 2020). There is no existing verification mechanism to check the authenticity of data entered into the blockchain. Mutability is one of the challenges that arise in blockchain-based frameworks. To remove the biases of collected data, a fake detection mechanism could be integrated with the blockchain system (Galvez et al. 2018; Feng et al. 2020).
2. **Less storage capacity and Interoperability:** Blockchain technology is not suitable for storing large amounts of data. For example, a multilayer application contains a vast number of transactions to be executed and the speed slows down in processing a large number of transactions at a time (Casino et al. 2021). Multiple private blockchain networks are developed, which are not compatible or interoperable with each other (Galvez et al. 2018; Feng et al. 2020; Gunasekera and Valenzuela 2020; Katsikouli et al. 2021).
3. **Scalability**: It is a problem that a blockchain network can process only a few transactions per second. Though lightning networks are proposed to deal with blockchain scalability issues, they have not been fully solved and are yet to be explored in depth. Therefore, blockchain technology needs substantial computational power to compete with transaction speed which could slow down due to the large data storage demand. Scalability would be improved in terms of throughput, latency, and capacity of the blockchain platform. So, this is the major technical barrier to the adoption of blockchain technology for experimental research platforms (Tian 2016; Salah et al. 2019; Casino et al. 2021; Gunasekera and Valenzuela 2020)
4. **Insufficient resources**: The process of collaborating with all the stakeholders on the blockchain platform is complex. The inadequacy of skilled personnel is an impediment to developing a blockchain network (Kayikci et al. 2022). Moreover, there is a lack of awareness and knowledge (Katsikouli et al. 2021) and a lack of digital skills and trust (Singh et al. 2022; Sodhi and Tang 2021) among users. The study by Bumblauskas et al. (2020) clarifies in their study that blockchain technology is posi-

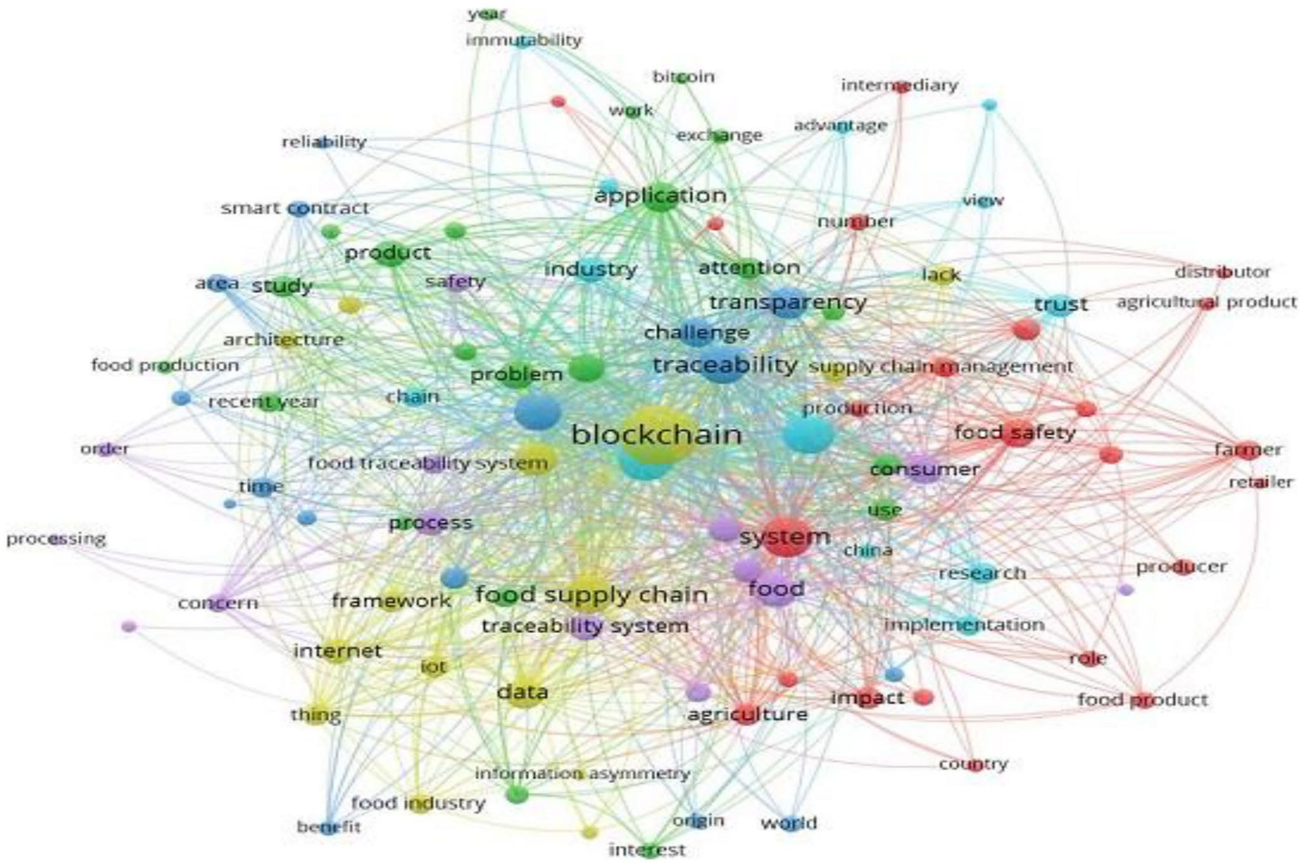



**Fig. 10** Text analysis on all keywords of the 150 selected articles

tively incorporated into the supply chain sector without changing the behavior of any stakeholders in the future. The lack of up-gradation of resources and insufficient technical solutions are the major concerns to incorporating blockchain technology into the food supply chain (Galvez et al. 2018).

5. **Standardization of processes**: Standardization of various processes in the traceability system is a critical con-

**Fig. 11** Distribution of implementation papers on the basis of platforms used

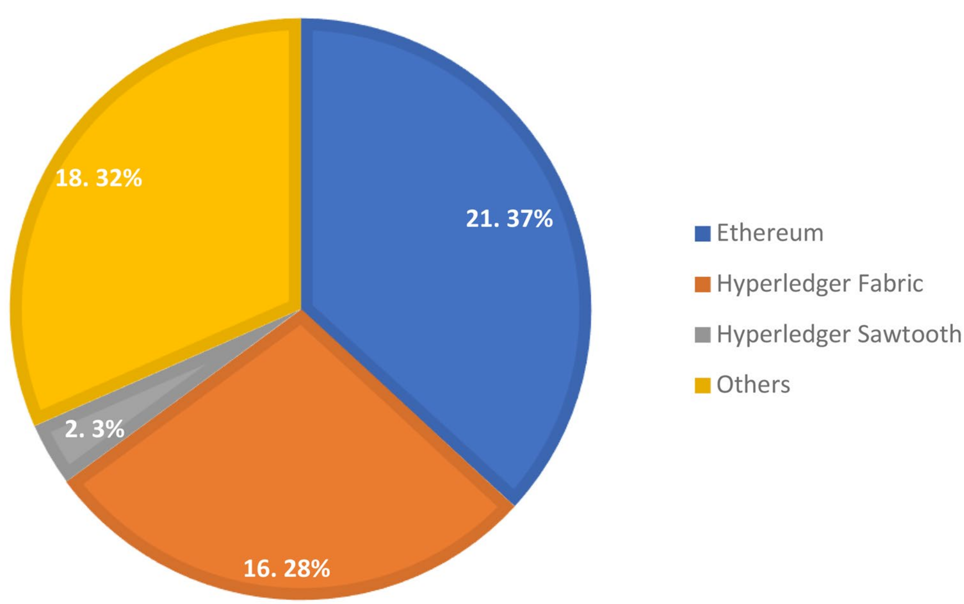


**Table 12** Comparative analysis of highly cited implementation articles in the literature

| Reference | Article | Journal and Cite score | Objective of the study | Type of block Chain | Blockchain Platform | Results | Advantages | Limitations |
|---|---|---|---|---|---|---|---|---|
| Caro et al. (2018) | Blockchain-based traceability in Agri-Food supply chain management: A practical Implementation Based | IoT Vertical and Topical Summit on Agriculture—Tuscany (IOT Tuscany) (244) | Overcome IoT challenges & make a decentralized solution for Agri-food traceability system | Private blockchain | Ethereum and Hyperledger Saw tooth | The performance of AgriBlockIoT was measured on two different platforms such as Ethereum and Hyperledger in terms of latency, network traffic, and CPU load. Hyperledger sawtooth has better results than Ethereum blockchain<br>The latency of the sawtooth platform is 0.021 s as compared to Ethereum's 16.55 s | Within a traceability system, the AgriBlockIoT system generates records that are transparent, fault-tolerant, immutable, and auditable | No performance metric for constrained hardware |
| Mao et al. (2018) | Credit Evaluation System Based on Blockchain for Multiple Stakeholders in the Food Supply Chain | International journal of environmental research and public health (90) | Food safety and traceability | Consortium blockchain | Hyperledger Fabric | Credit evaluation texts were sentiment-analyzed using long short-term memory (LSTM)<br>LSTM model F1-scores increase with corpus size and stay around 90%<br>LSTM outperforms support vector machine (SVM) and narrowband (NB) on the Chinese text dataset | Verify food supply chain trader credit and transaction data<br>Fixes stakeholder information asymmetry | Have considered only emotion tags of credit evaluation, and worked on a small dataset and less storage capacity of each node |
| Salah et al. (2019) | Blockchain-Based Soybean Traceability in Agricultural Supply Chain | IEEE Access (122) | Food safety and traceability | Public blockchain | Ethereum blockchain | Smart contracts were used to verify the transaction or function at each level<br>Algorithms were defined to describe the working principle of a proposed model, from purchasing seeds to the delivery of products in the markets | Provide tracking and tracking of the soybean supply chain<br>Remove intermediates<br>Create trust and provide a decentralized traceability system for any crop or production | The model lacks automated payments and proof of delivery |
| Lin et al. (2019) | Food Safety Traceability System Based on Blockchain and EPCIS | IEEE Access (106) | Food safety and traceability of agri-food supply chain | Public blockchain | Ethereum blockchain | Data was managed on-chain and off-chain<br>Upload and response times were used to evaluate system performance<br>Information query response averages 2 ms<br>1 GB on-chain data and query counts and 1,000 times per second, respectively | Highly decentralized system<br>Tamper-proof and prevents the loss of information<br>Highly reliable<br>Reduce the cost of using traceability systems | The speed of the consensus algorithm was very slow, which decreased the overall throughput |
| George et al. (2019) | Food quality traceability prototype for restaurants using blockchain and food quality data index | Journal of cleaner production (54) | Food quality traceability for restaurants | - | - | A blockchain prototype measured pork food quality index<br>Shelf life and product weightage were correlated using curve estimation | Data is secure<br>Maintains food quality and safety | The details of soil fertility, weather conditions, etc., were not taken into consideration |

**Table 12** (continued)

| Reference | Article | Journal and Cite score | Objective of the study | Type of block Chain | Blockchain Platform | Results | Advantages | Limitations |
|---|---|---|---|---|---|---|---|---|
| Tsang et al. (2019) | Blockchain-Driven IoT for Food Traceability with an Integrated Consensus Mechanism | IEEE Access (66) | Food traceability and quality assurance | Public blockchain | Ethereum blockchain | IoT technologies collected shipment and supply chain data. Cloud databases held the data<br>The blockchain IoT mechanism assessed fuzzy food quality throughout the supply chain<br>Over traditional blockchain, the lightweight and vaporisation blockchain mechanism was developed | The creation of a safe and dependable food supply chain traceability network. Intelligent food quality evaluation of customised shelf life and time-quality decay reduces computational load and hardware capabilities with a lightweight and vaporised blockchain design | The proposed mechanism was limited to the perishable food supply chain and<br>Proof of stake consensus algorithm (PoSCS) to supply chain functions |
| Bumblauskas et al. (2020) | A blockchain use case in food distribution: Do you know where your food has been? | International Journal of Information Management (84) | Traceability and transparency | Private blockchain | Hyperledger Sawtooth v1.0 | The proof of concept (POC) was used for the consensus mechanism<br>A web application was developed for customers for traceability of eggs via scannable QR codes<br>The scan rate of the web application was 21.2%<br>The average time each user spent on the web app was 2 min and 48 s | Customer relations<br>Optimizes<br>Prevents food fraud<br>Blockchain revolutionises food | The study did not incorporate the adoption mechanism of blockchain and no standardization exists for the traceability solutions |
| Shahid et al. (2020) | Blockchain-Based Agri-Food Supply Chain: A Complete Solution | IEEE Access (27) | Ensures traceability, trust, and delivery mechanism in the agri-Food supply chain | Public blockchain | Ethereum blockchain | Performance can be evaluated based on parameters such as traceability, trading, delivery, and reputation. A reputation system provides trust among trading entities to ensure the credibility of the system<br>It also maintains the integrity and immutability of transactions<br>Smart contracts prevent any kind of interference, hence providing security<br>The proposed smart contract was highly robust against denial-of-service attacks | Transparency, immutability, and traceability are all provided<br>It guarantees the transactions cannot be faked and that man-in-the-middle attacks are not successful<br>secures a situation where there is no trust | Refund and return mechanisms, fake review detection mechanisms, and attack analysis on the reputation system have not been integrated into the system for trading agri-food products |

**Table 12** (continued)

| Reference | Article | Journal and Cite score | Objective of the study | Type of block Chain | Blockchain Platform | Results | Advantages | Limitations |
|---|---|---|---|---|---|---|---|---|
| Zhang et al. (2020) | Blockchain-Based Safety Management System for the Grain Supply Chain | IEEE Access (13) | Food safety and information security mechanism in grain supply chain | | Hyperledger fabric | The engineering, procurement and construction industry (EPC) was used for collecting data from products used<br>A storage mechanism was developed for information management<br>Node database stores the information of each blockchain node offline and encrypted hash encrypted was stored in blockchain node in a ledger<br>Each node contains complete information and ensures the security and credibility of data<br>Smart contracts monitor food security | Blocks were traceable and could not be tampered with<br>Information is transparent<br>Eliminate information authenticity<br>The blockchain consensus mechanism develops trust among stakeholders<br>Blockchain provides complete and authentic information on the whole grain supply chain | No data verification mechanism was considered |
| Hao et al. (2020) | A novel visual analysis method of food safety risk traceability based on blockchain | International Journal of Environmental Research and Public Health (11) | Food traceability | Consortium blockchain | Hyperledger Fabric | A quantitative analysis method was proposed to check the food safety risk<br>Data downloads and uploads to the blockchain both used smart contracts<br>Heat maps were used to analyse the risks, and visualisation analysis was done to verify them<br>Migration and force-oriented graphs can be used to visualise the traceability | Ensure authenticity, integrity, and reliability of data | Sampling errors have occurred in sampling data which may affect the validity of the results |

**Table 12** (continued)

| Reference | Article | Journal and Cite score | Objective of the study | Type of block Chain | Blockchain Platform | Results | Advantages | Limitations |
|---|---|---|---|---|---|---|---|---|
| Chen et al. (2021) | Effective Management for Blockchain-Based Agri-Food Supply Chains Using Deep Reinforcement Learning | IEEE Access (0) | Food safety and traceability of agri-food supply chain | - | - | ASC developed a blockchain-based framework using the proof of work (PoW) mechanism<br>To maximise product profit, the deep reinforcement learning-based supply chain management (DR-SCM) approach was created<br>Three different scenarios were used to compare and assess DR-SCM and Q-learning methods<br>In various scenarios involving the management of the agricultural supply chain (ASC), DR-SCM outperforms Q-learning in terms of the trade-off between profit optimization and learning effectiveness | Guarantees the food safety and product traceability of the ASC system<br>DR-SCM was highly flexible in arranging production and storage<br>Agricultural production and storage were well-controlled | Have not evaluated the robustness of the algorithms used |
| Cocco et al. (2021) | A Blockchain-Based Traceability System in Agri-Food SME: Case Study of a Traditional Bakery | IEEE Access (0) | Verify the quality of Carasau Italian bread food through a transparent and auditable traceability system | Public blockchain | Ethereum blockchain | Proposed DApp for Carasau Italian bread in the Sardinia region<br>An IPFS was used to store the data<br>On the packaging, RFID and near field communication (NFC) tags were used to monitor the tracking and traceability geometric parameters<br>Overall, the proposed system improves data management in a secure and transparent manner | Guarantees transparent and auditable traceability system, user can verify the product quality & confirm the hygienic conditions | The system cost and gas to execute Ethereum blockchain & cost of setting a wireless sensor network (WSN) was not considered |
| Wang et al. (2021a, b) | Smart Contract-Based Agricultural Food Supply Chain Traceability | IEEE Access (0) | Food safety and quality | Consortium blockchain | Hyperledger Fabric | IPFS was used to store the complete information of farmers and IPFS hash value was stored in smart contracts<br>Smart contracts were used by the farmers to process any event in the supply chain<br>Hyperledger smart contacts were used to track the complete information of the tracking process | Hyperledger smart contracts can save resource consumption & eliminate intermediaries | Have not worked on the security of smart contracts |

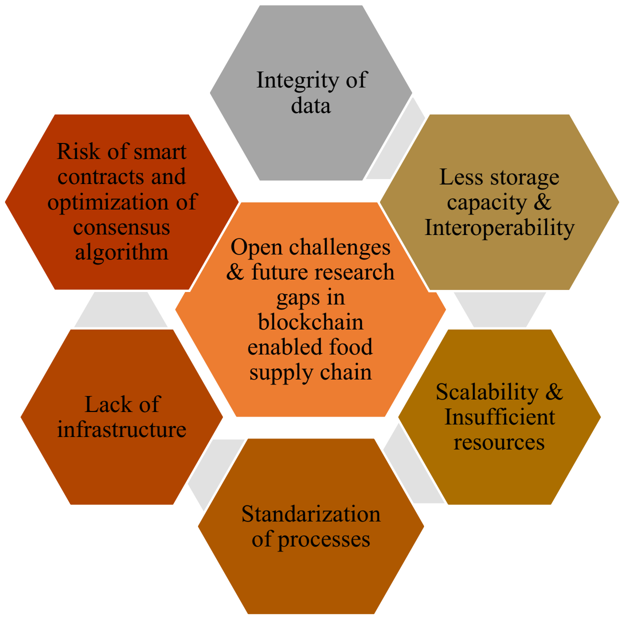



**Fig. 12** Challenges and future research gaps in the food supply chain by using blockchain technology

straint in the future. The type of data to be shared and the information of involved actors should be standardized before uploading on the blockchain platform. Privacy and security standards related to the standards and regulations should be explored in the future (Salah et al. 2019; Behnke and Janssen 2020).

6. **Lack of Infrastructure**: In the blockchain, not everything will be under the organization's control which decreases the oversight of the associated system. The blockchain quality traceability system faces a major challenge of security and public key infrastructure (Baralla et al. 2021; Dang et al. 2022).
7. **Risk of smart contracts:** Smart contracts are newer and there is limited research on their security. Poorly designed smart contracts can be exploited in the future but cannot be removed. The smart contracts are public and visible to all and the attackers can easily target the available code. The open-source code of smart contracts reduces the attack cost of hackers and becomes vulnerable to attacks (Wang et al. 2021a, b). Many security attacks such as call stack attacks, time dependency attacks, concurrency bugs, and re-entrancy vulnerability can be performed on the blockchain (Salah et al. 2019).
8. **Optimization of consensus algorithm:** Blockchains are dependent on communication and consensus mechanisms. Therefore, a good communication and correct consensus mechanism would be needed to maintain the status while working in blockchain technology. The Proof-of-Work (PoW) consensus algorithm requires high computational power to compete with other miners (Tsang et al. 2019). And the speed of data on the blockchain platform was also restricted by the consensus algorithm (Lin et al. 2019).

## 6 Discussion

The results are thoroughly covered in this section, along with their managerial ramifications. Additionally, it outlines the significant obstacles and constraints to the adoption of blockchain technology in the food supply chain. The findings reveal that blockchain implementation can largely benefit the food supply chain but their implementation still faces several issues.

Supply Chain information sharing and trust management are unprecedented. Furthermore, the monitoring of supply chain is a key governance factor for reducing transactional cost and business partners exploitation of information asymmetryIt is unclear whether supply chain monitors are providing buyer firms with complete and accurate product supply chain information (Short et al. 2016). Supply chains are changing how organisations collaborate, share, and connect to solve these issues (Akbari and Hopkins 2022). Therefore, due to an extreme disruption supply chains are increasingly relying on digital technologies for innovation to provide significant opportunities in the supply chain. Therefore, adopting new technologies has an impact on a variety of supply chain functions, such as procurement, manufacturing, logistics, warehousing, inventory management, retailing, and customer and supplier relationships. The study by Autry et al. (2010) shows a positive relationship between perceived usefulness and ease of use and the firm's intention to use a technology in supply chain. Therefore, blockchain technology has come into picture to provide innovative ideas in the food supply chain sector, promote food traceability system and wok efficiently than traditional monitoring mechanism (Chod et al. 2020).

With supply chain management becoming more and more popular, blockchain technology can offer high levels of accuracy, transparency, and real-time tracking of goods, data, owners, and actions taken at various stages (Difrancesco et al. 2022). Through the literature it was found that blockchain adoption is socially beneficial for the society, nonetheless their adoption is scare and imbalanced (Iyenger et al. 2022). The blockchain technology reduces the information symmetry and provide full traceability which brings revenue benefits to every member of supply chain (Dong et al. 2022). Furthermore, supply chain parties can make instantaneous, trustworthy, and less expensive payments thanks to blockchain technology. Table 13 contrasts the traditional supply chain with the blockchain-based agri-food supply chain.

Implementing a blockchain can aid in restoring transparency between producers and consumers. Additionally,

**Table 13** Comparison of the blockchain based agri-food supply chain system over traditional system

| Attributes | Blockchain enabled system for the agri-food supply chain | Traditional system |
|---|---|---|
| Immutability | The information once stored cannot be altered | The admin in the centralized system can easily alter information |
| Smart contracts | They automatically execute when predetermined conditions are met according to the signed agreement | No automation |
| Trust | Creates trust among various stakeholders in agri-food supply chain | Centralized system can create trust issues |
| Storage | Distributed network of system | Centralized storage system |
| Architecture | Fully decentralized | Centralized |

blockchain technology's distributed ledger and collaborative nature boost trust among different supply chain participants while delivering traceability and transparency. This function helps to lessen the need for a third party and gets rid of the chain's fraudulent activities. Additionally, blockchain technology increases efficiency in the complex agriculture supply chain and adds sustainability to the sector of supply chains (Mukherjee et al. 2022). The results of the study using SLR demonstrate the necessity of implementing blockchain in the food supply chain. It gives the scientific panorama of existing studies in this area, including conceptual, empirical, and experimental studies. The PRISMA methodology is adopted to conduct the SLR from 2016 to 2021. According to the literature, 39% of studied papers are implementation-based, 27% of them belong to framework-based studies, 19% of papers belong to management-based studies and, 15% of papers are survey-based. Based on the comparative analysis, different type of blockchain exists in which public blockchain is the highest frequently used blockchain in the implementation of the food supply chain. Ethereum and hyperledger are the most frequently used platforms for blockchain which brings organisation together and enables a new level of trust and transparency in the supply chains. VOSviewer software is used to observe the prominent trends and themes in this domain. "Blockchain" and "Food supply chain" are the highly occurred keywords having a frequency of 0.0716 and 0.1752, respectively. In addition, Fran casino and, Thomas K. Dasaklis are the leading authors working in this domain. All parties that handle the products should be connected to the blockchain platform, and farmers, suppliers, distributors, and retailers must all be involved for the blockchain technology to be successfully implemented in the food supply chain. The shortcomings of conventional supply chains can be addressed by blockchain technology. This study further highlights some of the barriers in adopting blockchain technology in food supply chain and implementing their applications in various scenarios (Han and Rani 2022). Some of the open challenges and future research trends includes high scalability, sufficient resources, data integrity, optimization of consensus algorithm and security of smart contracts need to be focused on while designing a blockchain platform for food supply chain management. Furthermore, there exist limited platforms for education and training of blockchain systems in developing countries, due to which new users need help accessing the market fluctuations and ambiguity. It is evident from the challenges (mentioned in Section 5) that pay close attention to the hardware deployment, storage capacity, transaction speed, scalability issue, and overall technical performance of the blockchain-enabled food supply chains. Aside from the blockchain features, it is still a new technology to explore and it is insufficiently tested yet. The issues that stakeholders may need to discuss in the future include whether the supply chain will adopt blockchain technology, how the conditions for adoption will change in this cutthroat environment, and how blockchain could improve the sustainability of the blockchain-enabled food supply chain (Fan et al. 2020). According to Mirabelli and Solina (2020), the use of blockchain in the agriculture supply chain is still a relatively new idea, and there aren't many actual case studies in the literature yet. It is unclear how blockchain technology might in the future help the supply chain for agriculture. Therefore, to fill in these knowledge gaps, future research could concentrate on the implementation of a blockchain-based agriculture food supply chain.

## 7 Conclusion and future aspects

The innovation based on technology is not only studied in the field of engineering; they are and gain using researchers' interest in other areas as well. This study aims to determine whether blockchain technology is being used more frequently in the food supply chain. It offers a comprehensive review of the literature using PRISMA guidelines and bibliometric evaluation of 150 articles. A supply chain begins with the producer, includes numerous middlemen along the way, and concludes with the product being delivered to the customer. In the age of digitization, blockchain technology can do away with the need for middlemen in the food supply chain and fosters confidence among all parties involved. Blockchain technology enhances data privacy and increases the transparency and traceability of the food supply chain. This study provides information regarding the year of publication starts, type of publication, citation analysis, bibliometric analysis, authorship pattern, keyword analysis and trend of blockchain in the field of the food supply chain. The findings of this study will provide managers and researchers with evidence that the right investment in blockchain technology in the food supply chain does significantly contribute to the bottom line; they should be able to make better and transparent allocation of the resources for the food supply chain. The structured data acquired from various academic search engines were analyzed and visualized using VOS viewer software. This study indicates the increase of blockchain usage and their publications in the food supply chain during the year 2016 to 2021, and "blockchain" is the highest occurring keyword in the publications. Therefore, it is a leading topic in the field of food supply chain management. The comparative analysis of the existing literature revealed that blockchain is moving from its nascent stage to its maturity stage. It appears as a promising technology in the food supply chain in multiple aspects, such as tracing and tracking food, determining the quality of food, ensuring food safety and security, supply and demand matching, and providing transparency in terms of price and stakeholders involved and sales. At the end of the study, open challenges and future prospects are also discussed, which serve as significant areas for future research.

## Declarations

**Competing interest** The authors have no competing interest to declare that are relevant to the content of this article.

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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