Discovering the Global Landscape of Agri-Food and Blockchain: A Bibliometric Review

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***Abstract*—The agri-food supply chain encompasses all the entities involved in the production and processing of food, from producers to consumers. Traceability is crucial in ensuring that food products are available, affordable, and accessible. Blockchain technology has been proposed as a way to improve traceability in the agri-food supply chain by providing transparency and trust. However, research in this area is still in its early stages. This study aims to examine the trend of blockchain in agri-food supply chain traceability for food security. A bibliometric analysis was conducted on 1047 scholarly works from the Scopus database, starting in 2016. The analysis looked at citation patterns and the development of blockchain technology in agri-food supply chain research and identified trends by source title, nation, institution, and key players. The analysis also examined the frequency of keywords, titles, and abstracts to identify key themes. The analysis has revealed a strong correlation between blockchain technology and traceability in the agri-food supply chain, indicating a promising area for further research. The results show that blockchain-based research for traceability in the agri-food supply chain has increased and is being widely distributed, particularly in regions beyond Europe. The potential benefits it can bring to the supply chain will contribute to the success of the Sustainable Development Goals (SDGs) by ensuring a safe and sufficient global food supply.**

Keywords*—*Agri-food supply chain; bibliometric; blockchain; traceability

I. INTRODUCTION

Food security, nutrition, and safety are all interrelated. 600 million people around the world are sick because of contaminated food, which causes 420,000 deaths and 33 million healthy life years (DALYs) every year. In low- and middle-income countries, unsafe food costs US$110 billion every year. 40% of foodborne illnesses are experienced by children younger than five years old [1]. The agri-food sector and its supply chain play a crucial role in the global food system, involving the production, processing, transformation, and delivery of food products [2]. The study in [3] emphasise the difficulties that the agri-food industry encounters as a result of globalisation, such as the risks to food security, shortages in infrastructure, financial instability, and incidents of food fraud. This will be solved by implementing traceability in the agri-food supply chain.

However, the complex structure of the agri-food supply chain, which encompasses several stakeholders such as farmers, distributors, processors, wholesalers, retailers, and end consumers, creates difficulties [4].

Traceability refers to the capacity to systematically monitor and trace the movement of a product across the supply chain, starting from its origin to its final destination. The objective of traceability is to provide fast retrieval of dependable data, hence facilitating quick analysis and decision-making [5], [6]. For this reason, traceability has gained major importance in the agri-food sector due to customer demand for transparency, accountability, and food safety. Factors driving this demand include increasing supply chain efficiency, technological advancements, sustainability, food safety, regulations, certifications, and data collection and analysis [7]. Traceability is an essential feature of blockchain technology for supply chain applications [8], with a growing number of blockchain applications focusing on enabling supply chain traceability across various industries [9], [10], [11]. Blockchain technology has been suggested to improve traceability in the agri-food supply chain because it offers a transparent, reliable, and tamper-proof solution to managing product-related traceability information [12].

Blockchain technology is a decentralized system that provides immutability, security, and transparency in the ledger of transactions across a network of computers. Due to its capabilities, its application as across various industry such agriculture, healthcare and manufacturing. [13], has found traceability to be the primary enabler for blockchain technology implementation in the agri-food supply chain, followed by auditability, immutability, and provenance. For example, the provenance of food can be traced using blockchain technology, thus creating reliable food supply chains and fostering confidence between consumers and producers [6]. Besides that, blockchain-based supply chain technologies are anticipated to enhance performance, competitiveness, transparency, and trust among all participants [14]. This technology enhances operational efficiency, expedites processes, and eliminates the need for physical documentation, therefore providing accessibility, transparency, and integrity. By enhancing supply chain traceability, accountability, and efficiency, blockchain technology has the potential to revolutionise the manufacturing sector. It can address concerns such as intrinsic security and content modification requiring authentication and processing. It is also capable of managing assemblies and products, ensuring the privacy of data storage [15]. A novel framework that utilises a blockchain network to facilitate supply chain traceability and counterfeit detection of COVID-19 vaccines has been proposed by [16]. It facilitates the secure management of supply chain operations for distribution companies to prevent fraudulent vaccines and transform supply chain management in the healthcare industry. This

information will aid practitioners and policymakers in implementing blockchain technology in the agri-food supply chain to ensure food safety and security.

The globalisation of agricultural production has resulted in an increased focus on ensuring the safety, quality, and validation of standards throughout food supply chains. Blockchain technology offers a novel way for tracing products in intricate ecosystems. Various methodologies have been utilised to establish the ability to track and trace products in the agricultural food supply chain. A framework that utilises blockchain technology has been proposed for the agri-food supply chain in Bangladesh to resolve the issue of inadequate communication between producers and consumers in the traditional agricultural network [17]. [18]present ShrimpChain, a hybrid public-private Blockchain architecture, designed to enhance traceability and provide a full view of the supply chain in the shrimp industry. This framework aims to address the limitations of the traditional paper-based record-keeping methods now used in the fragmented shrimp supply chain. A blockchain-powered solution for monitoring and tracing soybeans in the agricultural supply chain is presented by [19] to improve efficiency and safety by eliminating the need for centralised authorities. The increasing need for ethical and ecological standards requires the ability to track items from their origin to their final point of sale. Utilising block-chain technology, along with RFID and QR codes, can effectively overcome limitations in current systems and streamline processes, such as monitoring the entire journey of cheese supply chains [20]. This technology can also enable smart contracts to automate supply chain management and product quality control [12]. Nevertheless, the integration of blockchain technology into the agri-food supply chain remains nascent, presenting challenges including but not limited to scalability, energy consumption, privacy, and complexity [21], [22], [23]. In order to fully realize its potential to revolutionize the agri-food supply chain through the provision of transparency, provenance, and efficiency, it is critical to address these challenges.

Subsequently, substantial progress has been made in the field of agri-food blockchain research; therefore, it is vital to remain abreast of the latest developments in the body of literature. A bibliometric analysis was performed on published blockchain in agri-food research, regardless of timeframe, in order to determine the scope and depth of scholarly work pertaining to blockchain in the agri-food sector. It attempts to respond to four primary research questions.

RQ1. What is the current trend and impact of publication in agri-food and blockchain?

- Growth of publication by year
- Sources Type and Types of Document
- Languages of documents
- Most active source titles

RQ2. Which are the most productive and influential countries, institutions and authors on agri-food and blockchain research?

- Total Publication by Country Top 15
- Most active institutions Top 15
- Authorship Analysis Top 15

RQ3. Which are the most prevalent themes of agri-food and blockchain between scholars?

- Keyword analysis
- Title and abstract analysis

RQ4. Which are the most influential articles on agri-food and blockchain research?

- Citation analysis

This work contributes to the existing research on the application of blockchain technology in the agri-food industries by providing a comprehensive bibliometric analysis of previous papers on the topic. The study provides insights into the current status of the topic, prominent publications, authors, journals, and organisations in the agri-food industries. The study's findings could guide future research on the topic and offer policymakers and industry stakeholders' better knowledge of the application of blockchain technology in the agri-food sector.

The subsequent sections of this paper are organised in the following manner: Section II provides a comprehensive evaluation of blockchain technology and its possible applications in the agri-food industry. Section III discusses the methodology and data collection for the study. The findings from our bibliometric analysis, which encompass publication output, citation impact, research themes, and collaboration patterns, are outlined in Section IV. Section V of our report explores into our study findings and their connection to the previously indicated research questions. Section VI serves as the concluding part of this article, containing its final remarks and findings.

II. Related Work

In recent years, blockchain technology has received a lot of interest as a potential solution for improving transparency, traceability, and efficiency in agri-food supply chains. Blockchain improves traceability by allowing consumers to trace their food products from farm to table. The transparency alleviates concerns about food safety and authenticity [24]. Several studies have been conducted to address blockchain challenges and limitations such as scalability, data privacy, data accuracy, security, lack of regulations and adoption [25], [26], [27], [28], [29], [30]. However, additional research is required to explore the potential of blockchain technology in agri-food supply chains and to develop effective frameworks and models for its implementation. For instance, [31], [32] introduced a food safety supply chain traceability system that relies on HACCP (Hazard Analysis Critical Control Point), blockchain, and the Internet of Things. In addition, he commented on the benefits and limitations of RFID and blockchain. The suggested traceability system in the study successfully implemented automated data collection and storage to enhance information transparency and improve food

safety. [33] [34] suggested a traceability system that utilizes blockchain technology and Internet of Things devices for gathering data. The study in [35] examined the utilization of blockchain technology in the food supply chain and evaluated particular cases of traceability within the existing food supply chain. The study in [19] conducted an analysis on the traceability of soybean supply chain, specifically focusing on the use of a smart contract to guarantee the safety, credibility, and security of information.

Previous research has examined the attributes and capabilities of blockchain technology in relation to food traceability issues. These studies have also emphasized the advantages and challenges associated with the deployment of traceability systems based on blockchain technology. While the prospective benefits of BCT in the agri-food sector are promising, it is essential to possess a comprehensive understanding of the present state of research. This can be achieved by doing a bibliometric analysis of the literature.

III. Methodology

A. Database Selection

The Scopus database was employed to conduct the analysis of the documents that were acquired for this bibliometric investigation. Scopus, the preeminent academic database, comprises an extensive collection of citations spanning 240 disciplines, including over 28,000 active titles, 7000 publishers, 93 million documents, 17.6 million author profiles, 234,000 volumes, and over 94,800 institutional profiles. The reason for selecting this database is its ability to offer an all-encompassing depiction of the scientific research output worldwide. The study in [36] found that WoS covers 54% of Scopus publications, while Scopus includes 84% of WoS titles. Scopus offers smart tools for tracking, analyzing, and visualizing research, ensuring critical analysis from around the world is not missed. At present, the Scopus database is considered by the international scientific community to be one of the most important sources of pertinent data [37]. Consequently, Scopus is recommended as a valuable database for extracting materials pertinent to the subject matter investigated in this study.

B. Inclusion Criteria

During the procedure of data collection, we employed a keyword to determine the relevant documents. The phrases ("food" or "agri-food," or "agro-food") and ("blockchain" or "block-chain") were utilized to search the Scopus database for information contained in article titles and abstracts. The search was conducted on December 5, 2023, resulting in the discovery of a total of 1053 documents. The documents went through additional screening to exclude unrelated subject areas such as business, management and accounting, mathematics, social sciences, environmental science, and energy. The focus was narrowed down to only computer science and engineering, resulting in a total of 1047 documents retrieved by Scopus. Furthermore, the review of publications was conducted using the standardized methodology of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement. The steps of this technique are illustrated in a flow chart (see Fig. 1). Therefore, this article ensures compliance by following the precise procedures outlined in the PRISMA protocol (Petersen et al., 2008).

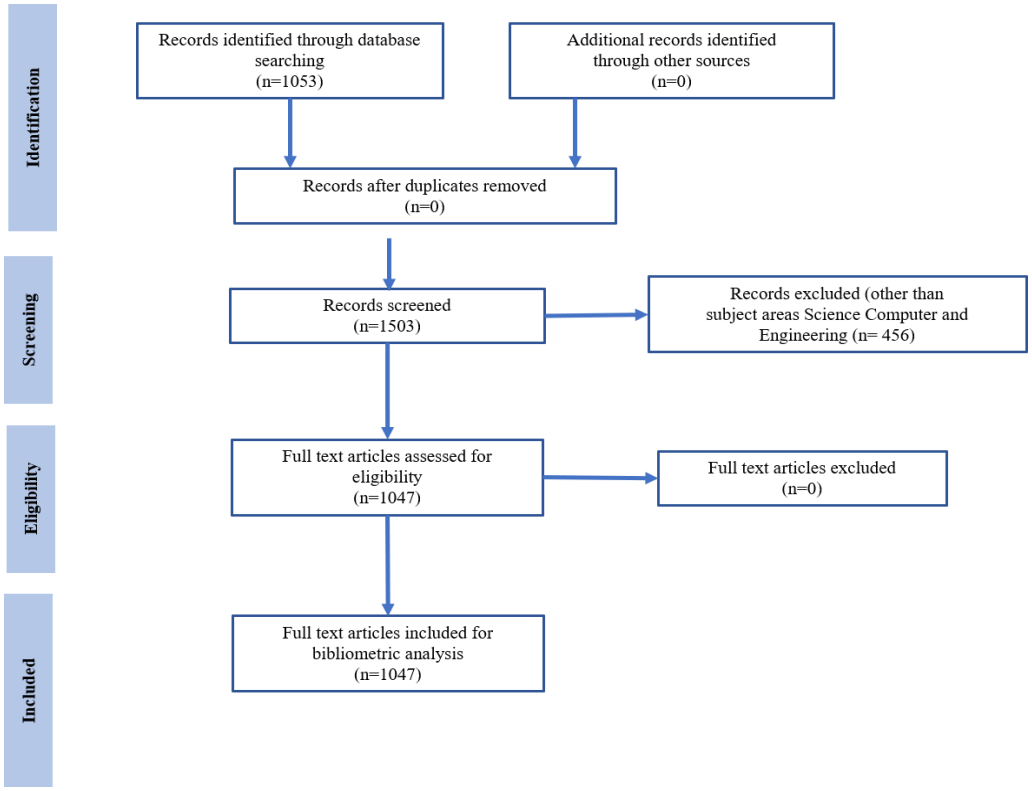

Fig. 1. PRISMA flowchart.

C. Data Analysis and Tools

Fig. 2 depicts the research framework to acquire the ultimate results. Bibliometric analysis is frequently used due to its capacity to provide dependable quantification and evaluation of the publications that are indexed in the database being studied [39]. This research additionally adds by utilizing the bibliometric technique to enhance academics' comprehension of the literature regarding the implementation of blockchain technology in the agri-food sector. Hence, bibliometric analyses remain a vital tool for identifying gaps in any given subject or field [40]. A total of 1047 documents as resulted in data collection phases were downloaded in CSV Excel and RIS format for the analysis process. The metadata in the CSV Excel and RIS file were analyzed using VOSviewer software to identify the primary research areas and generate several visual representations and tables.

Microsoft Excel was utilized for frequency analysis, while VOSviewer was employed for data visualization. Harzing's Publish or Perish was utilized for citation metrics and analysis. The data were analysed according to the geographical location of the research, the number of publications per year, the presence of highly cited works, and the journals that had the greatest number of relevant papers. This study investigates the application of blockchain in agri-food supply chain research using the abstract and title keywords fields and covering all languages in the Scopus database.

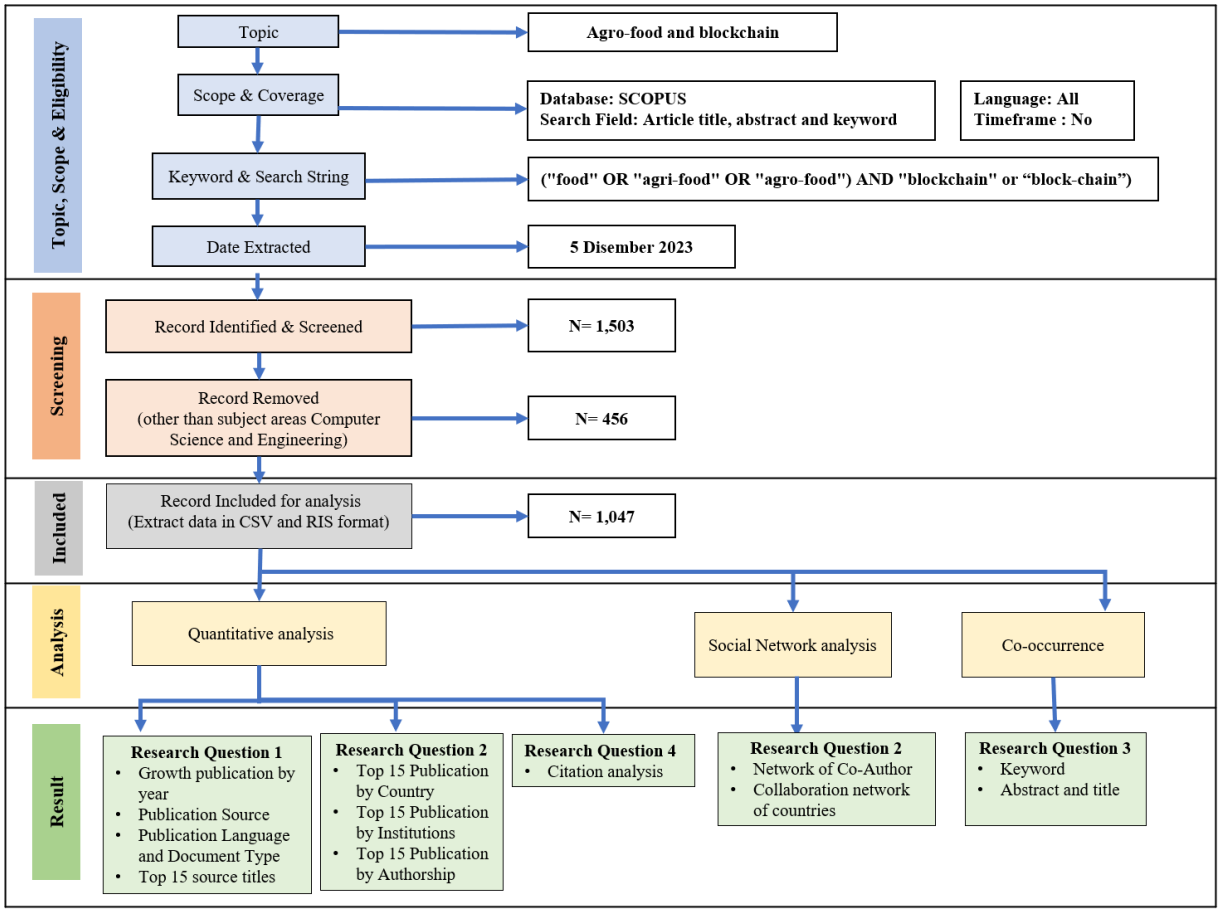

Fig. 2. Research framework.

IV. Analysis Results

A. Development and Progress of the Agri-Food and Blockchain Research

To address the first research question, we examined the progress and dissemination of Agri-food and blockchain research based on the following factors: (a) the annual count of published studies; (b) the sources and types of documents; (c) the languages in which the documents were written; and (d) the titles of the sources.

1) The annual count of published studies: Table 1 shows annual growth of publication by year for agri-food and blockchain, along with various metrics such as total publications (TP), percentage of total publications (%), number of total publications (NCP), total citations (TC), average citations per publications (C/P), average citations per cited publication(C/CP), h-index and g-index.

The number of publications has increased from 1 in 2016 to 278 in 2022, with an increasing trend in average citations per publication (C/P) and C/CP. The h-index and g-index provide insights into the author's impact, with the h-index increasing from 5 in 2017 to 32 in 2021 and the g-index reaching 55 in 2021. However, in 2023, there will be a slight decline in total publications because the year has not yet been

completed. Additionally, as depicted in Fig. 3, the number of citations for documents published in 2020 appeared to have peaked at 6,667, with an average of 46.62 citations per publication. However, beginning in 2021, the number of citations began to decline. The increase in total citations in 2020 may be attributed to the COVID-19 pandemic, which has emphasized the criticality of food traceability in guaranteeing food safety. Conversely, papers that were published in 2016 received the fewest citations (one citation per publication out of a total of 74 citations). The low number of citations is presumably related to the nascent stage of blockchain implementation in the agri-food sector. From 2016 to 2020, however, the overall quantity of citations increased dramatically. Total publications are on the rise, as depicted in Fig. 3, whereas total citations are declining after 2020. The sources for blockchain in agri-food research, document categories, most active source titles, and the language of documents utilized in blockchain in agri-food publications are further explored subsequently to the identification of the annual growth document.

2) The sources and types of documents: An investigation was conducted to determine the publication areas of agri-food and blockchain documents through an analysis of the data grouped by document source categories. There are five primary sources—journals, conference proceedings, books, book series, and trade journals. Journals constituted the most prevalent source, comprising 414 (or 39.54%) of the total, followed by publications for conference proceedings (n = 379, 36.20%), as shown in Fig. 4. Book series, comprising 16.91%, offer comprehensive perspectives on specific themes. Individual books, accounting for 6.49%, provide in-depth exploration and authoritative references. Trade journals, a smaller but specialized portion, make up 0.86% of the total publications.

Document type analysis was also performed on the data. As summarized in Fig. 5, the Scopus search yielded ten distinct categories of documents that were published on the agri-food and blockchain. The majority of publications (n = 442, 42.22%) are categorized as Conference papers, as indicated in the table followed by Article (n = 360, 34.38%). However, book chapter, Conference review and review articles category comprised less than 10% of the total publications. Less than 1% of the total publications were comprised of the remaining document categories, including books, editorials, notes, erratum, and short survey.

3) Languages of documents: In total, research papers for agri-food and traceability were composed in five languages. English was the most extensively utilized language, accounting for 98.09% of all publications, as shown in Fig. 6. Chinese was the second most prevalent language, comprising 1.62% of the total. Most of the remaining documents (less than 0.5%) were published in German, Polish, and Spanish. In conclusion, only three documents were published in a single language: German, Polish, and Spanish. This represents the tiniest fraction of the overall document count, amounting to 0.30%.

TABLE I. GROWTH OF PUBLICATION BY YEAR

Year	TP	%	NCP	TC	C/P	C/CP	h	g
2024	6	0.57%	0	0	0.00	0.00	0	0
2023	263	25.12%	91	558	2.12	6.13	11	26
2022	278	26.55%	182	2066	7.43	11.35	24	37
2021	218	20.82%	167	3575	16.40	21.41	32	55
2020	143	13.66%	117	6667	46.62	56.98	34	80
2019	97	9.26%	85	4001	41.25	47.07	32	62
2018	35	3.34%	26	1642	46.91	63.15	15	26
2017	6	0.57%	6	522	87.00	87.00	5	6
2016	1	0.10%	1	74	74.00	74.00	1	1

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P =average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index

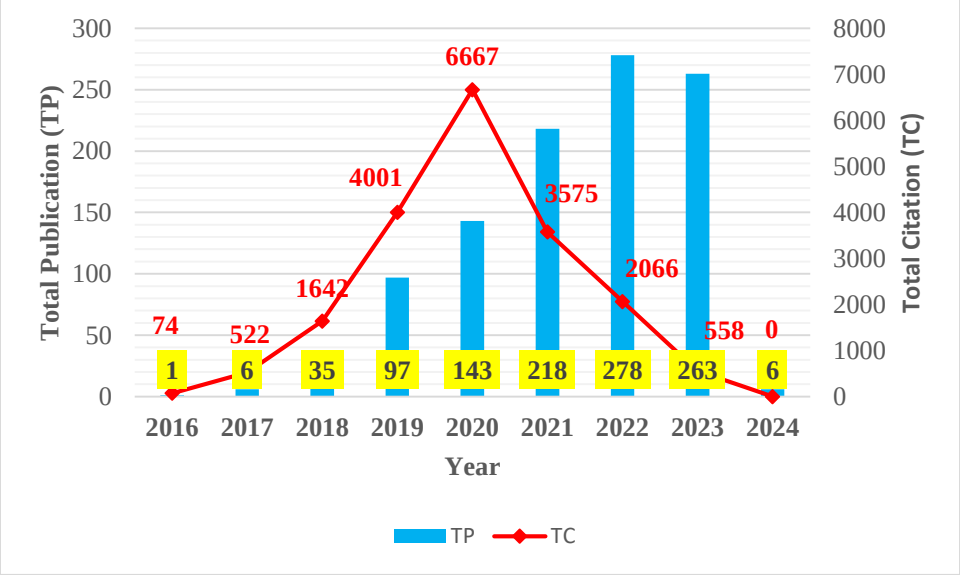

Fig. 3. Total publications and citations by year.

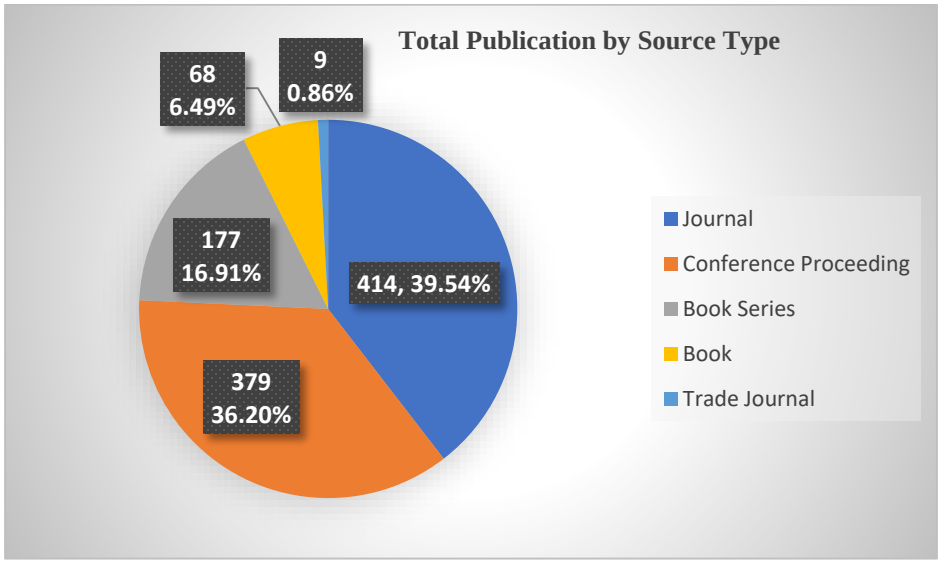

Fig. 4. Total publications based on source type.

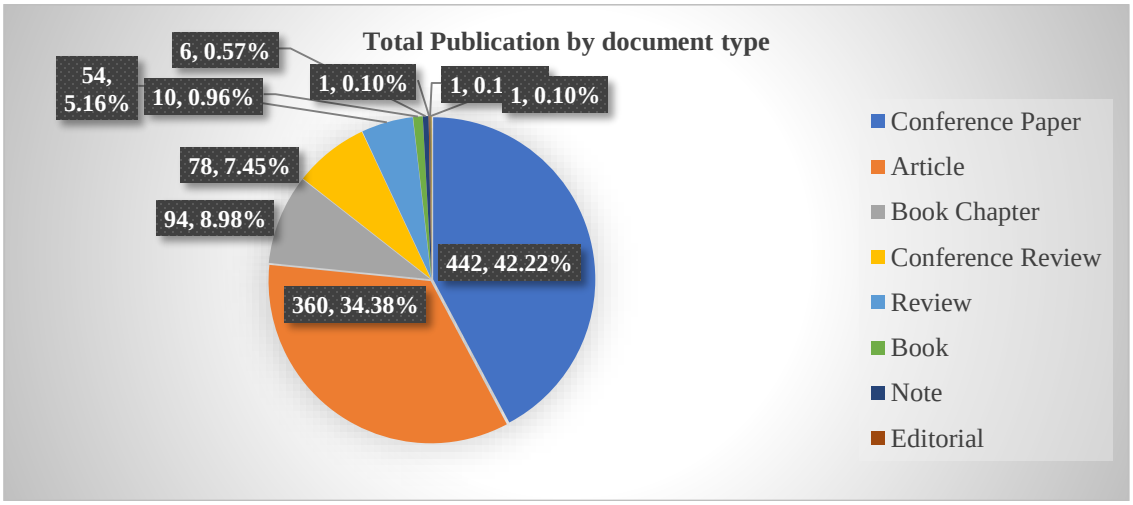

Fig. 5. Total Publication based on document type.

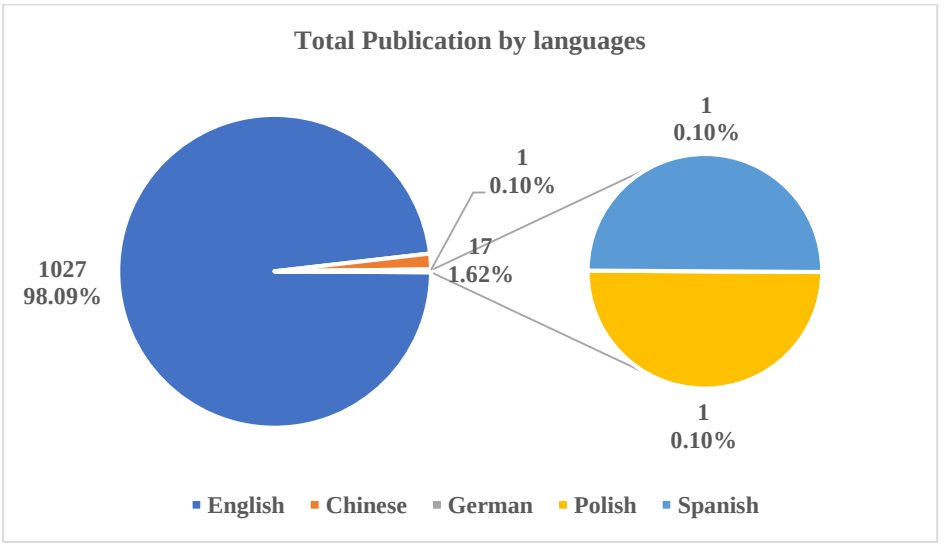

Fig. 6. Total publication based on languages.

4) Publication by source title: After identifying the current trends in sources, document types, and languages of agri-food blockchain research, the last criteria are to examine the source title. The results show that the journal that made the most substantial contribution to the agri-food and blockchain literature was Sustainability Switzerland (n = 42). Lecture Notes in Networks and Systems (n = 35), IEEE Access (n=34) and ACM International Conference Proceeding Series (n=32) are nearly identical indicating a significant 9.65% contribution, as reported by these result. The Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics subsequently appeared, comprising more than 25 articles. However, the rest of publication, contribute less than 20 articles. Despite having a smaller number of publications in total, Journal of Cleaner Production exhibited the second highest citations (n = 1215), after IEEE Access (n = 2246). The top fifteen most active source titles of blockchain in agri-food based on total publication are shown in Table II and while Fig. 7 compares total publication versus total citations.

TABLE II. TOP 15 SOURCE TITLE

Source Title	TP	%	Publisher	Cite Score 2022	SJR 2022	SNIP 2022	NCP	TC	C/P	C/CP	h	g
Sustainability Switzerland	42	4.01%	MDPI	5.8	0.664	1.198	38	803	19.12	21.13	14	27
Lecture Notes In Networks And Systems	35	3.34%	Springer Nature	0.7	0.151	0.19	12	33	0.94	2.75	3	4
IEEE Access	34	3.25%	IEEE	9	0.926	1.422	30	2246	66.06	74.87	19	30
ACM International Conference Proceeding Series	32	3.06%	Association for Computing Machinery	28.5	4.457	7.155	15	173	5.41	11.53	6	13
Lecture Notes In Computer Science Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics	26	2.48%	Springer Nature	2.2	0.32	0.542	15	305	11.73	20.33	8	15
Advances In Intelligent Systems And Computing	18	1.72%	Discontinued in Scopus as of 2021				12	145	8.06	12.08	7	12
Communications In Computer And Information Science	17	1.62%	Springer Nature	1	0.194	0.241	9	132	7.76	14.67	4	9
Journal Of Cleaner Production	16	1.53%	Elsevier	18.5	1.981	2.379	14	1215	75.94	86.79	11	14
Lecture Notes In Electrical Engineering	13	1.24%	Springer Nature	0.6	0.147	0.158	3	14	1.08	4.67	2	3
Ceur Workshop Proceedings	11	1.05%		1.1	0.202	0.223	2	3	0.27	1.50	1	1
Lecture Notes Of The Institute For Computer Sciences Social Informatics And Telecommunications Engineering	9	0.86%	Springer Nature	0.7	0.159	0.137	1	4	0.44	4.00	1	1
Lecture Notes On Data Engineering And Communications Technologies	9	0.86%	Springer Nature	0.7	0.125	0.104	5	16	1.78	3.20	2	3
Sensors	9	0.86%	MDPI	6.8	0.764	1.317	7	118	13.11	16.86	5	7
Applied Sciences Switzerland	8	0.76%	MDPI	4.5	0.492	0.974	8	280	35.00	35.00	6	8
IFIP Advances In Information And Communication Technology	8	0.76%	Springer Nature	1.4	0.255	0.364	2	9	1.13	4.50	2	2

Notes: TP = total number of publications; TC = total citations; CiteScore = average citations received per document published in the source title; SJR = SCImago Journal Rank measures weighted citations received by the source title; SNIP = source normalised impact per paper measures actual citations received relative to citations expected for the source title's subject field;

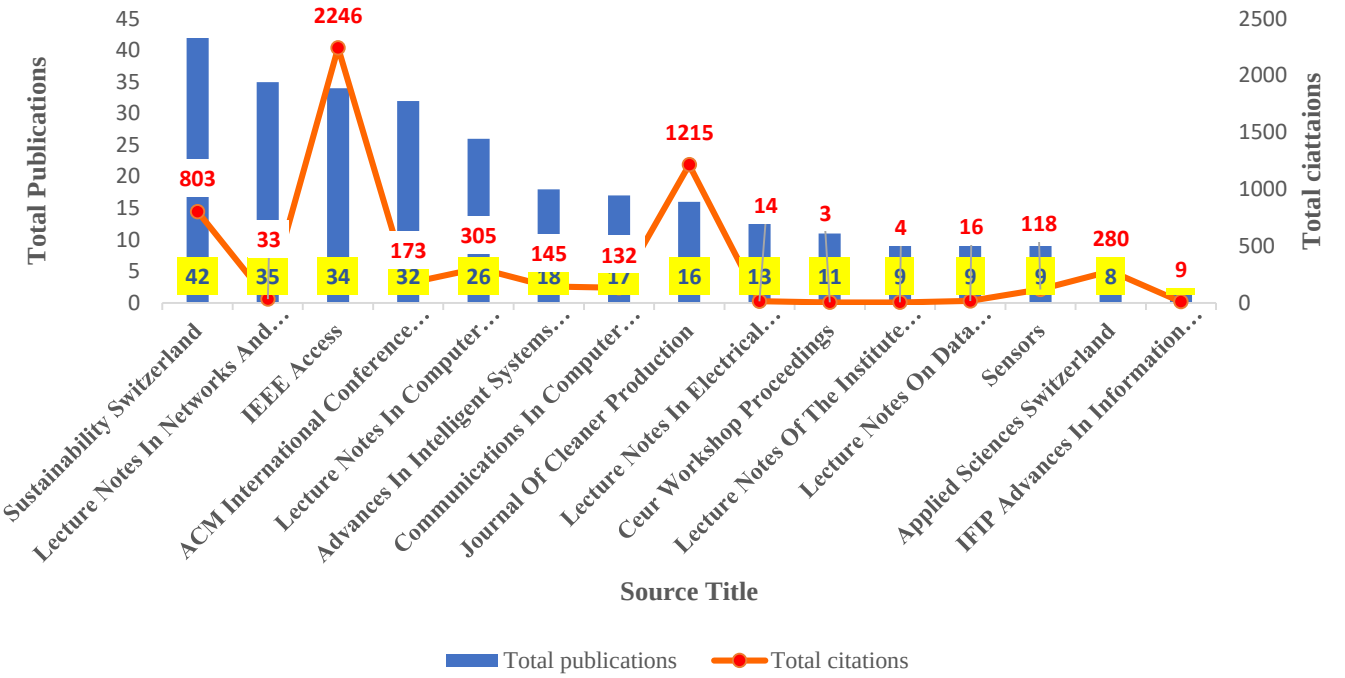

Fig. 7. Top 15 source title based total publications and total citations.

B. *Most Influential Countries, Institutions and Authors on Agri-Food and Blockchain*

This part concentrates on addressing the second research question, which aims to assess the level of scientific collaboration in the fields of agri-food and blockchain. This assessment is conducted through four main analyses: (a) publications categorized by country, (b) identification of the most active institutions involved in agri-food and blockchain research, and (c) analysis of authorship patterns.

1) Publications by countries: The published indicators for the top 15 countries in terms of agri-food and traceability research are summarized in Fig. 8 and Table III. With 293 documents, India has the highest number of scientific publications, followed by China (n = 163), Italy (n = 82), the United States (n = 79), the United Kingdom (n = 71), and Australia (n=42).

TABLE III. TOP 15 PUBLICATION BY COUNTRY

Country	TP	%	NCP	TC	C/P	C/CP	h	g	Continent
India	293	27.98%	187	4342	14.82	23.22	29	62	Asia
China	163	15.57%	112	3355	20.58	29.96	32	55	Asia
Italy	82	7.83%	61	2181	26.60	35.75	20	46	Europe
United States	79	7.55%	65	3827	48.44	58.88	25	61	North America
United Kingdom	71	6.78%	56	3052	42.99	54.50	23	55	Europe
Australia	42	4.01%	31	728	17.33	23.48	13	26	Oceania
Pakistan	29	2.77%	25	744	25.66	29.76	13	25	Asia
Saudi Arabia	29	2.77%	24	669	23.07	27.88	11	24	Asia
Turkey	29	2.77%	24	560	19.31	23.33	12	23	Europe
Malaysia	27	2.58%	20	284	10.52	14.20	7	16	Asia
Germany	24	2.29%	16	200	8.33	12.50	8	14	Europe
South Korea	24	2.29%	20	615	25.63	30.75	13	20	Asia
Spain	21	2.01%	17	475	22.62	27.94	11	17	Europe
Canada	19	1.81%	16	746	39.26	46.63	9	16	North America
France	19	1.81%	16	664	34.95	41.50	11	16	Europe

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P =average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index

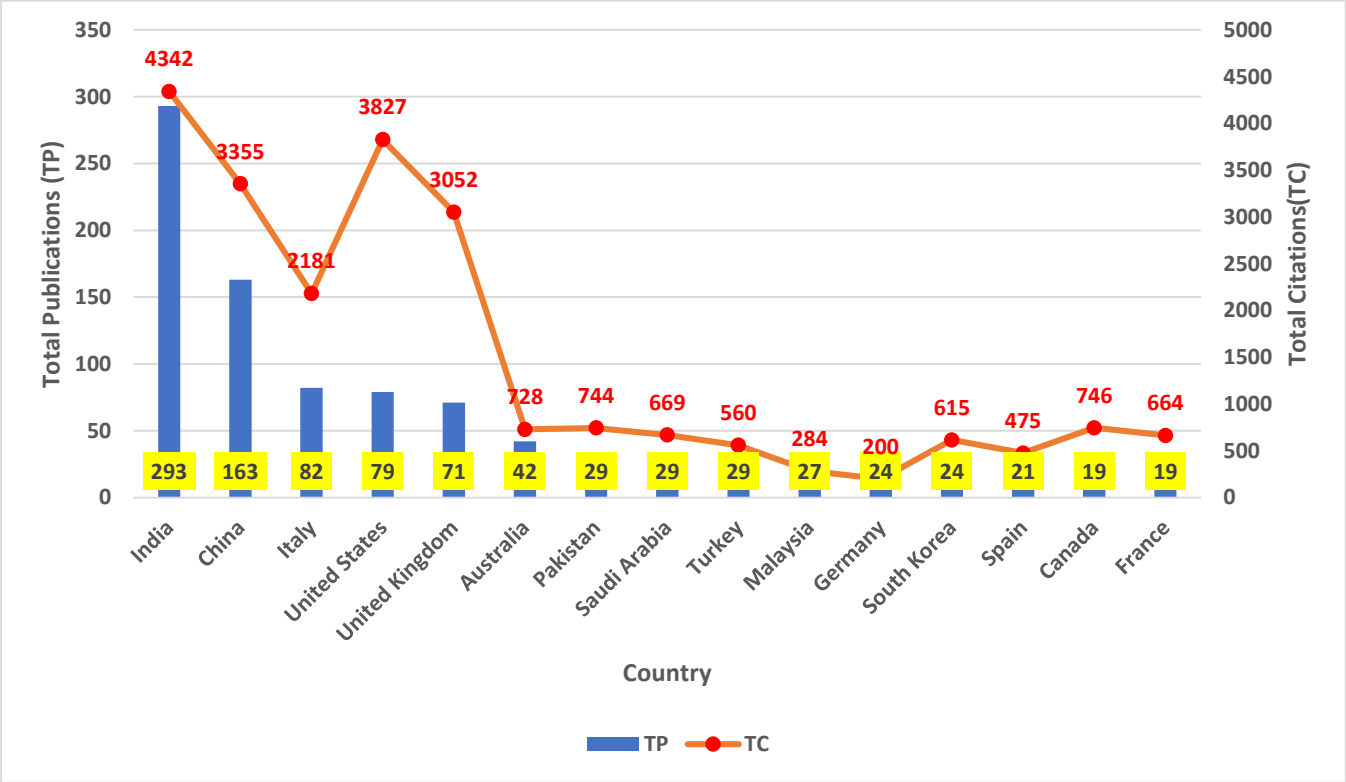

Fig. 8. Top 15 publication by country.

The national associations of the remaining authors, which included Pakistan, Saudi Arabia, Turkey, Malaysia, Germany, South Korea, and Spain, accounted for fewer than 30 articles dispersed across the globe. The countries with the fewest contributors are Canada and France, with 1.81% of total publications. It appears that agri-food and blockchain are of the utmost importance in Asia, Europe, North America, and Oceania. In terms of citation counts, Fig. 8 shows India maintains its position as the leader of all countries, showing a significant influence on the output of research with the highest total citations. With 3827 citations, the United States demonstrates its dominance in North America and has taken second place, beating China with 3355 citations. The significance of the United Kingdom in research activities is evident in the 3052 citations compared to other countries in Europe, including Italy, Germany, Turkey, Spain, and France. Despite having relatively few publications, Australia has made significant contributions to the global research community in terms of citations (n =728). The total citation metrics offer valuable insights regarding the recognition and influence of research output in each respective country.

2) The most active institutions: Table IV depicts prominent institutions in the field of agri-food and blockchain research, including the SRM Institute of Science and Technology, Beijing Technology and Business University, Queensland University of Technology, Università degli Studi di Cagliari, and Presidency University Bangalore. The SRM Institute of Science and Technology in India is the leading institution in terms of total publications, with a total of 20 publications, which is the highest count. This signifies substantial research output by the institution. Beijing Technology and Business University Beijing Institute of Technology, both based in China, have made significant contributions to agri-food and blockchain research. Beijing Technology and Business University ranks second with 11 publications, while Beijing Institute of Technology ranks sixth with 8 publications. However, the National Institute of Industrial Engineering has a significant C/CP of 163.88, indicating a strong influence with the highest citation. The second rank for citation is the Hong Kong Polytechnic University, followed by the Università degli Studi di Cagliari, the Wageningen University and Research, and the Università della Calabria.In contrast, SRM Institute of Science and Technology has a notable average C/CP of 3.50. Most of the institutions that were evaluated are located in India, with SRM Institute of Science and Technology, Presidency University Bangalore, National Institute of Industrial Engineering, Lovely Professional University, University of Petroleum and Energy Studies, and Vellore Institute of Technology being notable contributors. This highlights the significance of India's leadership in agricultural and blockchain-based research. In addition, the result demonstrates a worldwide distribution of institutions, encompassing China, India, Italy, Australia, Viet Nam, the Netherlands, and the United Kingdom. This diversity shows the global extent of the research field.

TABLE IV. THE MOST ACTIVE INSTITUTIONS

Institution	TP	%	Country	NCP	TC	C/P	C/CP	h	g
SRM Institute of Science and Technology	20	1.91%	India	8	28	1.40	3.50	3	5
Beijing Technology and Business University	11	1.05%	China	7	226	20.55	32.29	5	7
Queensland University of Technology	9	0.86%	Australia	8	179	19.89	22.38	5	8
Università degli Studi di Cagliari	9	0.86%	Italy	9	465	51.67	51.67	8	9
Presidency University Bangalore	9	0.86%	India	4	53	5.89	13.25	4	4
Beijing Institute of Technology	8	0.76%	China	8	107	13.38	13.38	4	8
Università della Calabria	8	0.76%	Italy	7	296	37.00	42.29	5	7
National Institute of Industrial Engineering	8	0.76%	India	8	1311	163.88	163.88	7	8
Lovely Professional University	8	0.76%	India	6	186	23.25	31.00	4	6
University of Petroleum and Energy Studies	8	0.76%	India	6	46	5.75	7.67	4	6
The Hong Kong Polytechnic University	7	0.67%	China	6	975	139.29	162.50	5	6
Vellore Institute of Technology	7	0.67%	India	6	63	9.00	10.50	3	6
RMIT University	7	0.67%	Viet Nam	2	5	0.71	2.50	2	2
Wageningen University & Research	6	0.57%	Netherlands	5	365	60.83	73.00	4	5
Cranfield University	6	0.57%	United Kingdom	5	126	21.00	25.20	5	5

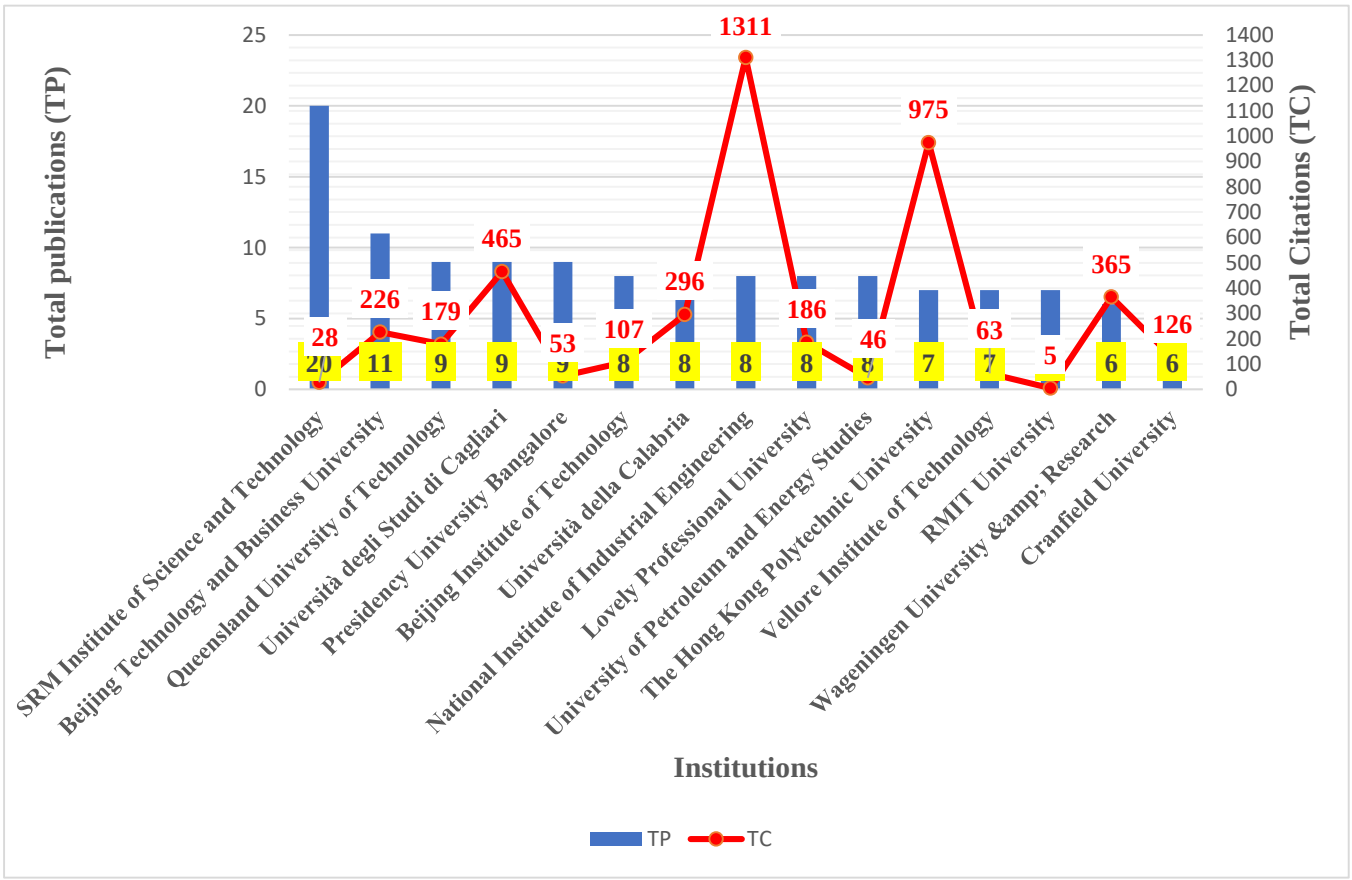

Fig. 9. The most active institution based on publication versus citation.

3) Authorship analysis: The analysis in Table V presents the total number of publications (TP) by different authors, highlighting their contributions to academic research. Xu. J and Zhang X are prominent contributors, each having seven publications. The authors Xu, J. and Zhang, X. from Beijing Technology and Business University in China have a collaborative impact (C/CP) of 26.50, which means that their articles are referenced an average of 26.50 times. This indicates a substantial impact and acknowledgment of their combined academic efforts, highlighting the importance of collaborative research at the university. Marchesi, M., Mirabelli, G., Solina, V., and Tonelli, R. from Italy have achieved impressive average citations per publication (C/P) scores of 61.20, 51.40, 51.40, and 35.20, respectively. This highlights the significant research output produced by Italian affiliations. Table VI illustrates a wide-ranging geographical

influence, featuring authors originating from Australia, India, Italy, and China. Authors from various affiliations and nations exhibit a worldwide presence in research. Calculating the average number of citations per publication and per cited article offers valuable insights into the influence of an author's work. The h-index and g-index offer a comprehensive perspective on the academic impact of an author. This study used the VOSviewer software to conduct co-author analysis, enabling a thorough examination of authors' collaboration and generating a network visualization (see Fig. 10). The analysis relies on the premise that significant writers have been referenced at least once in five publications related to agri-food and blockchain. The calculation is performed using the fractional counting technique. Distinct attributes, such as color, size of circles, font size, and line width, enhance the intensity of the authors' association. Authors who are associated with one another are often listed one after the other, as seen by the use of the same color. The Fig. 10 indicates that the prominent authors Xu J. and Zhang X collaborated closely with other authors, including Li H., Zhao Z., and Xu J. Based on the result, it seems that Cao S and Foth M, both from Australia, have had a similarly effective collaboration with colleagues from China.

Fig. 11 presents a network visualization map of the author's associated country. The analysis only includes nations that have cited more than five articles and more than 1 citation. According to the fractional counting method, the results suggest that India has a substantial impact on international collaboration. India maintains strong diplomatic ties with Ukraine and South Korea, while China has established connections with Hong Kong and Serbia.

Next section will highlight the third research question highlighted the most prevalent themes of agri-food and blockchain between scholars.

C. The Most Prevalent Themes of Agri-Food and Blockchain between Scholars

The fundamental objective of the third research question is to discover the predominant themes of blockchain in agri-food research among experts. This step involved analysing the important areas of the research based on (a) the frequency of keywords and (b) the titles and abstracts of the documents.

1) Keywords analysis: The careful selection of suitable keywords is crucial in finding the availability of a document during a search. Therefore, the regular selection of suitable keywords may serve as an indicator of the quality of the writing. A network visualization of the author's keywords, each of which appeared a minimum of three occurrences, is illustrated in Fig. 12. A co-occurrence of two keywords within the same article suggests that there is a connection between the two subjects [37]. In order to answer the third research questions, we utilized the keyword and co-occurrence analysis from VOSviewer. In order to map the keywords allocated to each article, the author's analyzed keywords utilizing VOSviewer, a software application designed for generating and visualizing bibliometric networks (see Fig. 12).

TABLE V. AUTHORSHIP ANALYSIS TOP 15

Author Name	TP	%	Affiliation	Country	NCP	TC	C/P	C/CP	h	g
Xu, J.	7	0.67%	Beijing Technology and Business University, Beijing	China	6	159	22.71	26.50	4	6
Zhang, X.	7	0.67%	Beijing Technology and Business University, Beijing	China	6	159	22.71	26.50	4	6
Cao, S.	6	0.57%	The University of Queensland, Brisbane	Australia	5	133	22.17	26.60	5	5
Sun, C.	6	0.57%	National Engineering Laboratory for Agri-product Quality Traceability, Beijing	China	5	120	20.00	24.00	4	5
Tanwar, S.	6	0.57%	Nirma University, Institute of Technology, Ahmedabad	India	5	107	17.83	21.40	5	5
Wang, X.	6	0.57%	Beijing Institute of Fashion Technology, Beijing	China	5	153	25.50	30.60	4	5
Ahamed, N.N.	5	0.48%	Presidency University Bangalore, Bengaluru,	India	3	34	6.80	11.33	3	3
Foth, M.	5	0.48%	Queensland University of Technology	Australia	5	170	34.00	34.00	5	5
Luo, N.	5	0.48%	National Engineering Laboratory for Agri-product Quality Traceability, Beijing	China	4	58	11.60	14.50	3	4
Marchesi, M.	5	0.48%	Università degli Studi di Cagliari	Italy	5	306	61.20	61.20	5	5
Mirabelli, G.	5	0.48%	Università della Calabria, Rende	Italy	5	257	51.40	51.40	4	5
Solina, V.	5	0.48%	Università della Calabria, Rende	Italy	5	257	51.40	51.40	4	5
Tonelli, R.	5	0.48%	Università degli Studi di Cagliari	Italy	5	176	35.20	35.20	5	5
Vignesh, R.	5	0.48%	Presidency University Bangalore, Bengaluru,	India	2	26	5.20	13.00	2	2
Zhao, Z.	5	0.48%	Beijing Technology and Business University, Beijing	China	5	153	30.60	30.60	4	5

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P =average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index

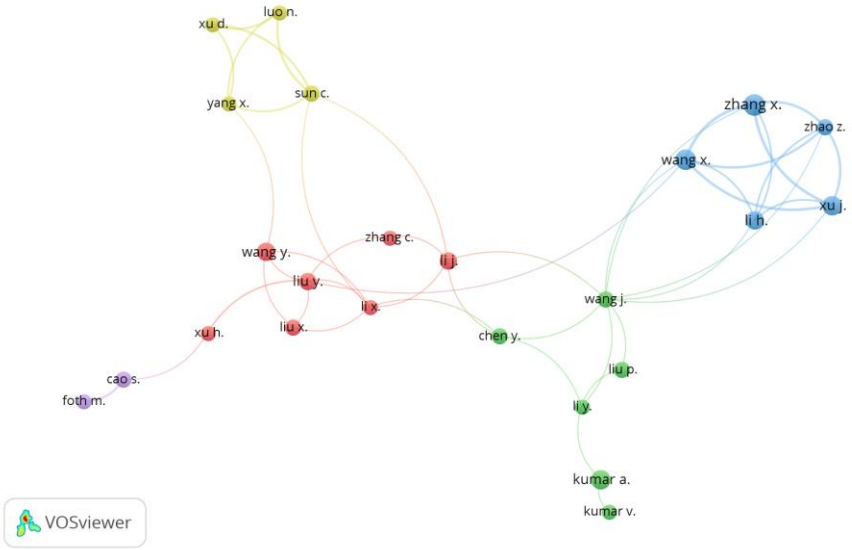

Fig. 10. Network visualisation map of the co-authorship based on author.

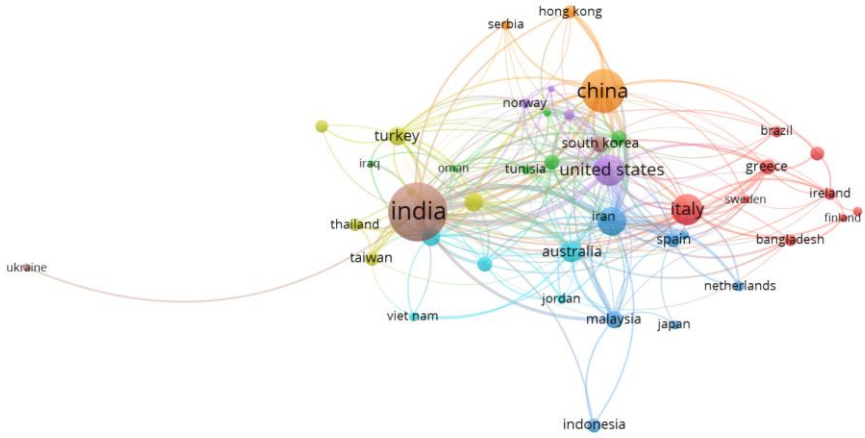

Fig. 11. Network visualisation map of the co-authorship based on countries.

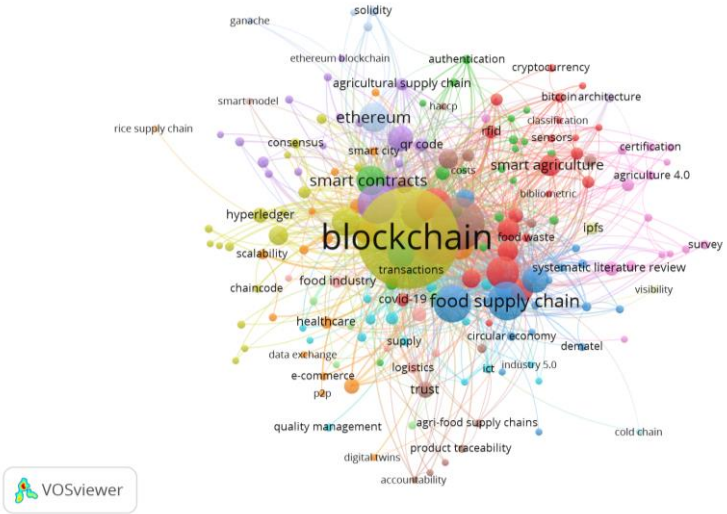

Fig. 12. Network visualisation map of the author keywords.

TABLE VI. TOP 20 KEYWORDS

Keywords	Total Publications	%
Blockchain	787	75.17%
Block-chain	401	38.30%
Supply Chains	353	33.72%
Food Supply	331	31.61%
Internet Of Things	194	18.53%
Food Supply Chain	171	16.33%
Supply Chain Management	169	16.14%
Traceability	169	16.14%
Smart Contract	150	14.33%
Food Safety	138	13.18%
Supply Chain	138	13.18%
Agriculture	117	11.17%
Blockchain Technology	87	8.31%
Digital Storage	87	8.31%
Distributed Ledger	87	8.31%
Traceability Systems	85	8.12%
Transparency	81	7.74%
IoT	71	6.78%
Food-safety	68	6.49%
Food Traceability	65	6.21%

The relationships between other keywords are represented by the thickness, colour, circle size, and font size of connecting lines [41]. Frequently categorized keywords in the same colour are frequently bundled together. The analysis revealed seventeen clusters containing 184 items based on the author's keyword. The diagram suggests that blockchain, blockchains, consensus, consortium blockchain, distributed ledgers, food chain, Hyperledger, Hyperledger fabric, permissioned blockchain, private blockchain supply chain management and supply chain traceability have similar colours, indicating that these keywords were closely related and usually occurred together. The search query included the following primary keywords: Blockchain, Block-chain, Supply Chains, Food Supply, Internet of Things, Food Supply Chain, Supply Chain Management, Traceability, Smart Contract, Food Safety, Supply Chain and Agriculture. These terms appear more than 10% of the time in the results. Table VI lists the twenty most common keywords used in agri-food and blockchain research.

2) Title and abstract analysis: In this section of the study, VOSviewer was employed to examine the titles and abstracts of collected documents for occurrences and the frequency of co-occurrences per document. Specifically, this study builds the co-occurrence network by employing the binary counting method. Fig. 13 depicts a graphical illustration of a network that shows the occurrence of terms based on their presence in the title and abstract fields. The network includes terms that appear at least 15 times. The width of the node represents the weight of the item, while the thickness of the connecting line indicates the intensity of the link between items. When words that are connected in meaning are displayed in the same colour, there is a higher probability that they will occur together [37]. The terms safety, product, smart contract, transaction, storage, consumer, and food product, indicated in red, are interconnected and commonly coexist in the diagram. VOSviewer generates four separate colours based on the title and abstract of the publication, representing four clusters that consist of 246 terms.

Fig. 14 illustrates the arrangement of a title-based phrase co-occurrence network. A binary counting technique was employed, ensuring a minimum of ten occurrences for each phrase. The data suggests that the VOSviewer software creates four distinct clusters and a total of 27 items. Within the domain of agri-food and blockchain research, the term 'blockchain technology' gained the central position as the core node of the entire network. Cluster 1 contains the concepts of agri-food supply chain, block chain, blockchain application, food safety, food supply chain management, healthcare, impact, smart contract, and survey, whereas Cluster 2 consists of block chain technology, blockchain technology, case study, covid, design, food, implementation, and traceability system. Furthermore, Cluster 3 has artificial intelligence, food industry, food traceability, and smart agriculture and thing, whereas the last cluster, Cluster 4, only has internet, opportunity, and thing.

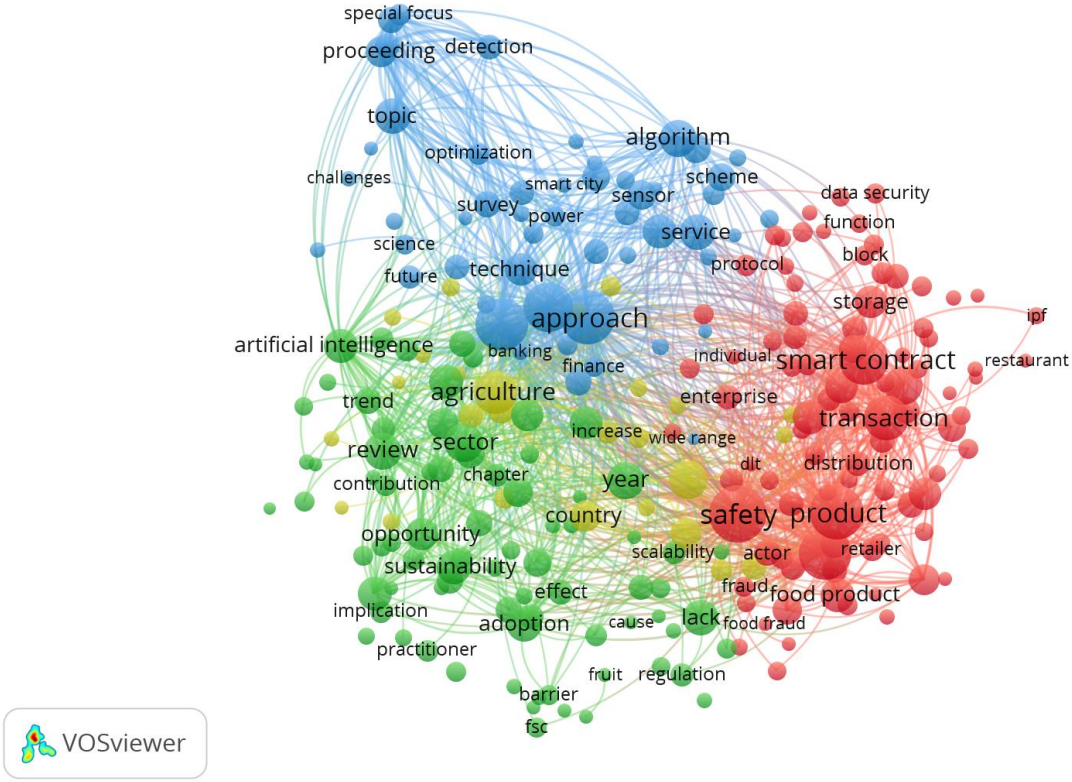

Fig. 13. VOSviewer visualisation of a term co-occurrence network based on title and abstract.

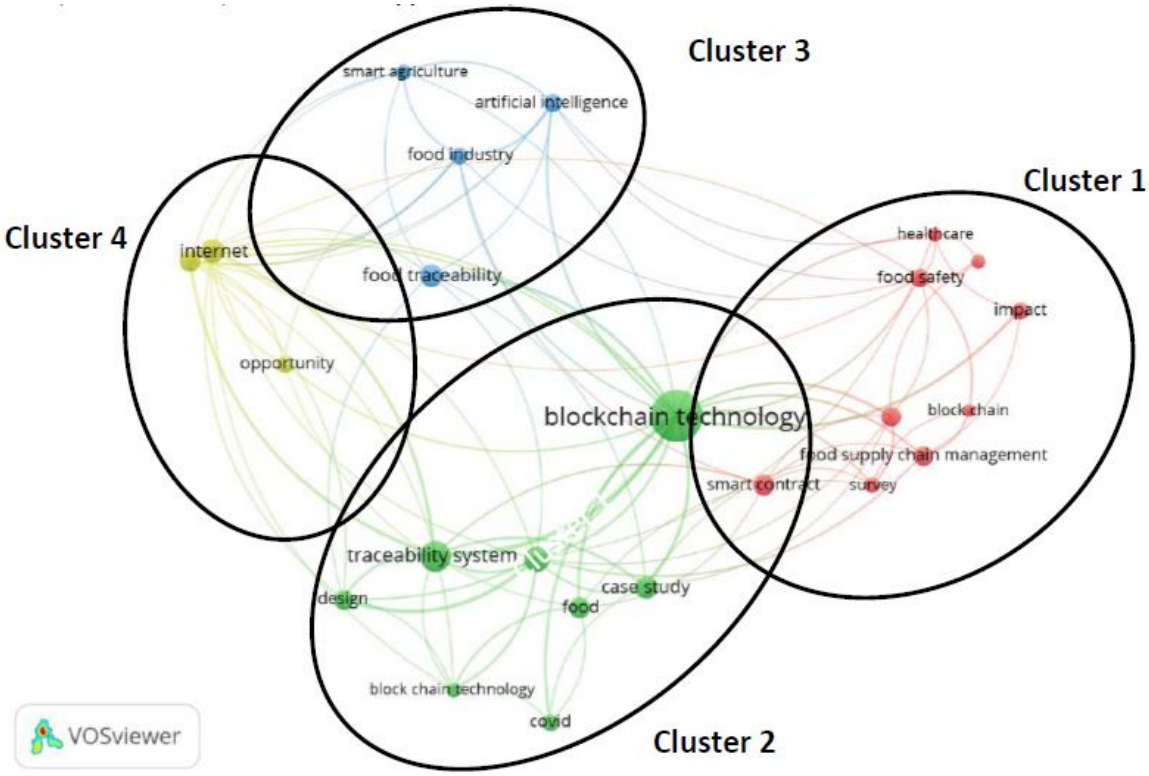

Fig. 14. VOSviewer visualisation of a term co-occurrence network based on title fields.

D. The Most Influential Articles on Agri-Food and Blockchain

This section examines the fourth research question, which is to discover the most influential articles on agri-food and blockchain through citation analysis.

1) Citation analysis: Table VII represents a compilation of research citations on agri-food and blockchain from the Scopus database. Over a span of nine years (2016–2024), a total of 19,105 citations were documented for 1,047 published papers. This corresponds to an average of 2,729.29 citations per year. Table VIII summarized the top 20 articles on blockchain in agri-food research, based on the frequency of citations for each document. The research article titled "Blockchain-based traceability in agri-food supply chain management: A practical implementation," published in 2018 by M.P. Caro, M.S. Ali, M. Vecchio, and R. Giaffreda, has received the highest number of citations, with a total of 507. This article was presented at the 2018 IoT Vertical and Topical Summit on Agriculture in Tuscany, IOT Tuscany 2018. The second and third publications, published in 2021 and 2020, respectively, are research articles on blockchain technology in the supply chain. They were written by M. Kouhizadeh, S. Saberi, and J. Sarkis and have a total of 497 citations. The other publication, written by P. Dutta, T.-M. Choi, S. Somani, and R. Butala, has a total of 494 citations.

TABLE VII. CITATION METRICS

Metrics	Data
Papers	1047
Citations	19105
Years	9
Cites_Year	2729.29
Cites_Paper	18.25
Authors_Paper	3.52
h_index	63
g_index	120

TABLE VIII. TOP CITED ARTICLES IN AGRI-FOOD AND BLOCKCHAIN RESEARCH

Authors	Year	Title	Source	Cites	Cites/Year
M.P. Caro, M.S. Ali, M. Vecchio, R. Giaffreda	2018	Blockchain-based traceability in Agri-Food supply chain management: A practical implementation	2018 IoT Vertical and Topical Summit on Agriculture - Tuscany, IOT Tuscany 2018	507	101.4
M. Kouhizadeh, S. Saberi, J. Sarkis	2021	Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers	International Journal of Production Economics	497	248.5
P. Dutta, T.-M. Choi, S. Somani, R. Butala	2020	Blockchain technology in supply chain operations: Applications, challenges and research opportunities	Transportation Research Part E: Logistics and Transportation Review	494	164.67
S.S. Kamble, A. Gunasekaran, R. Sharma	2020	Modeling the blockchain enabled traceability in agriculture supply chain	International Journal of Information Management	471	157
S.S. Kamble, A. Gunasekaran, S.A. Gawankar	2020	Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications	International Journal of Production Economics	431	143.67
H. Feng, X. Wang, Y. Duan, J. Zhang, X. Zhang	2020	Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges	Journal of Cleaner Production	382	127.33
K. Salah, N. Nizamuddin, R. Jayaraman, M. Omar	2019	Blockchain-Based Soybean Traceability in Agricultural Supply Chain	IEEE Access	379	94.75
K. Behnke, M.F.W.H.A. Janssen	2020	Boundary conditions for traceability in food supply chains using blockchain technology	International Journal of Information Management	372	124
G. Zhao, S. Liu, C. Lopez, H. Lu, S. Elgueta, H. Chen, B.M. Boshkoska	2019	Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions	Computers in Industry	371	92.75
M. Lezoche, H. Panetto, J. Kacprzyk, J.E. Hernandez, M.M.E. Alemany Díaz	2020	Agri-food 4.0: A survey of the Supply Chains and Technologies for the Future Agriculture	Computers in Industry	338	112.67
G. Perboli, S. Musso, M. Rosano	2018	Blockchain in Logistics and Supply Chain: A Lean Approach for Designing	IEEE Access	329	65.8

		Real-World Use Cases			
R. Sharma, S.S. Kamble, A. Gunasekaran, V. Kumar, A. Kumar	2020	A systematic literature review on machine learning applications for sustainable agriculture supply chain performance	Computers and Operations Research	308	102.67
D. Bumblauskas, A. Mann, B. Dugan, J. Rittmer	2020	A blockchain use case in food distribution: Do you know where your food has been?	International Journal of Information Management	291	97
A.A. Siyal, A.Z. Junejo, M. Zawish, K. Ahmed, A. Khalil, G. Soursou	2019	Applications of blockchain technology in medicine and healthcare: Challenges and future perspectives	Cryptography	263	65.75
Y. Liu, X. Ma, L. Shu, G.P. Hancke, A.M. Abu-Mahfouz	2021	From Industry 4.0 to Agriculture 4.0: Current Status, Enabling Technologies, and Research Challenges	IEEE Transactions on Industrial Informatics	254	127
L. Klerkx, D. Rose	2020	Dealing with the game-changing technologies of Agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways?	Global Food Security	252	84
D. Tse, B. Zhang, Y. Yang, C. Cheng, H. Mu	2017	Blockchain application in food supply information security	IEEE International Conference on Industrial Engineering and Engineering Management	235	39.17
Q. Lin, H. Wang, X. Pei, J. Wang	2019	Food Safety Traceability System Based on Blockchain and EPCIS	IEEE Access	230	57.5
A. Khatoon	2020	A blockchain-based smart contract system for healthcare management	Electronics (Switzerland)	220	73.33
S. Mondal, K.P. Wijewardena, S. Karuppuswami, N. Kriti, D. Kumar, P. Chahal	2019	Blockchain inspired RFID-based information architecture for food supply chain	IEEE Internet of Things Journal	217	54.25

V. DISCUSSIONS

In this section, we shall discuss the findings of our biblimetric review to address the research questions outlined below.

A. RQ1. What is the Current Trend and Impact of Publication in Agri-Food and Blockchain?

Sugandh, Nigam, Misra and Khari conducted the current bibliometric analysis of the literature's influence on agri-food and blockchain research [42]. They used literature search tools to examine the years 2014 through 2022, as retrieved from ACM, IEEE Xplore, PubMed, the Web of Science, and Scopus. According to the study, publications on this topic began in 2018 and continued to increase from that point forward. However, without time constraints in search criteria, our study found that the first paper on agri-food and blockchain research was published in 2016 and has kept increasing until now. In 2017, the average number of citations per publication peaked at 87.00, demonstrating that publications have a substantial impact. This indicates a rise in research activities or a concentration on sharing research results. Additional inquiry may uncover patterns or advancements. In term of citation pattern, it demonstrates the increasing as well with domination in 2020

Agri-food blockchain research relies heavily on journals, which constitute 39.54% of all published works in this field. Scholarly journals are esteemed for their meticulous peer review procedure and reputation for reliability. Conference proceedings, comprising 36.20% of the total, also function as a medium for disseminating progress in the area. Nevertheless, the agri-food blockchain research environment shows a lower prevalence of book series, books, and trade journals, indicating the importance of real-time discussions and exchange of ideas. Conference papers are the primary focus of agri-food and blockchain research, making for 42.22% of all papers published. These papers serve as a medium for scholars to share and encourage cutting-edge developments while facilitating direct discussions. Articles make a substantial contribution, representing 34.38% of the overall publications. The presence of many document formats, such as book chapters, conference reviews, and reviews, indicates a comprehensive approach for sharing knowledge. Nevertheless, when compared to conference papers and articles, book publishing, notes, editorials, errata, and short surveys have a comparatively insignificant impact.

English is the predominant language used in scholarly papers related to the agri-food and blockchain fields, representing 98.09% of all articles. This demonstrates the worldwide significance of English as the predominant language for academic discourse. The inclusion of Chinese, German, Polish, and Spanish languages, while in smaller proportions, highlights the diversity of participants and readers in this field. Researchers and policymakers should recognize the linguistic variety present in scholarly publications, as acknowledging and studying literature in different languages can offer complementary perspective and understandings.

The publication titled "Sustainability Switzerland" from MDPI is the most active source in the topic, with 42 publications and a high Cite Score of 5.8. The journal "Lecture Notes in Networks and Systems" published by Springer Nature has a notable Cite Score and SJR of 0.151. Springer Nature takes several positions inside the top 20, demonstrating its strong presence. Meanwhile, MDPI highlights the influence of open-access publishing. IEEE Access has a substantial overall citation count; however, Journal of Cleaner Production has an impressive CiteScore of 18.5 and SNIP of 2.379. Despite being discontinued in Scopus, Advances in Intelligent Systems and Computing continues to have influence. The inclusion of other source types, such as Ceur Workshop Proceedings, Sensors, Applied Sciences Switzerland, enriches the field.

Given the consistent growth in the number of publications since 2018, it is evident that research on the implementation of blockchain technology in agriculture is currently a popular and rapidly increasing field. Indeed, there has been a steady increase in the quantity of publications until now.

B. RQ2. Which are the Most Productive and Influential Countries, Institutions and Authors on Agri-Food and Blockchain?

According to Sugandh, Nigam, Misra and Khari, China has become the leader in agri-food and blockchain research [42]. However, our findings show that India has become the top contributor to publications, with India accounting for 293 articles compared to China, which accounts for 163 articles. Despite having a smaller number of publications compared to India and China, The United States has a notable citation effect, with a C/CP value of 48.44, suggesting a significant amount of influence. Italy, the United Kingdom, Germany, Spain, and France, among other European countries, provide substantial contributions, demonstrating a strong research environment.

The substantial number of publications in India is indicative of a flourishing research environment, which is supported by increased funding, collaboration, and the exploration of diverse research fields. This phenomenon offers prospects for global cooperation and the exchange of insights between Indian scholars and researchers. The cumulative representation of Asian countries (India, China, Pakistan, Saudi Arabia, Malaysia, South Korea) in publications highlights the growing impact of the region in multidisciplinary research.

The National Institute of Industrial Engineering in India, along with other esteemed institutions such as SRM Institute of Science and Technology, Presidency University Bangalore, and Lovely Professional University, has a substantial influence on the academic community. The institute's 8 publications and average citation of 163.88 demonstrate a substantial influence on research quality and visibility. This can be linked to the organization's emphasis on research areas that have a significant impact and the implementation of effective mechanisms for collaboration. These findings also indicate that India are leading in this topic nowadays. Additionally, both Beijing Technology and Business University and Beijing Institute of Technology demonstrate a significant average number of citations per article, suggesting a noteworthy influence in their respective areas of research. Table IV and Fig. table

9 presents a comprehensive overview of the worldwide distribution of active contributors to scholarly production, emphasizing the global nature of research collaboration and the significant role played by different countries in shaping the academic landscape. This analysis highlights the importance of institutions in India and China, suggesting these regions as key areas of focus for scholars interested in this topic. There are opportunities for cross-continental collaboration and knowledge sharing, which promotes a global research environment.

The research community is mostly influenced by two authors who possess identical publication records, suggesting potential constraints in collaboration. The analysis includes authors from varied locations like China, Australia, India, and Italy, exhibiting global collaboration in the field of study. The presence of many perspectives enhances the research environment and facilitates a more comprehensive comprehension of the topic. Italian authors, such as Marchesi, Mirabelli, Solina, and Tonelli, have a significant influence on the academic community, as seen by their high average citation metrics. Promoting collaboration among different institutions and locations has the potential to enrich the research output by incorporating different perspectives.

C. RQ3. Which are the Most Prevalent Themes of Agri-Food and Blockchain between Scholars?

The term "Blockchain" and its related forms (Block-chain, Blockchain Technology, Distributed Ledger) are prominently used, highlighting the significant emphasis on blockchain in agri-food research. This highlights the crucial role of technology in influencing progress in the field. The extensive prevalence of blockchain-related terminology indicates a significant scholarly interest and recognition of the revolutionary potential of blockchain technology in agri-food systems. Researchers and practitioners are actively investigating different facets, ranging from supply chain management to traceability and smart contracts.

The presence of "Internet of Things (IoT)" in the list of prominent keywords signifies the increasing practice of combining IoT with blockchain technology in agricultural and food systems. This combination is expected to effectively resolve concerns pertaining to traceability, transparency, and real-time monitoring. The terms "Food Safety," "Traceability," and "Food Traceability" are clearly highlighted, highlighting a significant issue within the agri-food sector. This indicates a deliberate and focused attempt to improve food safety measures and establish strong traceability mechanisms.

The research highlights the combination of technology, specifically blockchain, with traditional agricultural techniques, as seen by the use of keywords such as "Agriculture".

D. RQ4. Which are the Most Influential Articles on Agri-Food and Blockchain?

The most-cited articles in the field of agri-food research contain an extensive range of perspectives and implementations of blockchain technology. Traceability, sustainability, supply chain operations, and the intersection of blockchain technology and emerging technologies such as Industry 4.0 are among the topics covered.

The substantial number of references to these articles demonstrates the importance of blockchain technology in addressing many different kinds of obstacles in the agri-food sector. Scholars and industry professionals are presently engaged in an intensive investigation of the theoretical underpinnings, barriers to adoption, and greater impact of blockchain technology on sustainability, in addition to its practical applications in supply chain traceability.

The articles on traceability, such as "Blockchain-based traceability in agri-food supply chain management" and "Modelling blockchain-enabled traceability in agriculture supply chain," highlight the industry's interest in enhancing traceability in the agri-food supply chain. They also explore the potential of blockchain technology in achieving sustainable practices in a data-driven agriculture supply chain based on articles "Blockchain technology and the sustainable supply chain" and "Achieving sustainable performance in a data-driven agriculture supply chain." The articles "From Industry 4.0 to Agriculture 4.0" and "Blockchain-inspired RFID-based information architecture for food supply chain" demonstrate the integration of blockchain with other technologies in an interdisciplinary manner.

E. Implications of Study, Limitation and Future Recommendation

This study aims to examine the current direction and pattern of research on agri-food and blockchain by assessing the publication status, citation patterns, thematic content, and providing recommendations for future research in this field. The present study offers a thorough overview of recent research on blockchain in the agri-food sector, including growing trends in publications, journal performance, collaboration patterns, and research elements. This study contributes to a better understanding of the subject matter. Every sign indicates growth in this area of study, potentially resulting in new opportunities for enhancing global food systems. Furthermore, their contributions will assist novice academics in acquiring a comprehensive outlook on this particular domain [43]. This study uses the bibliometric technique to improve academics' understanding of the literature on blockchain technology application in the agri-food sector because bibliometric analyses remain a vital tool for identifying gaps in any given subject or field [40]. Therefore, researchers might employ this methodology to carry out their investigations, particularly when performing comprehensive examinations of relevant material pertaining to their area of focus.

The results of this study will support particular researchers in comprehending the ability of blockchain, IoT, and other emerging technologies to improve traceability, sustainability, and supply chain operations in the agri-food industry. Additionally, it will provide ideas for future research. Due to its widespread adoption in the global agri-food sector, we expect the application of blockchain to remain significant in the future. It is particularly popular in Asian countries like India, China, Pakistan, Saudi Arabia, and Malaysia, where there is active production of blockchain in agri-food publications. This indicates that its popularity is increasing and its global utilisation is on the rise. Although the assessment has garnered significant interest, the authors have given comparatively less consideration to its use in domains beyond food traceability.The deployment of blockchain technology (BCT) requires further investigation to explore governance frameworks, assess the sustainability and environmental impact of BCT in agriculture, understand user adoption and acceptance, and integrate BCT with advanced technologies like the Internet of Things (IoT) and artificial intelligence (AI) [42]. These paths of research will enhance our understanding of BCT's capacity in both the food and agriculture sectors. Consequently, these areas demand greater attention from other academics and practitioners, which will facilitate the development of further research.

The study is based on a bibliometric analysis of published agri-food and blockchain research from 2016 to 2024. However, it's crucial to acknowledge that this analysis informs the discussion, which is subject to certain limitations. The study restricts its scope to the Scopus database and concentrates on the frequently used keywords in document titles and abstracts in the field of computer science and engineering. This study did not consider more comprehensive databases, such as Web of Science, Google Scholar, and EBSCO Hosts, which provide substantial coverage of the use of blockchain in the agri-food sector. Thus, it has the potential to limit the overall influence of the publication patterns on the subject of the study. In future studies, researchers can use diverse databases to perform searches, modify and compare the outcomes of distinct keyword terms, and examine variations in agri-food and blockchain research across different thematic domains. In addition, researchers can utilise bibliographic coupling analysis to quantify document similarity and identify earlier research that is pertinent to their current research. Besides that, the future direction in agri-food and blockchain study needs to comply with sustainability concept to sustain production and meet the demand for food. At this point, utilizing blockchain technology in agricultural and food research has the potential to yield significant and meaningful outcomes.

VI. CONCLUSIONS

We conducted a bibliometric analysis of the Scopus database's literature on agri-food and blockchain research, focusing on 1047 articles in the field of computer science and engineering. This study revealed a significant increase in publications since 2016, with the first paper published in 2016. Notably, there is a strong emphasis on utilising journals and conference proceedings to share research developments. English became the dominant language for research papers on this topic, indicating its worldwide importance. We recognized India and China as the primary contributors to papers, with India demonstrating a thriving research culture and a substantial impact on worldwide collaboration. The widespread use of blockchain-related terms, such as "blockchain" and "distributed ledger," highlights the significant academic interest in the transformative capabilities of blockchain technology in agri-food systems. The publications that have the most impact on this topic encompass a variety of viewpoints and applications of blockchain technology, with a particular focus on its significance in addressing numerous challenges in the agri-food industry. The increasing presence of Asian countries in academic papers exemplifies the region's growing influence in a variety of research fields. The National Institute of Industrial Engineering in India, in conjunction with other institutes, has a significant impact on the quality and prominence of research. Two writers with similar publication records primarily influence the research community. However, the inclusion of multiple perspectives enriches the research environment and enables a more thorough comprehension of

the subject matter. Researchers and practitioners are increasingly focusing on blockchain technology in agri-food research due to its potential in supply chain management, traceability, and smart contracts. Researchers are currently investigating the integration of the Internet of Things (IoT) and blockchain technology to tackle issues related to traceability, transparency, and real-time monitoring. The research also focuses on enhancing food safety procedures and establishing robust traceability tools to solve challenges related to safety and traceability. The research underscores the use of blockchain technology in conventional agricultural practices, emphasising the significance of agri-food in a sustainable and effective manner.

REFERENCES

[1] World Health Organization, 'Food safety', Fact Sheets. Accessed: Apr. 20, 2024. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/food-safety

[2] S. Deekonda, 'Agri-Food Supply Chains from Circular Economy Perspective', in Y. &. Ramakrishna, Handbook of Research on Designing Sustainable Supply Chains to Achieve a Circular Economy, 2023, pp. 286–305.

[3] A. Mohammed, V. Potdar, and M. Quaddus, 'Exploring Factors and Impact of Blockchain Technology in the Food Supply Chains: An Exploratory Study', Foods, vol. 12, no. 10, p. 2052, May 2023, doi: 10.3390/foods12102052.

[4] R. Granillo-Macías, I. J. González-Hernández, and E. Olivares-Benitez, 'Blockchain for Agri-Food Supply Chain Traceability'.

[5] T. Bhatt, G. Buckley, J. C. McEntire, P. Lothian, B. Sterling, and C. Hickey, 'Making Traceability Work across the Entire Food Supply Chain', J Food Sci, vol. 78, no. s2, Dec. 2013, doi: 10.1111/1750-3841.12278.

[6] H. Xiong, T. Dalhaus, P. Wang, and J. Huang, 'Blockchain Technology for Agriculture: Applications and Rationale', Frontiers in Blockchain, vol. 3, Feb. 2020, doi: 10.3389/fbloc.2020.00007.

[7] M. Krstić, G. P. Agnusdei, S. Tadić, and P. P. Miglietta, 'Prioritization of e-traceability drivers in the agri-food supply chains', Agricultural and Food Economics, vol. 11, no. 1, p. 42, Oct. 2023, doi: 10.1186/s40100-023-00284-5.

[8] G. M. Hastig and M. S. Sodhi, 'Blockchain for Supply Chain Traceability: Business Requirements and Critical Success Factors', Prod Oper Manag, vol. 29, no. 4, pp. 935–954, Apr. 2020, doi: 10.1111/poms.13147.

[9] F. Casino et al., 'Blockchain-based food supply chain traceability: a case study in the dairy sector', Int J Prod Res, vol. 59, no. 19, pp. 5758–5770, Oct. 2021, doi: 10.1080/00207543.2020.1789238.

[10] W. A. H. Ahmed and B. L. MacCarthy, 'Blockchain-Enabled Supply Chain Traceability in the Textile and Apparel Supply Chain: A Case Study of the Fiber Producer, Lenzing', Sustainability, vol. 13, no. 19, p. 10496, Sep. 2021, doi: 10.3390/su131910496.

[11] G. Baralla, A. Pinna, R. Tonelli, M. Marchesi, and S. Ibba, 'Ensuring transparency and traceability of food local products: A blockchain application to a Smart Tourism Region', Concurr Comput, vol. 33, no. 1, Jan. 2021, doi: 10.1002/cpe.5857.

[12] A. Marchese and O. Tomarchio, 'A Blockchain-Based System for Agri-Food Supply Chain Traceability Management', SN Comput Sci, vol. 3, no. 4, Jul. 2022, doi: 10.1007/s42979-022-01148-3.

[13] S. S. Kamble, A. Gunasekaran, and R. Sharma, 'Modeling the blockchain enabled traceability in agriculture supply chain', Int J Inf Manage, vol. 52, Jun. 2020, doi: 10.1016/j.ijinfomgt.2019.05.023.

[14] R. Ekawati, Y. Arkeman, S. -, and T. Candra, 'Proposed Design of White Sugar Industrial Supply Chain System based on Blockchain Technology', International Journal of Advanced Computer Science and Applications, vol. 12, no. 4, 2021, doi: 10.14569/IJACSA.2021.0120459.

[15] M. Javaid, A. Haleem, R. Pratap Singh, S. Khan, and R. Suman, 'Blockchain technology applications for Industry 4.0: A literature-based review', Blockchain: Research and Applications, vol. 2, no. 4. Elsevier Ltd, Dec. 01, 2021. doi: 10.1016/j.bcra.2021.100027.

[16] U. J. Munasinghe and M. N. Halgamuge, 'Supply chain traceability and counterfeit detection of COVID-19 vaccines using novel blockchain-based Vacledger system', Expert Syst Appl, vol. 228, Oct. 2023, doi: 10.1016/j.eswa.2023.120293.

[17] S. T. Tasnim, M. A. Islam, R. J. Taifa, S. Mahbub, and M. R. Ahmmad Rashid, 'Agri-food Traceability Using Blockchain Technology to Ensure Value Chain Management and Fair Pricing in Bangladesh', in 2022 IEEE 8th World Forum on Internet of Things (WF-IoT), IEEE, Oct. 2022, pp. 1–6. doi: 10.1109/WF-IoT54382.2022.10152086.

[18] Md. Akhtaruzzaman Khan, Md. Emran Hossain, A. Shahaab, and I. Khan, 'ShrimpChain: A blockchain-based transparent and traceable framework to enhance the export potentiality of Bangladeshi shrimp', Smart Agricultural Technology, vol. 2, p. 100041, Dec. 2022, doi: 10.1016/j.atech.2022.100041.

[19] K. Salah, N. Nizamuddin, R. Jayaraman, and M. Omar, 'Blockchain-Based Soybean Traceability in Agricultural Supply Chain', IEEE Access, vol. 7, pp. 73295–73305, 2019, doi: 10.1109/ACCESS.2019.2918000.

[20] A. K. Hadi and S. Salem, 'A proposed methodology to use a Block-chain in Supply Chain Traceability', in 4th International Iraqi Conference on Engineering Technology and Their Applications, IICETA 2021, Institute of Electrical and Electronics Engineers Inc., 2021, pp. 313–317. doi: 10.1109/IICETA51758.2021.9717543.

[21] A. Sarfaraz, R. K. Chakrabortty, and D. L. Essam, 'AccessChain: An access control framework to protect data access in blockchain enabled supply chain', Future Generation Computer Systems, vol. 148, 2023, doi: 10.1016/j.future.2023.06.009.

[22] L. Wang et al., 'Smart Contract-Based Agricultural Food Supply Chain Traceability', IEEE Access, vol. 9, 2021, doi: 10.1109/ACCESS.2021.3050112.

[23] J. Tan, S. B. Goyal, A. Singh Rajawat, T. Jan, N. Azizi, and M. Prasad, 'Anti-Counterfeiting and Traceability Consensus Algorithm Based on Weightage to Contributors in a Food Supply Chain of Industry 4.0', Sustainability (Switzerland), vol. 15, no. 10, 2023, doi: 10.3390/su15107855.

[24] L. Yogarajan, M. Masukujjaman, M. H. Ali, N. Khalid, L. H. Osman, and S. S. Alam, 'Exploring the Hype of Blockchain Adoption in Agri-Food Supply Chain: A Systematic Literature Review', Agriculture (Switzerland), vol. 13, no. 6. MDPI, Jun. 01, 2023. doi: 10.3390/agriculture13061173.

[25] T. L. Yap, R. Nayak, N. T. H. Vu, D. T. Bui, T. T. T. Pham, and D. W. E. Allen, 'Adopting blockchain-based traceability in the fruit supply chain in a developing economy: facilitators and barriers', Information Technology & People, Oct. 2023, doi: 10.1108/ITP-02-2023-0168.

[26] U. J. Munasinghe and M. N. Halgamuge, 'Supply chain traceability and counterfeit detection of COVID-19 vaccines using novel blockchain-based Vacledger system', Expert Syst Appl, vol. 228, p. 120293, Oct. 2023, doi: 10.1016/j.eswa.2023.120293.

[27] Z. Shahbazi and Y.-C. Byun, 'A Procedure for Tracing Supply Chains for Perishable Food Based on Blockchain, Machine Learning and Fuzzy Logic', Electronics (Basel), vol. 10, no. 1, p. 41, Dec. 2020, doi: 10.3390/electronics10010041.

[28] J. Wang et al., 'Blockchain-Based Information Supervision Model for Rice Supply Chains', Comput Intell Neurosci, vol. 2022, pp. 1–17, Mar. 2022, doi: 10.1155/2022/2914571.

[29] N. K. Jadav, T. Rathod, R. Gupta, S. Tanwar, N. Kumar, and A. Alkhayyat, 'Blockchain and artificial intelligence-empowered smart agriculture framework for maximizing human life expectancy', Computers and Electrical Engineering, vol. 105, p. 108486, Jan. 2023, doi: 10.1016/j.compeleceng.2022.108486.

[30] A. Aldoubaee, N. H. Hassan, and F. A. Rahim, 'A Systematic Review on Blockchain Scalability', International Journal of Advanced Computer Science and Applications, vol. 14, no. 9, pp. 774–784, 2023, doi: 10.14569/IJACSA.2023.0140981.

[31] F. Tian, 'A Supply Chain Traceability System for Food Safety Based on HACCP, Blockchain & Internet of Things', in 2017 international conference on service systems and service management , 2017, pp. 1–6.

[32] F. Tian, 'An agri-food supply chain traceability system for China based on RFID & blockchain technology', in 2016 13th International Conference on Service Systems and Service Management (ICSSSM), 2016.

[33] M. P. Caro, M. S. Ali, M. Vecchio, and R. Giaffreda, 'Blockchain-based traceability in Agri-Food supply chain management: A practical implementation', in 2018 IoT Vertical and Topical Summit on Agriculture - Tuscany, IOT Tuscany 2018, Institute of Electrical and Electronics Engineers Inc., Jun. 2018, pp. 1–4. doi: 10.1109/IOT-TUSCANY.2018.8373021.

[34] T. Surasak, N. Wattanavichean, C. Preuksakarn, and S. C.-H., 'Thai Agriculture Products Traceability System using Blockchain and Internet of Things', International Journal of Advanced Computer Science and Applications, vol. 10, no. 9, 2019, doi: 10.14569/IJACSA.2019.0100976.

[35] J. F. Galvez, J. C. Mejuto, and J. Simal-Gandara, 'Future challenges on the use of blockchain for food traceability analysis', TrAC - Trends in Analytical Chemistry, vol. 107. Elsevier B.V., pp. 222–232, Oct. 01, 2018. doi: 10.1016/j.trac.2018.08.011.

[36] Y. Gavel and L. Iselid, 'Web of Science and Scopus: a journal title overlap study', Online Information Review, vol. 32, no. 1, pp. 8–21, Feb. 2008, doi: 10.1108/14684520810865958.

[37] A. Z. Mansour, A. Ahmi, O. M. J. Popoola, and A. Znaimat, 'Discovering the global landscape of fraud detection studies: a bibliometric review', J Financ Crime, vol. 29, no. 2, pp. 701–720, Mar. 2022, doi: 10.1108/JFC-03-2021-0052.

[38] K. Petersen, R. Feldt, S. Mujtaba, and M. Mattsson, 'Systematic Mapping Studies in Software Engineering', in 12th International Conference on Evaluation and Assessment in Software Engineering, 2008, pp. 1–10. [Online]. Available: www.splc.net

[39] N. Carmona-serrano, J. López-belmonte, J. L. Cuesta-gómez, and A. J. Moreno-guerrero, 'Documentary analysis of the scientific literature on autism and technology in web of science', Brain Sciences, vol. 10, no. 12. MDPI AG, pp. 1–20, Dec. 01, 2020. doi: 10.3390/brainsci10120985.

[40] M. Yurtcu and C. O. Güzeller, 'Bibliometric analysis of articles on computerized adaptive testing', Participatory Educational Research, vol. 8, no. 4, pp. 426–438, Dec. 2021, doi: 10.17275/per.21.98.8.4.

[41] R. Wahid, A. Ahmi, and A. S. A. F. Alam, 'Growth and Collaboration in Massive Open Online Courses: A Bibliometric Analysis', International Review of Research in Open and Distance Learning, vol. 21, no. 4, pp. 292–322, Nov. 2020, doi: 10.19173/IRRODL.V21I4.4693.

[42] U. Sugandh, S. Nigam, S. Misra, and M. Khari, 'A Bibliometric Analysis of the Evolution of State-of-the-Art Blockchain Technology (BCT) in the Agrifood Sector from 2014 to 2022', Sensors, vol. 23, no. 14, Jul. 2023, doi: 10.3390/s23146278.

[43] M. H. Ansari et al., 'Bibliometric Analysis of Food Supply Chain Transformation using Digital Technology', in Proceedings of 3rd IEEE International Conference on Computational Intelligence and Knowledge Economy, ICCIKE 2023, Institute of Electrical and Electronics Engineers Inc., 2023, pp. 376–380. doi: 10.1109/ICCIKE58312.2023.10131782.