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Artificial Intelligence in Supply Chain of Agricultural Products: A Bibliometric Review

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ABSTRACT

Bibliometric analysis is a part of systematic review using quantitative analysis of the influential studies of the subject that inspires decision making and pool of knowledge for the academicians. Considering relevance and keeping this background in mind, this study reviews the existing literature about artificial intelligence in agricultural supply chain. Specifically, a bibliometric and VOS viewer analysis was conducted of the influential studies of the subject in terms of various aspects, such as authors, sources, countries/ regions, keywords, subject areas, citation overview, co-authorship, co-occurrence analysis of all keywords, bibliographic coupling and co-citation of cited references of the Scopus database between 2004 and 2024. The major subject areas were Computer Science, Engineering, Agricultural and Biological Sciences, Business, Management and Accounting and Environmental Science. The most productive journals were Sustainability (Switzerland), Computers and Electronics in Agriculture and Hassoun A as the most contributors. India, China and UK were the top three contributing countries. Based on the findings, the current study makes suggestions for the research topics that could be influential for further research.

Key words: Agricultural products, Artificial intelligence, Bibliometric review, Review, Supply chain, VOS viewer.

AI-agriculture integration is a transformative approach that enhances the efficiency, sustainability and transparency of the farm-to-consumer food supply chain. AI has wider applicability from soil preparation to post harvest but from the growers' point of view it is useful for digital world which is a technological gap. Poor understanding and large expenses associated with use of AI are some of the limitations (Mohan, 2023). Artificial intelligence-based technologies may provide solutions during transit, cold storage and thereby quality adherence and demand upliftment (Chandra, 2023; Tiwari *et al*., 2023). The combined effect of block chain and artificial intelligence on authenticity verification of organic legumes in supply chain has provided a thought-provoking potential of use of these technologies in agriculture food sector (Kim *et al*., 2024).

This article identifies the characteristics and research trends quantitatively and qualitatively and bibliometric analysis is adopted. Bibliometric review is a detailed approach for finding out and scrutinising large scientific data used to methodically evaluate the research articles and to evaluate their significance within the subject area. As an innovative literature review, bibliometric analysis provides a more unbiased analysis of the literature by avoiding subjective judgements at publication. The prevalent bibliometric analysis methods in scientific research are citation analysis, co-citation analysis, cooccurrence (co-word or keyword) analysis, bibliographic coupling and co-author analysis (Van Eck and Waltman, 2014; Zupic and Cater, 2015) (9a, 9b). However, citation analysis is the most commonly used, which is an impactful method that tries to investigate about most influential publications, authors, journals and institutions in a specific scientific discipline (Buhari, 2020 (10a); Kovačević and Hallinger, 2020 (10b); Hou *et al*., 2018 (10c); Ataş and Karadağ, 2017 (10d); Liñán and Fayolle, 2015; Zupic and Cater, 2015, Allen *et al*., 2009; Donthu *et al*., 2021).

On 23.12.2024 data were extracted from Scopus database with the following search strings and 395 documents were identified during the period 2004 to 2024 using the Boolean operators "AND" and "OR" (Fig 1).

The "Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)" statement is a set of guidelines designed to help authors in preparing a in creating a clear and replicable description of a Systematic Literature Review (Page *et al*., 2020) (11). PRISMA protocol follows for mapping of exclusion/inclusion process and to be precise in the specific study, conference papers were removed and after exclusion of "articles in press" and irrelevant documents related to the subject cited (nursing, pharmacy, health profession, medicine, psychology *etc*.) are excluded and studies included counts to 270. The exclusion criteria were considered based on its non relevance to the subject studied, not published on journals and language other than English. A combination of tools

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like Microsoft excel 2021 and bibliometric software VOS viewer (version 1.6.20_exe), which is a powerful network analysis software is used. The techniques for bibliometric analysis work across two categories: (1) performance analysis and (2) science mapping (Passas, 2024) (12). In essence, performance analysis accounts for the contributions of research constituents, whereas science mapping focuses on the relationships between research constituents. This study includes performance analysis (number of articles of the topic, author's contribution, country wise contribution, frequency analysis of keywords, sources and subject areas) science mapping and network analysis (co-authorship, co -occurrence of keywords, co-citation analysis, bibliographic coupling).

Trends in publication and citation of documents

While considering the top 10 contributing authors, Hassoun A has contributed the highest number of publications during that period (7) followed by Majumdar, A.S. (5), Zhang, M. (5), Ait-Kaddour, A. (4), Barba, F.J. (4) and Bouzembark, Y, Cropotova , J., Jagtap, S., Lorenzo J.M. and Onyeaka, H. (3 each) (Fig 2). Hassoun A' s publications at some of the sources with five top most citations may be mentioned as "Frontier in Microbiology, 2022.13.999001", (444 citations); "Foods, 2022, 11(14),2098" (322 citations); "Critical Reviews in Food Science and Nutrition, 2023, 63(23), pp. 6547- 6563" (269 citations); "Trends in Food Science and Technology, 2017, 68, pp. 26-36" (220 citations) and "Biomedicine and Pharmacotherapy, 2022, 156, 113945" (186 citations). Similarly, Jagtap, Sandeep has publications in "Foods, 2022, 11(14), 2098" (322 citations); "Journal of Food Engineering, 2023, 337, 111216", (150 citations); "Trends in Food Science and Technology,2020,106, pp.355-364," (149 citations); "Logistics, 2021,5(1),2", (140 citations) and "Business Strategy and the Environment, 2023,32(4), pp.1334-1356," (123 citations).

Country-specific distribution of documents shows the publications in different countries (Fig 3). As far as country-specific production is concerned, India has the maximum production with a frequency of 77 articles, followed by China (frequency 48), UK (frequency 36) USA (frequency 28), French (16), Italy (13), Australia (12), Canada (12), Spain (12) and Brazil (11). Sources of India with top three highest cited articles are "IEEE Internet of Things Journal, 2022, 9(9), pp.6305-6324", (642 citations); "Journal of Behavioural and Experimental Finance, 2021, 32, 100577", (513 citations) and "International Journal of Intelligent Network, 2022, 3, pp.150-164" (470 citations).

The major keywords used were artificial intelligence (159), supply chain management (44), internet of things (42), supply chain (35), machine learning (35); most producing sources were Sustainability Switzerland (15), Computers and Electronics in Agriculture (8), Critical Reviews in Food Science And Nutrition (6), Industrial Management and Data Systems (5) and IEEE Access (5), Journal of Cleaner Production (4); and subject areas were Computer Science (115), Engineering (106), Agricultural and Biological Sciences (83), Business , Management and Accounting (71) and Environmental Science (45), Social Sciences (40), Data Sciences (34).

Citation analysis is done to find out highest impactful author, most impactful journal, most impactful documents on the research area *etc*. Out of 270 documents, 205 documents have been cited with total of 7426 citations and h-index of 45 (Fig 4).

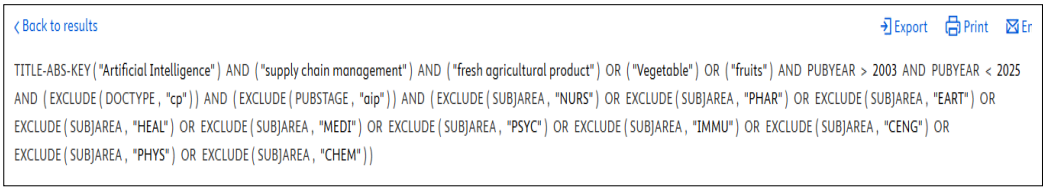
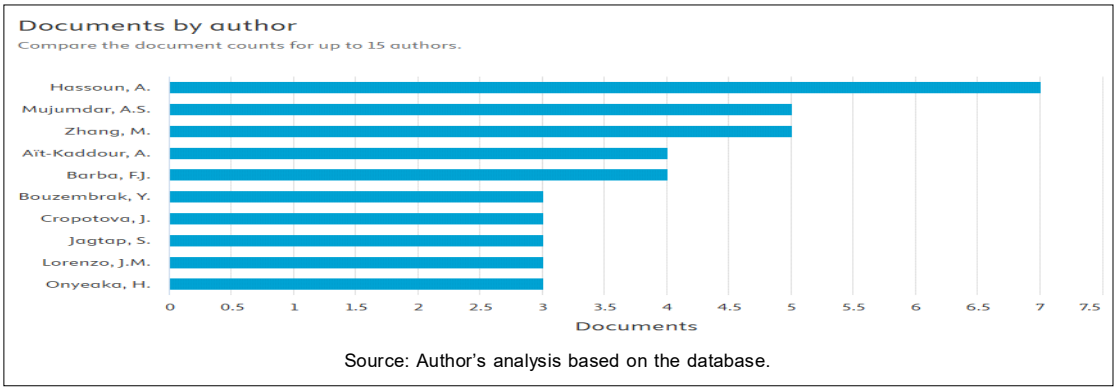


Fig 1: Search strings for data extraction.



Source: Author's analysis based on the database.

Fig 2: Influential contributing authors.

Agri-food 4.0

A survey of the Supply Chains and Technologies for the Future Agriculture has the highest citation (514) followed by four others, if we consider the top 5; From Industry 4.0 to Agriculture 4.0: Current Status, Enabling Technologies and Research Challenges (474); IoT, Big Data and Artificial Intelligence in Agriculture and Food Industry (417); Artificial intelligence and machine learning in finance: Identifying foundations, themes and research clusters from bibliometric analysis (333); Enhancing smart farming through the applications of Agriculture 4.0 technologies (250) and Smart logistics based on the internet of things technology: an overview (214) .

To begin comparing sources, up to 10 sources are selected *i.e*, Critical Reviews in Food Science and Nutrition, Computers and Electronics in Agriculture, Computers and Industrial Engineering, Sustainability (Switzerland), IEEE Access, Critical Reviews in Food Science and Nutrition, Journal-level metrics are essential tools for evaluating the impact and influence of academic journals. Here are some key metrics used in the academic community.

CiteScore™ Metricswas introduced in 2016, CiteScore metrics provide a family of eight indicators to analyze the publication influence of serial titles. CiteScore metrics offer more robust, timely and accurate indicators of a serial title's impact compared to other metrics. Cite Score is calculated as the number of citations received by a journal in one year to documents published in the three preceding years, divided by the number of documents indexed in Scopus published in those same three years.

Cites core is seen highest for the source "Critical Reviews in Food Science and Nutrition" and the lowest is for "IEEE Access" (Fig 5).

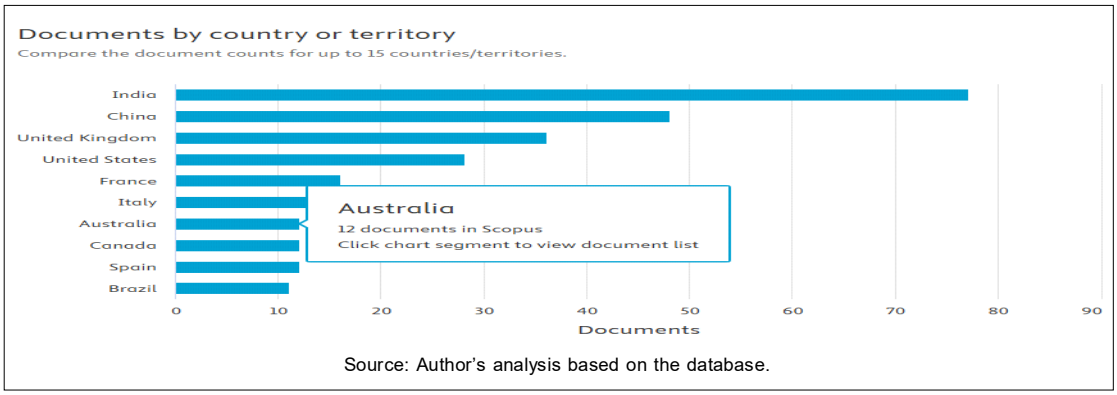
SCImago journal rank (SJR)

SJR is a prestige metric for journals, book series and conference proceedings. It weights the value of a citation based on the subject field, quality and reputation of the source. SJR is based on the transfer of prestige from the journal citing to the journal cited. The prestige of the citing journal is taken into account, making SJR a more nuanced measure of journal impact.

The lowest SCImago is seen at "Sustainability Switzerland" (2010) and the highest is "Critical Reviews in Food Science and Nutrition" (2021) (Fig 6).

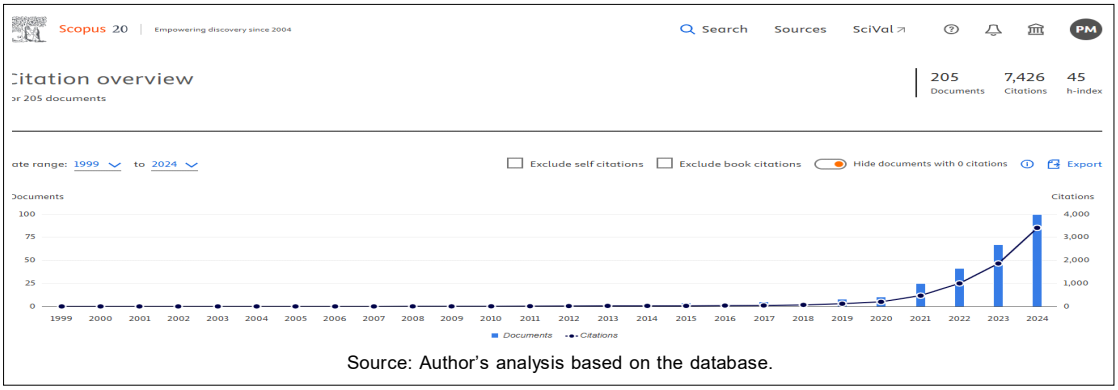
Source-normalized impact per paper (SNIP)

SNIP measures contextual citation impact by accounting for differences in disciplinary characteristics. It allows for the comparison of journals across different fields by normalizing the citation impact. SNIP is calculated by



Source: Author's analysis based on the database.

Fig 3: Major contributing countries.



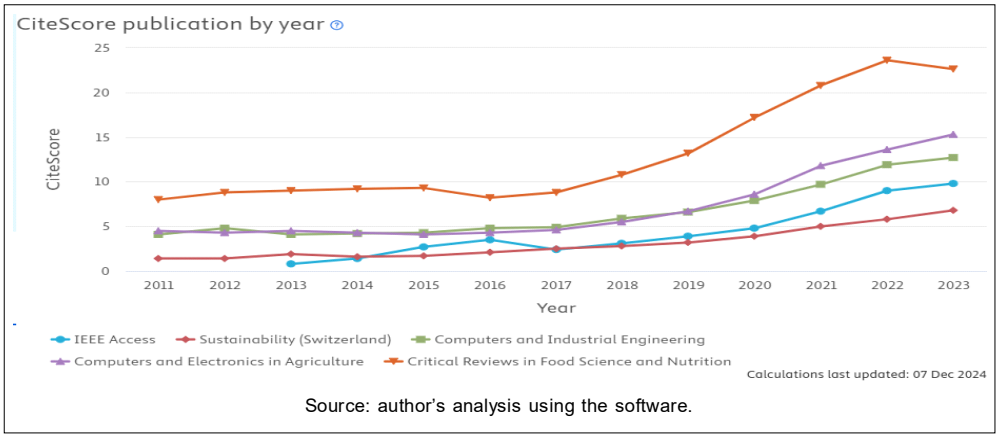
Source: Author's analysis based on the database.

Fig 4: Citation overview of documents.

dividing the raw impact per paper by the citation potential in the subject field. This metric helps to balance the citation rates that vary significantly between different disciplines. These metrics provide a comprehensive view of a journal's performance and influence, helping researchers, academics and institutions make informed decisions about where to publish and which journals to follow.

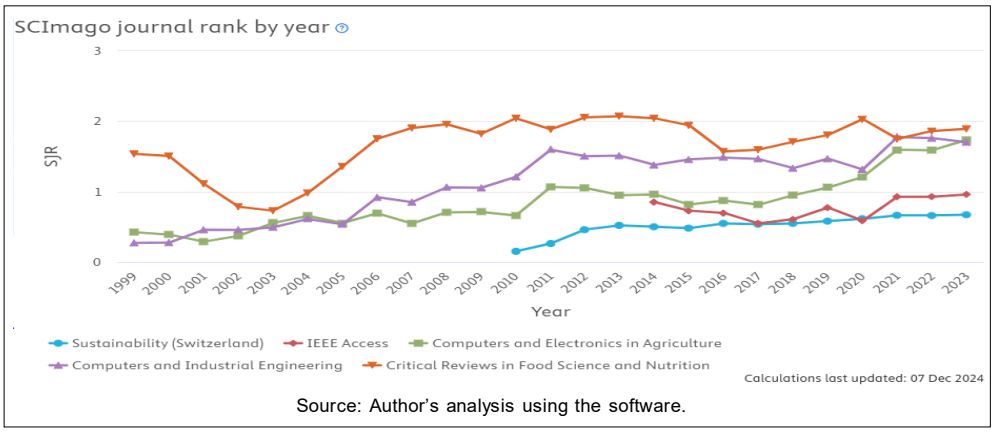
SNIP of sources per year is found highest in "IEEE Access" (2015) followed by "Critical Reviews in Food Science and Nutrition" (2022) but the lowest is found for "Sustainability (Switzerland)" in 2010 (Fig 7).

It is seen that the highest source citations by year is at "IEEE Access" (2024) and lowest is at "Sustainability (Switzerland)" during 2004-2010 (Fig 8) and Critical



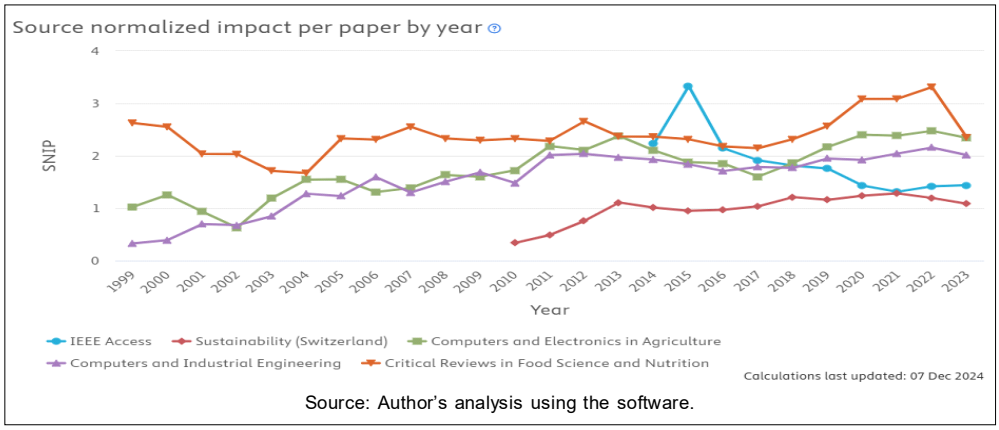
Source: author's analysis using the software.

Fig 5: Citescore publication by year of the sources.



Source: Author's analysis using the software.

Fig 6: Source analysis of SC Imago journal rank by year.



Source: Author's analysis using the software.

Fig 7: SNIP of sources per year (1999-2023).

Reviews in Food Science and Nutrition with highest percentage of review articles (Fig 9).

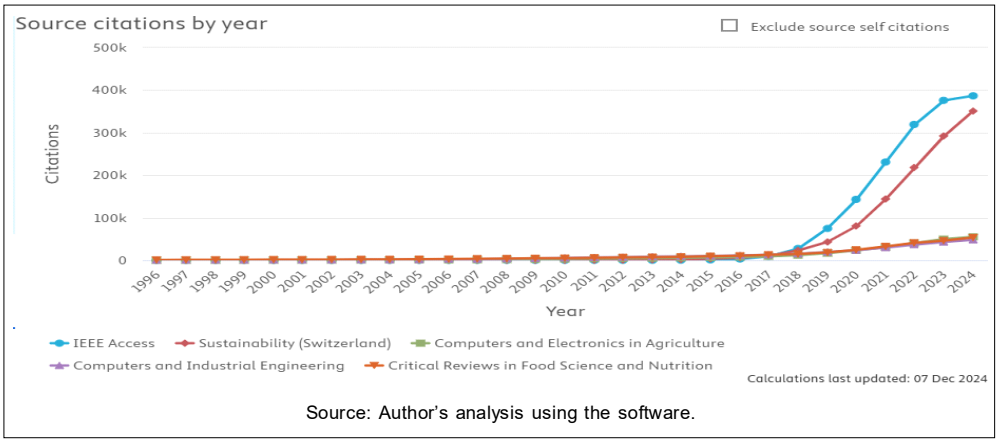
VOSviewer _1.6.20_exe (Visualising scientific landscapes) analysis

VOSviewer is generally used for bibliometric analysis, but it has also been shown to be useful for text analysis and visualization. It provides a workflow for dataset preparation and has the capacity to study text networks across a range of domains (Arruda *et al*., 2022; Bukar *et al*., 2023). VOSviewer is used to create co-authorship, key-word occurrences, citations, bibliographic coupling, co-occurrence analysis.

Co-authorship analysis finds research partnerships and monitors how research networks change over time. Co authorship with authors analysis in full network method where in maximum numbers of authors per document restricts at 25 and minimum number of documents of an author remains 5 and the result of out of 21208 authors 213 meet the thresholds. For each of the 213 authors, the total strength of co-authorship links with other authors is calculated and the greatest total link strength are selected. Co-authorship with authors' documents with citations and total link strength of top 15 are listed below and we find hassoun, abdo with highest total link strength. Some of the 213 items in the network are not connected to each other. The largest set of connected items consists of 102 items, 11 clusters, 326 links and total link strength 807 (Fig 10).

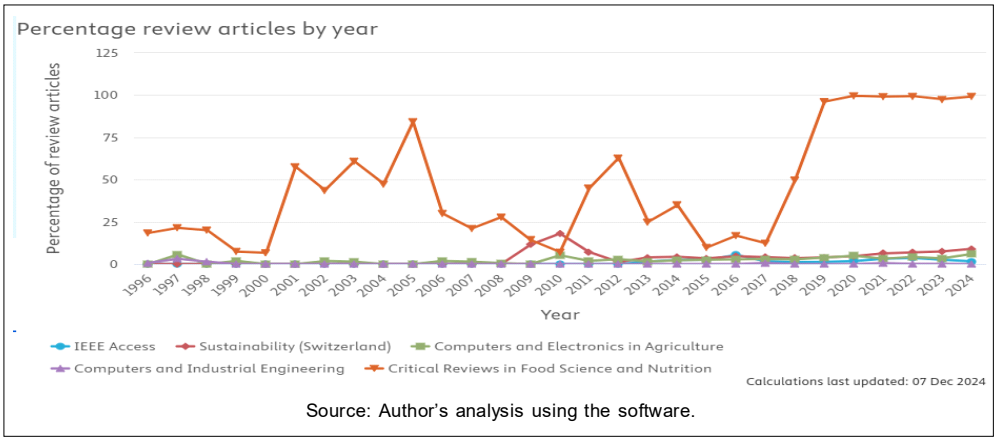
Co-occurrence analysis of all key words in full counting method to help understand the objectives of research to get a broader picture of the overall development of the study with minimum number of occurrences of a keyword as 5, out of 1938 keywords only 93 meet the requirements. Artificial intelligence is the keyword with the highest frequency and total link strength. The keywords' occurrences and total link strength for top 15 keywords are tabulated below (Fig 11).

Overlay visualisation of co-occurrence analysis of all key words has items-92, clusters -5, links -1661 and total link strength -3522. Cluster is a set of closely related nodes. Each node in a network is assigned to exactly one cluster. "Total link strength" refers to the sum of the strength of all connections (links) a particular node (keyword or author) has with other nodes in the network. The higher the total



Source: Author's analysis using the software.

Fig 8: Source citations by year.

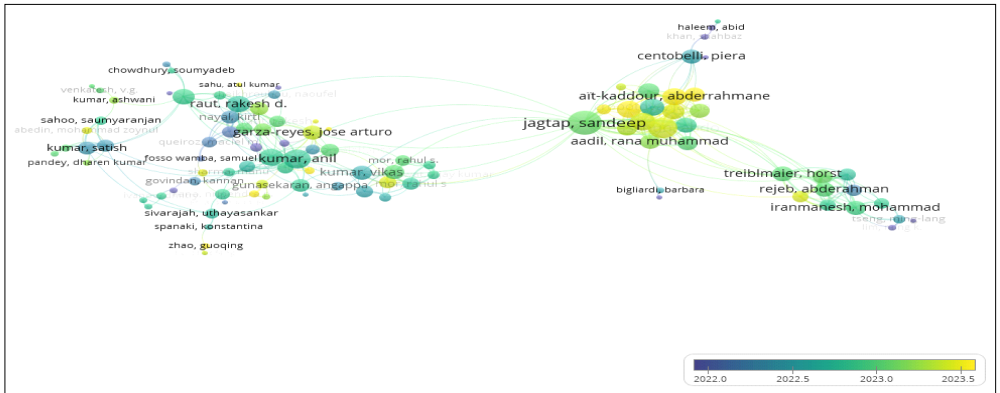


Source: Author's analysis using the software.

Fig 9: Percentage of review articles (Calculation on yearly basis).

link strength, the more significant the connections are considered to be. Some of the items with high total link strength in the clusters are analysed (Fig 12).

Bibliographic coupling occurs when two works reference a common third work. Bibliographic coupling with documents is analysed keeping minimum number of



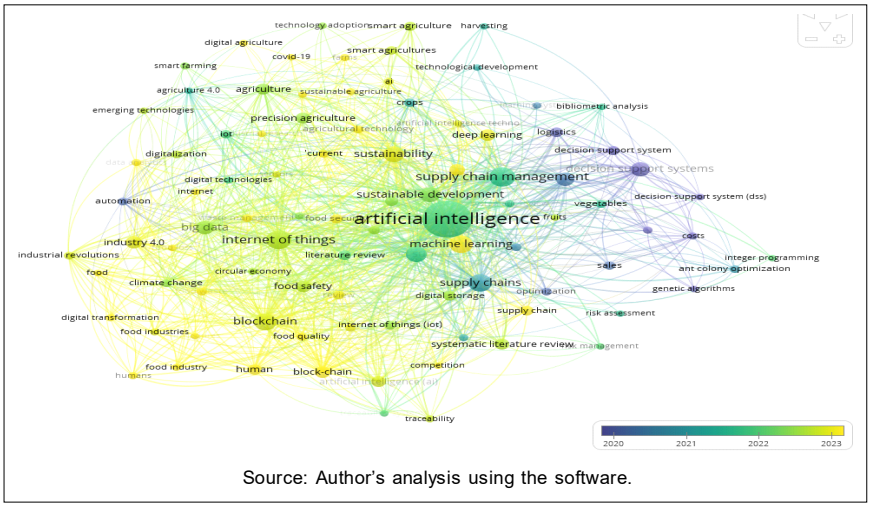
Source: Author's analysis using the software.

Fig 10: Overlay visualisation of co-authorship with authors.

Keyword	Occurrences	Total link strength
artificial intelligence	159	723
internet of things	42	266
blockchain	33	255
supply chain management	44	240
supply chains	36	239
food supply	30	237
sustainability	30	178
block-chain	17	155
sustainable development	26	151
big data	23	149
machine learning	36	144
decision making	23	139
industry 4.0	18	134
decision support systems	24	128
human	13	113

Source: Author's analysis using the software.

Fig 11: Co-occurrence analysis of all key words in full counting method.



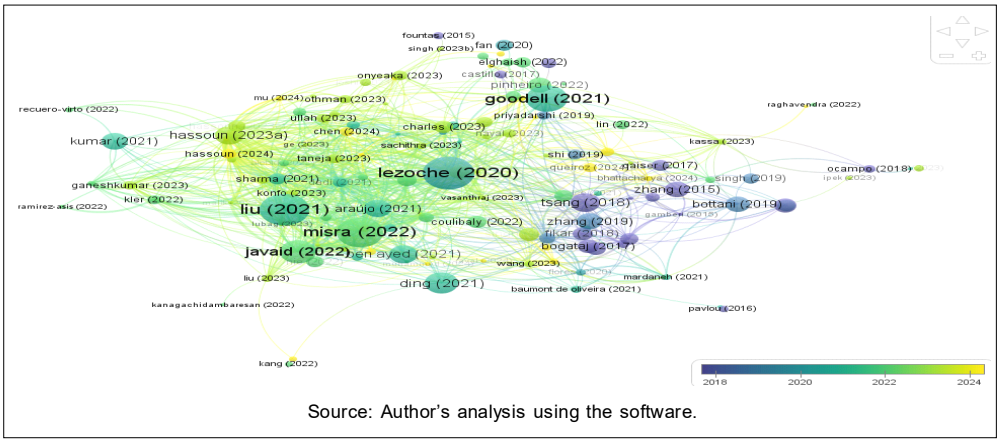
Source: Author's analysis using the software.

Fig 12: Overlay visualisation of co-occurrence analysis of all key words.

Document	Citations	Total link strength
hassoun (2024)	48	173
rejeb (2022a)	74	149
hassoun (2023a)	153	148
dadi (2021)	49	137
vasanthraj (2023)	9	121
vilas-boas (2023)	78	112
araújo (2021)	150	105
hassoun (2023b)	16	104
sharma (2021)	61	97
hassoun (2023c)	61	90
liu (2021)	474	87

Source: Author's analysis using the software.

Fig 13: Bibliographic coupling with documents.



Source: Author's analysis using the software.

Fig 14: Overlay visualisation of bibliographic coupling with documents.

citations of a document as 5 resulting in 153 meeting the threshold out of 270 documents and the largest set of connected items are 141. The overlay visualisation results in items -141, clusters -12, links -1321 and total link strength -2318. Top 10 documents with strong total link strength are tabulated as follows (Fig 13).

Bibliographic coupling, in relation to documents, explains the notion of conceptual relatedness between two documents based on the observation that both are citing the same third document in their reference lists - in other words, two documents are "coupled" if they cite the same references, which implies that they might be related in terms of subject matter or research focus (Fig 14).

CONCLUSION

This paper comprehensively collects, analyses and reviews various research areas of artificial intelligence in supply chain of fresh agricultural products from 2004-2024 using the Scopus database. The application of AI in the field of agricultural fresh products' supply chain is rapidly developing as it is evident by the keywords "artificial intelligence", "internet of things (IoT)" and "blockchain" and can forecast that the rise of use of artificial intelligence will keep attracting the attention of researchers and both Governments and corporates will make efforts in policy making and commercial planning. Analysis of the database indicates that India leads in this research area followed by China. Hassoun A. is the most influential author with an h-index 31 (2000-2025). Collaboration between authors, regions, co-citation of cited references providing total link strength with other cited references, bibliographic coupling with documents and author's co-occurrence with keywords provide the researcher with performance analysis and science mapping. Future research might incorporate theoretical knowledge of artificial intelligence in traditional agricultural product supply chain and cross - disciplinary research paradigm. AI adoption in agriculture can improve traceability about agriculture products in transit and thereby reduction in operational loss and waste amongst the stakeholders of supply chain and it improves market linkage to enable producers to collaborate with the retailers/consumers to fetch better price. But bibliometric analysis methodology has it's own limitations which has influence on this article too. Moreover. Although, the Scopus database covers large number of publications, there may be dearth of some valuable publications as some other databases like web of science, google scholar may also include relevant publications.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript. As no animal/ human body was used there is no ethical issues.

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