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Research Article

How is Industry 4.0 Changing Food Technology? A Scientometric Profile

Jiaur Rahaman*, M Sadik Batcha

Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India.

ABSTRACT

The food industry has changed due to the present industrial revolution, industry 4.0. The processes taking place in energy and food firms leverage aspects of the industry 4.0 paradigm, such as machine learning, the Internet of Things, and Big Data. The goal of this research is to give academics a summary of works that have been published on the topic of food technology. Hence, the review examines the most active authors, sources, organizations, and countries conducting studies in the subject domain. The selected documents from the Web of Science from 2013 to 2021, using Bibliometrix and VOSviewer software to gather relevant publication trends and identify the most significant networks. The results identified that the growth of food technology literature has many documents published in 2021. A total of 2529 documents were published in 527 sources, among which the most popular was Sustainability. Collaboration among authors reached 91 countries, the most prominent country was China. This research will be a vital tool for academics and policymakers in providing well-developed and better-oriented continuous training programs to lessen the skill gap between workers and jobs.

Keywords: Scientometric, Industry 4.0, Food technology, Web of Science, Bibliometrix tool.

Correspondence:
Jiaur Rahaman
Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India.
Email ID: jrahaman.mlis@gmail.com

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INTRODUCTION

Industry 4.0 is a technological revolution that envisions using machines, workpieces, and Information Technology systems connected to the value chain beyond a single organization (Filatov *et.al*., 2020). In all facets of human life, the Fourth Industrial Revolution concept is being adopted and applied (Noor Hasnan *et.al*., 2018). The 4 IR is a possible human life-saving invention that will replace human intelligence and manual labor with artificial intelligence and robotics. Academics are focusing on the revolution, while industry leaders are preparing for its inevitable and rapid deployment in foods, vehicles, telecommunications, services, security, health, and other industries. (Jambrak, *et.al* 2021). The agriculture and food industry, also referred to as "food 4.0," is the most significant employer of human resources. It is anticipated that the idea and application of 4IR will substantially impact this industry (Jones & Pimdee, 2017).

The term "Industry 4.0" was formulated by the President of the World Economic Forum in 2011 (Claudine & Raja, 2018). As the twenty-first century begins, the global food industry is facing numerous problems due to the effects of rapid population growth, accelerated deforestation in rainforests, land degradation, and desertification, increasing demand for food, energy, and water resources, and an increase in greenhouse gas concentrations in the atmosphere, climate change, as well as ever-changing consumer demands, and the growing legal pressure of the government, which have resulted in several forces for change (Bader & Rahimifard, 2018). Food insecurity is a global issue with ramifications in many countries, particularly in metropolitan areas, but its impact is uneven. Around 50 million children globally suffer from food insecurity, with half residing in South Asia and a quarter in Sub-Saharan Africa. According to the FAO, 793 million people, or one in nine people worldwide, lack enough food for their daily needs (Kakani, *et.al*., 2020).

The current industrial revolution, Industry 4.0, has caused dramatic and ongoing changes in the food industry in recent years (Amorim *et.al*., 2019). Devices that interact autonomously with one another through technology and devices that communicate autonomously and value chain activities are all considered to be part of "Industry 4.0" (Akyazi, *et.al*., 2020).

With the advent of digitalization and intelligent technologies like robotics, artificial intelligence (AI), the Internet of Things (IoT), machine learning, and so on, manufacturing processes are evolving. They are currently going through a new phase of automation that enables more creative and effective operations, products, and services (Rani *et.al*., 2020). The use of scientometric studies as a mechanism for rating the effectiveness of research is

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growing. Since these metrics are based on bibliographic databases created primarily for information retrieval, informetric studies are just a supplemental application of the systems (Wallin, 2005). Scientometrics has been acknowledged as a valuable method for developing a generalized picture of a scientific research field. The subject of bibliometrics has advanced quickly in recent years, which may be linked to social developments that have largely profited from the advent of the internet and computers (Janmaijaya *et.al.*, 2018). Science and Technology (Debackere, *et.al.*, 2002), medicine (Chen, *et.al.*, 2019), Medical research (Azer, 2015), food safety (Bouzembrak *et.al.*, 2019), and Agriculture (Velasco-Muñoz, *et.al.*, 2018) are some of the fields where scientometric research is highlighted in addition to computer science. The remainder of the essay is structured as follows. The earlier research on the 4. 0 industrial revolutions are included in Section 2. Section 3 describes the methodology and data collection process. The data analysis and interpretation are presented in Section 4. Section 5 presents the analysis and conclusion.

LITERATURE REVIEW

A scientometric analysis is a field of study that helps in the examination of current trends in the research in a given field and provides directions and inspirations for further research. Regarding present studies, no scientometric study has been published on the topic of assessing and evaluating industry 4.0 in the food industry were not found from any nation. The Fourth Industrial Revolution has, however, been the subject of numerous studies, including robots in Logistics 4.0 (Atzeni, *et.al.*, 2021), Project Management and Industry 4.0 (López-Robles, 2020), Industry 4.0 in Construction (Zabidin, *et.al.*, 2020), Knowledge Management in the Fourth Industrial Revolution (Fakhar Manesh *et.al.*, 2021), 4.0 in seaport (Rahaman, 2022). We determined it was suitable to fill the gap from the world perspectives literature in the metrics field as research studies related to industry 4.0 in the food business needed to be conducted.

STUDY QUESTIONS

An exhaustive review of the food technology literature published in the Web of Science will be made available to scholars and practitioners as a result of this study. We will address the following issues to accomplish this goal:

1. What are the most important, innovative works of food technology literature?
2. What are the potential future lines of inquiry in food technology literature?

MATERIALS AND METHODS

The most popular database used in scientometric and bibliometric research is the Web of Science (WoS). The data source used to search was the WoS core collection database, with index dates spanning from 2013 to 2021. The search strategy was "TOPIC ("industry 4.0" OR "smart manufacturing" AND "food industry") AND TOPIC ("robotics" OR "artificial intelligence" OR "internet of things" OR "machine learning" OR "information technology" OR "blockchain" OR "big data" OR "digitalization" OR "hybrid production" OR "digital technologies" OR "supply chain" OR "cloud computing" OR "cognitive computing" OR "ICT") is shown in Figure 1. When we refined our search by LANGUAGES and used the WoS database: (ENGLISH) Period: 2013 through 2014. SCI, SSCI, and A&HCI indexes. The outcome was discovered in 2529 peer-reviewed journal publications.

All the data were downloaded from the WoS and imported into the software for analysis. In this study, Microsoft Office Excel was used to create a figure on annual research output, and the bibliomerix tool and VOSviewer software were used to perform scientometric analysis. The VOSviewer was used to identify the co-author's countries, organizations, a co-authorship network, and to cluster visualization of co-occurrence keyword analysis.

RESULTS

Citation count by year from 2013 to 2021

Figure 2 displays the distribution of the 2529 articles by year between 2013 and 2021, with the average number of citations per document (21.04) and the average number of citations annually (5.96). According to information gathered from the Web of Science database, the first industry 4.0-related study (one article)

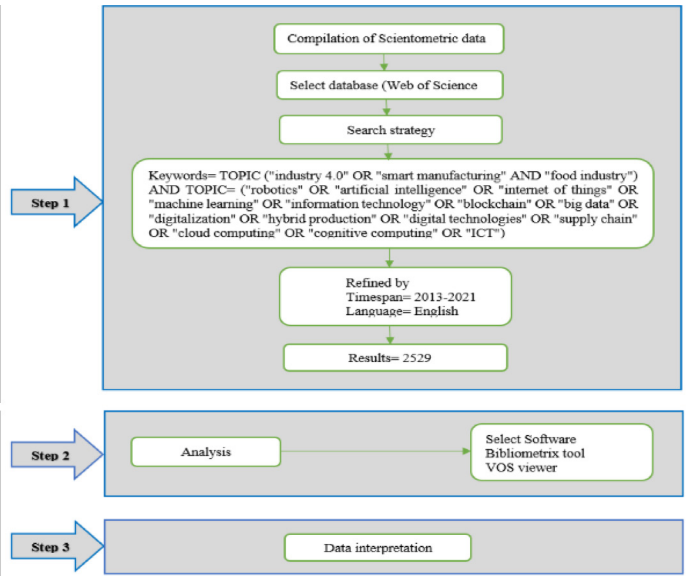

Figure 1: Research Design in the Domain of Food Technology

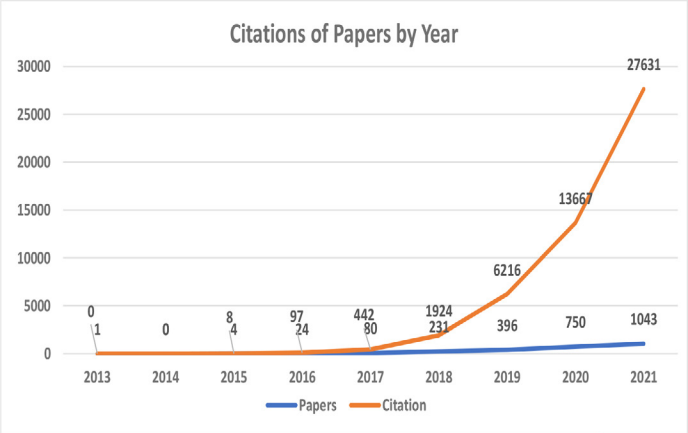

Figure 2: Citations of Papers by Year in the Web of Science

was published in 2013. Figure 2 shows that no articles were published in 2014. From 2015 to 2021, there was a consistent rise in published publications. However, the number of papers published in the recent four years has significantly increased. As a result, it is possible that in 2021, authors' interest in publishing in the WoS has shifted. The number of citations peaked in 2013 at 27631, possibly due to the substantial increase in recently published works with comparable topics. 13667 (2020), 6216 (2019), and 1924 come after that (2018).

Table 1 shows the frequency distribution of the top 10 cited papers published from the Web of Science database between 2013 and 2021 which is connected to the proposed keywords in this paper. According to the WoS, the first article was produced by

Table 1: Top 10 Highly Cited Papers on IR 4.0 in Food Technology

Rank	Paper	Title	Sources	Citations	CPY	Affiliation/ Country
1	Xu, L.D., 2018	Industry 4.0: State of the art and future trends	International Journal of Production Research	840	168	Old Dominion University, USA
2	Zhong, R.Y., 2017	Intelligent Manufacturing in the Context of Industry 4.0: A Review	Process Engineering Journal	732	122	The University of Hong Kong, Hong Kong
3	Liao, Y.X., 2017	Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal	International Journal of Production Research	648	108	National Huaqiao University, China
4	Hofmann, E., 2017	Industry 4.0 and the current status as well as future prospects on logistics	Computers in Industry	547	91.2	University of St. Gallen, Switzerland
5	Wang, S.Y., 2016	Towards Smart Factory for Industry 4.0: A Self-organized Multi-agent System with Big Data Based Feedback and Coordination	Computer Networks	546	78	South China University of Technology Institute of Mechatronic Engineering, China
6	Lu, Y., 2017	Industry 4.0: A Survey on Technologies, Applications, and Open Research Issues	Journal of Industrial Information Integration	525	87.5	University Of Central Oklahoma, USA
7	Kang, H.S., 2016	Smart manufacturing: Past research, present findings, and future directions	International Journal of Precision Engineering and Manufacturing-Green Technology	486	69.4	Sungkyunkwan University, South Korea
8	Sisinni E., 2018	Industrial Internet of Things: Challenges, Opportunities, and Directions	IEEE Transactions on Industrial Informatics	462	92.4	University of Brescia, Italy
9	Frank A.G., 2019	Industry 4.0 technologies: Implementation patterns in manufacturing companies	International Journal of Production Economics	447	111.8	Federal University of Rio Grande do Sul, Brazil
10	Dalenogare, L.S., 2018,	The expected contribution of Industry 4.0 technologies for industrial performance	International Journal of Production Economics	357	71.4	Federal University of Rio Grande do Sul, Brazil

Table 2: Top 10 Sources in the Domain of Food Technology

Rank	Sources	Papers	Citation	*h*-index	*g*-index	*m*-index	IF
1	Sustainability	130	2324	25	44	4.17	25.94
2	IEEE Access	107	3524	29	57	4.14	4.48
3	Sensors	90	1007	18	26	2.57	10.20
4	Applied Sciences-Basel	83	559	13	18	2.60	2.76
5	International Journal of Production Research	73	5332	33	73	0	8.43
6	IEEE Transactions on Industrial Informatics	61	2423	25	49	4.17	12.22
7	Computers in Industry	48	2312	25	48	3.57	9.96
8	Journal of Cleaner Production	46	1260	21	35	4.20	9.56
9	International Journal of Advanced Manufacturing Technology	45	555	14	21	2.80	3.55
10	Technological Forecasting and Social Change	42	2041	18	42	3.60	9.01

Table 3: Top 10 Active Authors in I4.0 in Food Technology

Rank	Authors	Papers	Citation	*h*-index	*g*-index	*m*-index
1	Wan JF	20	2319	16	20	2.28
2	Li D	18	1986	17	18	2.42
3	Kumar A	15	207	6	14	
4	Ivanov D	14	1426	11	14	1.57
5	Kumar N	14	411	9	14	1.8
6	Muller JM	13	896	9	13	
7	Dolgui A	12	1240	9	12	1.28
8	Gunasekaran A	12	656	8	12	
9	Tanwar S	12	492	10	12	2
10	Wang SY	12	1684	12	12	1.71

Nie, B.S. in 2013. The most influential paper during these periods had been published by Xu, L.D entitled "International Journal of Production Research", affiliated from Old Dominion University, the USA in 2018, Zhong, R.Y. from The University of Hong Kong, Hong Kong in 2017, and Liao, Y.X in National Huaqiao University, China 2017 with 840, 732, and 648 citations and the least was by Dalenogare, L.S. (2018) with 357 Citations among the top 10 cited articles.

Table 2 displays the documents used in this investigation, discovered in 2529 publications published in 527 journals. We discovered that the journal with the most publications, Sustainability (130 articles), provides the most to the study of food technology, followed by IEEE Access (107 papers) and Sensors (90). The highest cited source for this research was the International Journal of Production Research Access (5332 citations), which was followed by IEEE Access (3524) and IEEE Transactions on Industrial Informatics (2423). The International Journal of Production Research (73) and IEEE Access had the highest *h*-indexes (57). An academic journal's impact factor is a scientometric index determined by the WoS, the journal of Sustainability is the most influential journal for impact factors.

Based on total publications, citations, *h*-index, *g*-index, and *m*-index, Table 3 lists the top 10 authors who are most active in food technology. The total number of papers and citations determines the most prolific author. Their work was only included in the research domain if it related to the search criteria used by the authors. Based on the highest publications (20 papers) and highest citations (2319), Wan JF has the most significant output of any author. Kumar A and Li D (18 papers, citations from 1986) came next (15 papers, 207 citations). Based on the number of publications and the number of citations in the WoS database, Li D (17), Wan JF (16), and Ivanov D (11) had the highest *h*-indexes. Wan JF and Li D had the greatest *g*-indices in the topic domain (20 and 18 in the search domain).

A collaboration network finds people and social groups that, due to their network and location, may profit from greater information flow. In order to assess author competency, this study chose 7963 authors from the food technology literature; 102 authors fulfilled the cutoff for having at least 5 papers with at least 10 citations.

27 authors, 5 clusters, 49 links, and a total link strength of 96 describe the author's collaboration in the literature on food technology (Figure 3). The cluster in red represents Anil Kumar, Sunil Luthra, and Sachin Kumar, who collaborated. The author with the most output and contribution in this cluster is Wanke P, who has cluster 2, eight links, thirteen documents, and a total strength of seventeen.

The South China University of Technology China was the most active organization in publishing documents related to food technology (n-27, c-1985), followed by King Saud University from Saudi Arabia (n-26, c-1081). University of Cambridge (n-24, c-794), based on an analysis of active organizations, shared 2529 papers from 2741 institutions based on author affiliation (Table 4).

The top ten countries in the food technology literature for research collaboration are shown in Figure 4 as a network visualization map. The thickness of the connecting line affects how much research is collaborated on between the connected nations. A larger node size indicates that a country's foreign research partnership is stronger. A similar color scheme implies a strong desire to learn more about the subject. The VOS viewer tool was used to make this map. The South China University of Technology has the largest node among the top 10 active institutions in food technology.

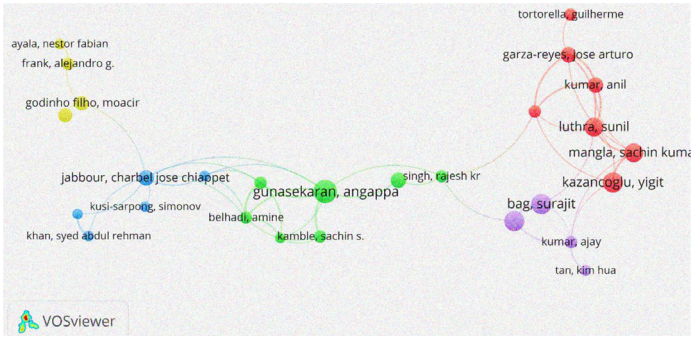

Figure 3: Co-Authorship Network of the Author in Food Technology

Co-authorship of countries and collaboration network

The nation's co-authorship examined their food technology work partnership. The size of the nodes indicates the country's dominance of the collaboration network, while the distance between nodes indicates how closely the countries are knit together (Figure 5). Figure 5 shows the national visualization network created using the VOS viewer tool and the country cooperation map created using RStudio (Figure6).

With a frequency of 71, the network connecting China to the UK had the highest level of cross-national cooperation. The frequency from China to the USA was 58 times per second. Whereas the second-highest research work collaborated between from the UK to India with a frequency of 40 and from the UK to the USA 27. It can be seen that the highest documents published in China (868), followed by Italy (506), and the UK (446) were found related to food technology research.

Three fields in food technology

In the current study on food technology, the three fields are connected in a three-field plot, which is highlighted in Figure 7. Making a three-filed fold required the usage of the Bibliometrix tool. The left-field displays the writers who have contributed the most to food technology, the center field shows the author names and the right-field lists references. The authors with the most significant contributions to food technology were Wan, JF; Li, D, and Muller, JM.

DISCUSSION AND CONCLUSION

Climate change, global population growth, high levels of food wastage and damage, and the risk of new diseases or epidemic breakouts are just a few of the concerns that threaten future food security and global security and should be addressed immediately. Industry 4.0, gaining momentum since 2013, is a significant driver for sustainable development and a successful catalyst in addressing important global challenges.

Table 4: Top 10 Active Organizations in Food Technology

Rank	Organization	Documents	Citations	Country
1	South China University of Technology	27	1985	China
2	King Saud University	26	1081	S. Arabia
3	University of Cambridge	24	794	England
4	Hong Kong Polytechnic University	21	773	Hong Kong
5	Universidade Federal Do Rio Grande Do Sul	21	1108	Brazil
6	Nanyang Technological University	20	877	Singapore
7	University of Melbourne	19	371	Australia
8	Shanghai Jiao Tong University	18	902	China
9	University of Auckland	18	1731	New Zealand
10	Federal University of Santa Catarina	18	285	Brazil

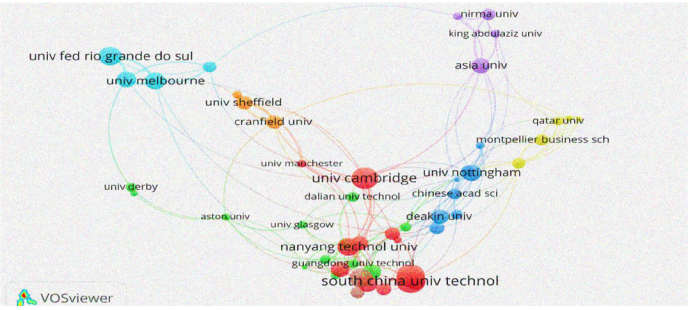

Figure 4: Co-Authorship Network of Organizations in Food Technology

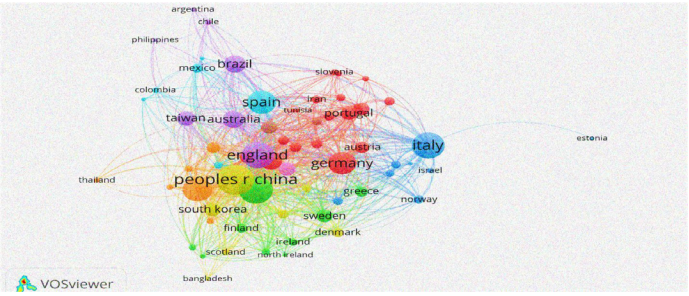

Figure 5: Co-Authorship of the Country Visualization Network in Food Technology

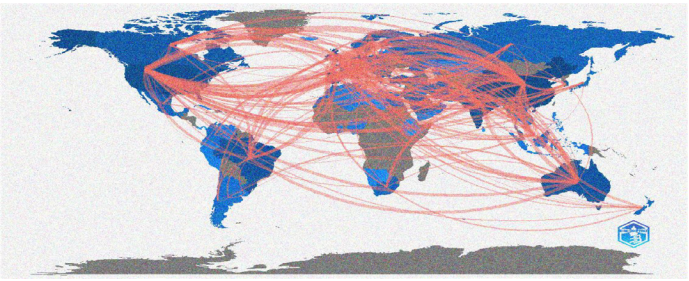

Figure 6: Country Collaboration Map in Food Technology

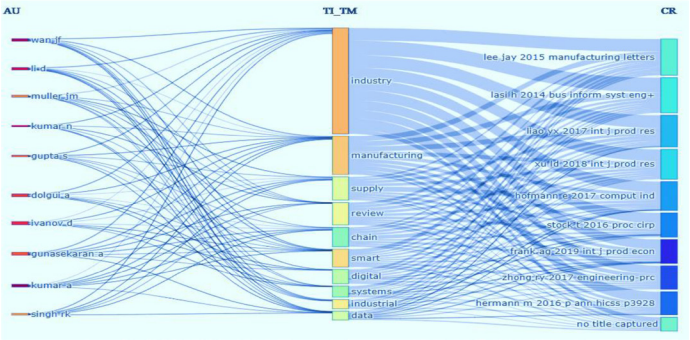

Figure 7: Three Fields in Food Technology Using Bibliometrix Tool

Based on the Web of Science database, this document provides a brief overview of the most cited papers, organizations, and nations in food technology research. According to the research's findings, there were 2529 papers published by 7963 authors on the study's subject between 2013 and 2021, a period of 21 years. We used the Bibliometrix tool and the VOS viewer program to investigate. Based on the materials released, it is evident that no articles were published in 2014. The number of citations peaked in 2013 at 1043, maybe due to the vast increase in recently published works with comparable topics. The amount of research has grown during the last few years, with China now having the most published authors in this area. Despite being the pioneering nations, Italy, the UK, and the USA, The cooperation network between nations, active nations, and source productivity all contribute to China's dominance in the industry. According to our research, the authors with the most citations have studied, including Wan, JF, and Li, D. The most influential journal is Sustainability. Based on the materials released, it is evident that no articles were published in 2014. The number of citations peaked in 2013 at 1043, maybe due to the vast increase in recently published works with comparable topics.

LIMITATIONS

There are some limitations to the current investigation.

An article from one of the Web of Science databases is included in the study. Grey material, such as government reports, was not included in the current analysis because it was primarily focused on peer-reviewed literature. As a result, this restriction should be considered when reading the current study. Despite this, the current analysis offers a complete picture of the productivity of food technology research and the subject areas that interest international academics.

The present study is unique and up to date because it includes new and significant information. The present study's findings will benefit food technology by disclosing vital details that can help influence their policies. Furthermore, it will emphasize how the industry can fund this type of research. Future research projects could build on this work by including more indices like Google Scholar, the Scopus database, the Emerging Sources Citation Index, and other akin indices.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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