Scientometric-based Knowledge Map of Food Science and Technology Research in India

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ABSTRACT

The study aims to explore domain specific knowledge map in the area of Food Science and Technology (FST) using scientometric tools and techniques. The study was based on the data extracted from Scopus in this area for the period 2011–2020. Global research output shows a highly skewed distribution with research concentrated in a few countries. The top two countries China and USA accounts for almost 25% of the global research output; India with 3.44% of output is ranked at 7th position globally. Indian papers are not making significant impact globally as seen through citations. One interesting characteristic of Indian research activity is high co-authorship. Highly cited Indian papers exhibit high degree of international collaboration underscoring that international collaboration is a significant factor in making global impact. The Indian research activity is also highly skewed in terms of institutions and authors involved. Most of the papers are concentrated in a few journals. The co-word analysis of highly cited papers based on keywords helps to identify topics which have high contemporary relevance. Antioxidant effects of plant foods, dietary health benefits, food processing, food safety and security, food bioactive compounds, malnutrition, functional foods were areas addressed prominently in the highly cited papers. The study is thus able to bring different facets of research activity in this area in India situating it within the global context.

Keywords: Knowledge Mapping, Research Productivity, Performance Measurement Indicators, Knowledge Networks, Food Science and Technology, SDGs.

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INTRODUCTION

Food is fuel for life. The food system needs to be sustainable and inclusive targeted to be healthier and bespoke food for all. Thus, the inclusiveness and endeavours to develop and sustain food supply chain has to be always "work in progress". Similarly, in pursuit of sustainability, progress and excellence, it is inevitable that any domain would need headway in research and development endeavours, and more so for Food Science and Technology (FST) domain. Food Science is an eclectic knowledge domain involving basic science and applied science of food, and an overlap with several principal domains and sub-domains such as agricultural science, chemical science, biological science, packaging technology food technology, food processing, microbiology, biochemistry, physiology, etc. Scientific research and the improvements in FST are an important agenda for society so as to eradicate hunger, maintain hygiene and ensure food safety. To feed 10 billion human-beings in 2050, the trade-offs between sustainability, food security, food safety, and making better use of food already

produced needs to be addressed in the right perspective, using hierarchy of strategies for reducing food losses and waste.[1] United Nations SDG 2 advocates for hunger-free society that can be achieved through food security, improved nutrition and promoting sustainable agriculture. Thus, solutions to sustainability and food security should integrate food safety considerations from the very beginning. It has been estimated that as a result of pandemic in 2020, 2.37 billion people are without food or unable to eat a healthy balanced diet on a regular basis.[2] It is indeed inevitable to address the issues of eradicating hunger, while achieving food safety and bringing improvements in FST through research and development. Food tech entrepreneurs, startups and other core companies are leading this change.

The food tech industry represents a fusion of food and technology,[3] characterised by technological development in food and related activities including preparation, storage, and delivery. More intricately, the food tech sector is an ecosystem made of all the agri-food entrepreneurs and startups from production to distribution, innovating on the products, distribution, marketing or business model, bringing disruptive changes and innovations to all its entailing sectors whether AgTech, Food Science, Food Service, Coaching, Delivery,

Retail.[4] This fast-moving ecosystem has revolutionised the operational front of the Indian food industry. In the retail sector, the food delivery business has great prospects as an online platform, next only to electronics and fashion products.[5] Similarly, the domain of processing and preservation (both raw and cooked food) have also been rising. On the knowledge generation front, its dissemination and management for effective utilization, the constant research endeavours coupled with assessing the health of research landscape is essential. Thus, it is important to study knowledge resource-base through research output in terms of publications for mapping sector to decipher trends in research in various domains and sub-domains of FST, its enduring impact and value-addition to various domains and subdomains of knowledge.

The present study is focussed on observation of research trends as reflected in the scholarly communication landscape through the analysis of the research output using scientometric mapping tools. Scientometrics plays an essential role in evaluating the bibliographic database and helps in policy decision-making.[6,7] Science mapping is a generic process of domain analysis and visualization using a set of scientometric and visual analytic tools, metrics, and indicators that can spot potentially significant patterns and trends, and facilitate in exploration and interpretation of visualized intellectual structures and dynamic patterns.[8] Current scientometric techniques and tools deal with the evaluation of research productivity of scientists, prediction of their career trajectories or the impact on funding decisions on the evolving structure of academic community. Such knowledge domain maps are generated primarily on the basis of scholarly bibliographic data using important scientometric tools.

Food safety, security, and sustainability is an integral part of public health safety and security especially in era dominated by COVID-19 pandemic. As innovative thinking in research and development activities lead to domain growth and development, this study aims to identify and analyse research front in the FST domain to draw evidence-based inferences, which, in turn, can aid several stakeholders, be it policy makers, researchers, and institutions as well.

LITERATURE REVIEW

The scientometric studies do not simply reflect reality, it actually transforms reality itself by impacting behaviour of academics and researchers.[9] Scientific research output has witnessed a rapid growth in the last one decade.[10] Hinze and Grupp[11] (1996) created thematic maps of biotechnology in the area of food science covering a nine-year period using the controlled terms of both patents and scientific publications and concluded that the less developed EU countries are producing more in this field.[12] Compared

increase in production of FST of CSIR–CFTRI with overall production in India and globally, using scientific publications, patents, PhD theses, and published standards covering a 40-year period from 1950 to 1990, and observed that the rate of growth was decreasing, while there was some increase in the growth itself. Similarly, Breslin[13] (2001) studied the successive framework programmes that have contributed to strengthen European food research through establishment of networks between research institutions, universities and companies from various European countries. Vijaya and Raghavan[14] (2007) conducted bibliometric analysis on articles published in five volumes of the Journal of Food Science and Technology, for the years 2000 to 2004 and 1964, comprising 779 articles along with citations. The study revealed that there is an increase in the number of contributions in successive volumes with India as the key contributor, mostly with joint authorship and 15% of contributions from the developed nations. Poornima *et al.*[15] (2011) have analysed 1,060 research publications published by Indian scientists during 1998 to 2010, indexed by Web of Science. The study focused on identification of prolific authors and institutions, scatter of papers over journals and authorship patterns and found that most of the prolific authors are from the highly productive institutions. Zhou, *et al.*[16] (2012) analysed the changes undergone in the Chinese meat industry and focused on the challenges and opportunities in the global market. The study by Muscio and Nardone[17] (2012) dealt with industry and academia relationship in the food science sector in Italy. Guerrero-Bote *et al.*[18] (2016) studied the food science research activities in Spain and their inclusion in international scientific journals. Jesus Blazquez-Ruiz, *et al.*[19] (2016) studied structure of food science based on co-word analysis and identified sub-domains and their correlation. The authors also deciphered most specialized themes and their degree of internal cohesion, besides portraying the period of keyword bursts. The analytical study by Turki and Jalali[20] (2020), corroborates that the core papers influencing Food technology research are either now focussing on innovative techniques or the old ones primarily being cited as they are contemplated to be decisive in the field by the research communities.

The above studies provide useful direction for undertaking this research.

RESEARCH OBJECTIVE

The study maps knowledge research output of Indian researchers in FST domain and compares it with the global output using scientometric tools and techniques.

The key purpose of this study is to analyse the research output of FST research using publication output emanating from India from 2011 to 2020 to understand the research trends and thereby recognise the areas of weakness and

strengths. The study identifies the growth pattern, both observed and expected, using time series analysis along with the key institutions and most-productive researchers who are contributing significantly to the development of core domain knowledge, and understanding the behaviour of the knowledge networks therein. Based on the outcome, it attempts to uncover key areas of research and gaps in areas that need attention.

The scientometric-based indication is used to understand the structure and dynamics of food research in India. From the past studies[21] in FST, it is evident that food safety, hygiene, security and sustainability are major research issues and as such, food cross contamination that has severe impact on public health, finds mention in several research endeavours by the researchers.

The study endeavours to identify emerging research fronts using keyword bursts as indicators for the identification of current research trends using co-word analysis, investigates micro structure of a research specialty based on their internal cohesion. This is expected to divulge the major areas of strength and areas that need attention.

METHODOLOGY

Publications indexed in the Scopus (https://www.scopus.com) database from Elsevier is the source of data. Each core area of science and technology is classified using the All Science Journal Classification (ASJC) Codes. The ASJC code 1106 for Food Science encompassing all its sub-domains was used to retrieve the data.

A total number of 449275 papers were retrieved using ASJC code from Scopus covering the period of 2011-2020. For about 5.22% (23,443) of these papers, country of origin could not be identified. Thus, while comparing the Indian output to the global reseaarch output in this segment, a total of 423825 papers have been considered (leaving out 5.22% of unidentified publications indicated above). Out of these papers, a total of 14649 publications are from India.

For keyword extraction and standadization, from each of these 14649 papers, the set of unique keywords auto assigned by the database and assigned to documents by their authors were identified and their frequency have been extracted using VOSviewer.

Analysis and Mapping Knowledge Research Trends

The basic focus of this study was to analyse and map the trends of Indian reseach output in the FST domain. We have analysed and mapped research productivity based on research output, citation analysis, collaborative knowledge network, research knowledge communication behaviour and co-word occurrence to understand the micro structure of a research

speciality, besides identifying the key institutions, and pivotal people contributing to the progression of the domain knowledge. Bibliometrix package has been used to analyze the data. International collaboration and knowledge networks and co-word analysis was analyzed and network visualization have been performed using VOSviewer.

RESULTS AND DISCUSSION

About 4.5 lakh publications in FST from world were identified. Of these, 14,649 research publications in FST from India were published in 293 sources, journals and books, etc. The retreived publications comprise of articles (89.8%); review papers (8.2%); conference papers (0.45%); book chapters (0.44%); erratum (0.36%); editorial (0.27%); short survey (0.232%); letter (0.11%); notes (0.136%); and data paper (0.006%) respectively.The type of documents analysed in this study primarily include articles, review papers, data papers, letters and notes and published conference papers.

Knowledge Pool: Research Output Trends in Indian and Global Context

The global research output in the FST domain revealed that 449275 papers have been published by 160 countries of the world during 2011-2020.

Global Trends

It has been observed that only top 22 countries have contributed for one percent or more of the total research output. The total outcome from 160 countries being 425810 papers, of these, 22 countries produced 326209 papers, accounting for 76.71% of the total global research output in this domain. India is 7th on the world map with 3.44% of publication share. Table 1 displays the top 10 countries, out of 22 which account for >=1% of the total research output in this domain. The analysis signals that there is a high dispersion and the distribution is distinctly skewed and concentrated within a few countries. The skewed distribution is a concern as research is needed to focus on local climate, challenges which is more in low-income economies. The research emerging from these countries are not visible. Global coordinated research is needed to address food safety, security, sustainability and the like to obviate malnutrition and hunger, echoed by United Nations SDGs as well. Table 1, besides indicating research publication output, also portrays the scenario of food exports/imports (% of merchandise exports/imports) and the GDP contribution by the respective sector in the overall economy of the corresponding countries. Of the top 1% FST publication producing countries in the world, 19 countries fall into top 25 world economies that contribute highest percentage share of the total global economy. This further brings to a very intriguing point that there is some correlation between the research output and the economic aspect of the country, which needs further investigation.

Table 1: Global research output in food science and technology domain, percentage share of top countries contributing >=1% viz food export/import and the top world economies

Sl. No.	Country	No of Publications	% Share of Contributions	Food exports (% of merchandise exports)	Food imports (% of merchandise imports)	Agriculture, forestry, and fishing, value added (% of GDP)	% Share of the global economy (GDP based on share of 2020 World Total)	Rank in the top 25 global economies (2020)
1	China	63162	14.85	2.7	7.8	7.7	17.39%	2
2	United States	50669	11.91	11.5	6.8	1.1	24.67%	1
3	Italy	20122	4.73	10.4	11.2	2.0	2.23%	8
4	Brazil	19567	4.6	38.9	6.3	5.9	1.71%	12
5	Spain	18789	4.42	19.0	11.9	3.1	1.51%	14
6	South Korea	16835	3.96	2	7	1.8	1.93%	10
7	India	14649	3.44	12.8	5.5	18.3	3.14%	6
8	Germany	13033	3.06	5.9	8.6	0.7	4.54%	4
9	United Kingdom	11353	2.67	7.6	10.1	0.6	3.26%	5
10	Canada	10954	2.57	15.1	9.4	1.7*	1.94%	9

Source: World Bank: World Development Indicators (Timeline 2020)

Data Available for 2018

Research Trends: Indian Scenario

Domain Knowledge Literature Growth: Observed and Expected

The data reveals an overall increase in number of publications in FST from India over the years from 2011 to 2020. The year 2020 was observed to be the most productive year with 13.58 % of cumulative output, while the year 2011 divulges the least during the period with 8.05%. There has been a gradual upward trajectory in research output from 2011 to 2020 with an exception in the year 2016 (8.91%) dipping from 11% as observed in 2015. The data shows that the total publications (n = 14649) have been cited more than 12 times during the period 2011 – 2020, wherein average citations per document for the period is 12.48 and average citations per year per document is 1.904.

Time Series Analysis was used to predict the growth of research output in the next 10 years, taking a 5-year block into consideration for calculation purposes. A largely linear trend is observed. The forecast trend shows for the years 2025 and 2030 research outputs are 2063 and 2262 respectively.

Table 2 highlights papers from India that have made major impact. It shows a few papers have made a major impact.

Key Institutions and Researchers

An attempt was made to study the key contributing institutions and the most prolific authors contributing to the research knowledge development and progression. The key parameters derived from the data analysis revealed the following.

Based on the quantitative analysis of research output published during the years 2011 to 2020, the most prolific authors contributing to FST research domain divulged that over 21.51% of the total research output in this research domain was contributed by 20 authors who therefore be considered as leaders in the research knowledge progression in the field of FST. These top 20 authors (accounting for 0.078%) have contributed to over 1/5th proportion of the total papers published during 2011-2020. Mostly these authors are from the key Indian institutions in this domain area as reflected in Figure 1a. This points at two core issues, (i) only a few authors are contributing to the domain which needs to be pondered over further, (ii) the top papers are consigned with a handful of key institutions.

Authorship Pattern

The authorship pattern has been deciphered by examining the number of authors contributing to the scholarly publications. Looking at the overall publication scenario of 14649 papers from India authored by 25691 authors (with 59792 author appearances), the analysis shows that single-authored papers constitute only 1.058% (269 authors), while over 98.9% (25422 authors) are multi-authored papers. Further, while looking at the author collaboration and knowledge network profiling aspect, the data divulged that proportion of documents per author is 0.57 and co-authors per document is 4.08. The data further corroborates that the multi-author model of research knowledge landscape is prevalent in this discipline with only 337 single authored papers published from India during 2011-2020. The Collaboration Index for Indian scientific output in the domain of FST is 1.78. The above analysis reiterates that multi author model of research landscape is prevalent in this discipline. The collaboration coefficient is 0.977 (calculated

Table 2: Top impact Indian papers based on citations per paper

Top impact papers	TC	TC per Year	NTC	TCA	TCI	TCC
Panche AN, 2016, J Nutr Sci doi: 10.1017/jns.2016.41	843	140.5	55.3	3	2	1
Kedare SB, 2011, J Food Sci Technol doi: 10.1007/s13197-011-0251- 1	613	255.7	27.4	2	1	1
Mishra K, 2012, Food Chem doi: 10.1016/j.foodchem.2011.07.127	490	49.0	24.1	3	1	1
Dhingra D, 2012, J Food Sci Technol doi: 10.1007/s13197-011-0365-5	456	45.6	22.4	4	1	1
Tripathi MK, 2014, J Funct Foods doi: 10.1016/j.jff.2014.04.030	452	56.5	27.9	2	1	1
Chalamaiah M, 2012, Food Chem doi: 10.1016/j.foodchem.2012.06.100	404	40.4	19.8	4	1	1
Loutfi A, 2015, J Food Eng doi: 10.1016/j.jfoodeng.2014.07.019	394	56.3	23.7	5	2	2
Kumar AK, 2017, Bioresour Bioprocess doi: 10.1186/s40643-017-0137-9	389	77.8	38.2	2	1	1
Chandrasekaran S, 2013, Food Res Int doi: 10.1016/j.foodres.2013.02.033	379	42.1	21.2	3	1	1
Ezhilarasi PN, 2013, Food Bioprocess Technol doi: 10.1007/s11947-012-0944-0	376	41.8	21.0	4	1	1
Bouis HE, 2011, Food Nutr Bull doi: 10.1177/15648265110321s105	375	34.1	16.8	5	3	3
Bourdichon F, 2012, Int J Food Microbiol-A doi: 10.1016/j.ijfoodmicro.2011.12.030	349	34.9	17.1	19	18	11
Chen C, 2019, Nature Sustain doi: 10.1038/s41893-019-0220-7	344	114.7	68.3	15	12	7
Jayathilakan K, 2012, J Food Sci Technol doi: 10.1007/s13197-011-0290-7	339	33.9	16.7	4	1	1
Patra AK, 2011, J Sci Food Agric doi: 10.1002/jsfa.4152	336	30.5	15.0	2	2	2
Dhall RK, 2013, Crit Rev Food Sci Nutr doi: 10.1080/10408398.2010.541568	300	33.3	16.8	1	1	1
Negi PS, 2012, Int J Food Microbiol doi: 10.1016/j.ijfoodmicro.2012.03.006	299	29.9	14.7	1	1	1
Ayala-Zavala JF, 2011, Food Res Int doi: 10.1016/j.foodres.2011.02.021	293	26.6	13.1	8	2	2
Pandey KR, 2015, J Food Sci Technol doi: 10.1007/s13197-015-1921-1	282	40.3	17.0	3	1	1
Shah MA, 2014, Meat Sci doi: 10.1016/j.meatsci.2014.03.020	275	34.4	17.0	3	1	1

TCI: Total contributing institutions; TCC: Total contributing countries
TC: Total citations; NTC: Normalised total citations; TCA: Total contributing authors;

using K. Subramaniam[22] formula), which further echoes that collaborative knowledge networking endeavours between more than one authors is pervasive. However, the point whether collaboration is primarily vested within the domestic sector or is also opening out beyond the national territories is to be seen.

Collaboration Network Model

The collaboration network here is based on the betweenness centrality which measures the magnitude to which a vertex lies on paths between other vertices or in other words is based on the number of shortest paths passing through a vertex. Vertices with a high betweenness play the role of connecting
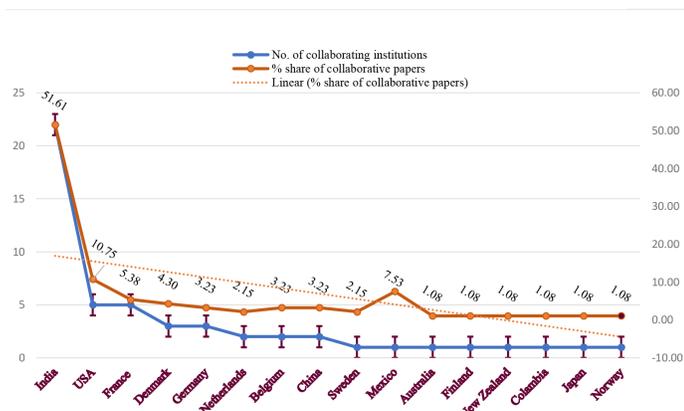
Figure 1a: Knowledge networks of Indian institutions with global partners viz-a-viz percentage share of collaborative papers of other countries with India

different groups and thus have considerable influence within a network by virtue of their control over flow of information passing between others. In social networks, vertices with high betweenness are the brokers and connectors who bring others together.[23] Individuals with high betweenness are the pivots in the network knowledge flowing. The vertices with highest betweenness also result in the largest increase in typical distance between others when they are removed. Thus, the author and institutional collaboration has been worked out using betweenness centrality measure to decipher the collaborative network relationships at author and institutional levels.

Collaboration: Author and Institutional Knowledge Networks

As against the most prolific authors, Table 2 depicts the highly cited papers (HCPs) from India and the collaboration knowledge network both within Indian institutions and with other countries regarding these HCPs. While analysing top papers based on the citations received per paper (Table 2), it was observed that these top HCPs have been contributed by 93 unique authors affiliated to 52 unique institutions from 16 countries. Of the percentage share of HCPs, India tops with 51.61%, followed by the USA (10.75%); Mexico (7.53%); France (5.38%); Denmark (4.30%); Belgium, China and Germany (3.23% each); Netherlands and Sweden (2.15% each); and Australia, Colombia, Finland, Japan, New Zealand, Norway (1.08% each). About 90% of the highly cited papers are multi-authored papers (with 3 authors contributing 30%; 20% by 4 authors, respectively)); while single authored papers constitute only 10%. The research themes tackled by the authors primarily embark upon antioxidants, plant foods, dietary health benefits, food processing, safety and security, bioactive compounds, malnutrition, functional foods, and the like.

Institutional Collaboration and Knowledge Networks

The institutional collaboration at the national level taking all papers into consideration shows that out of 50 unique Indian institutions contributing in this field, about 10% (5 institutions) have high degree of collaboration, while 20% (10 institutions) fall next in line and the remaining 70% in the subsequent category. At the macro level, looking at the institutional and country level collaboration and knowledge networking of these highly cited papers (Table 2), it shows that 65% of these papers emerged from single institution; 20% from two institutions; 10% from >5 institutions and 5% from 3 institutional networks. The research topic areas addressed by the authors of these highly cited papers primarily deal with antioxidant effects of plant foods, dietary health benefits, food processing, food safety and security, food bioactive compounds, malnutrition, functional foods and the like. It may also be pointed out that since most of these papers are product of collaborative endeavours, whether at the national or international level, the research topic areas in several ways are in harmony with the SDGs of the United Nations.

Ostensibly it seems derisive, that in the 1960s, the call for emphasizing the importance of scientific advancements in farming techniques to increase food production, brought about positive impacts, achieved by the research centres, and since then a fairly large number of institutions were set up and are engaged in FST research across the country, yet food science is concentrated in only a few institutions. Secondly, there is a high degree of dispersion observed. Though India is 7th on the world map w.r.t research output in the FST domain, however, the proportion of publications is not as perceptible as it should have been and that should be a matter of concern.

India's Collaboration Knowledge Networks with Other Countries

The international collaboration analysis based on highly cited papers reveals that 90% of these papers are product of collaborative research of 52 unique institutions in 16 countries, (Figure 1a). Concurrently, in terms of percentage share of collaborative HCPs generated through international collaboration knowledge networks, the USA (10.75%); Mexico (7.53%) and France (5.38%), respectively are the top three collaborating countries. Figure 1b provides total collaborative papers of India with other countries in FST during 2011–2020.The collaborative country is based on corresponding author's country. Out of 869 collaborative papers, India has collaborated 248 papers with the USA and 95 papers with South Korea. Looking at the single country vs. multiple country ratio, for every 1 SCP (single country paper) there are 0.07 MCPs (multiple countries paper) for India. The other underpinning outcome of the study shows that MCP ratio for India is low.
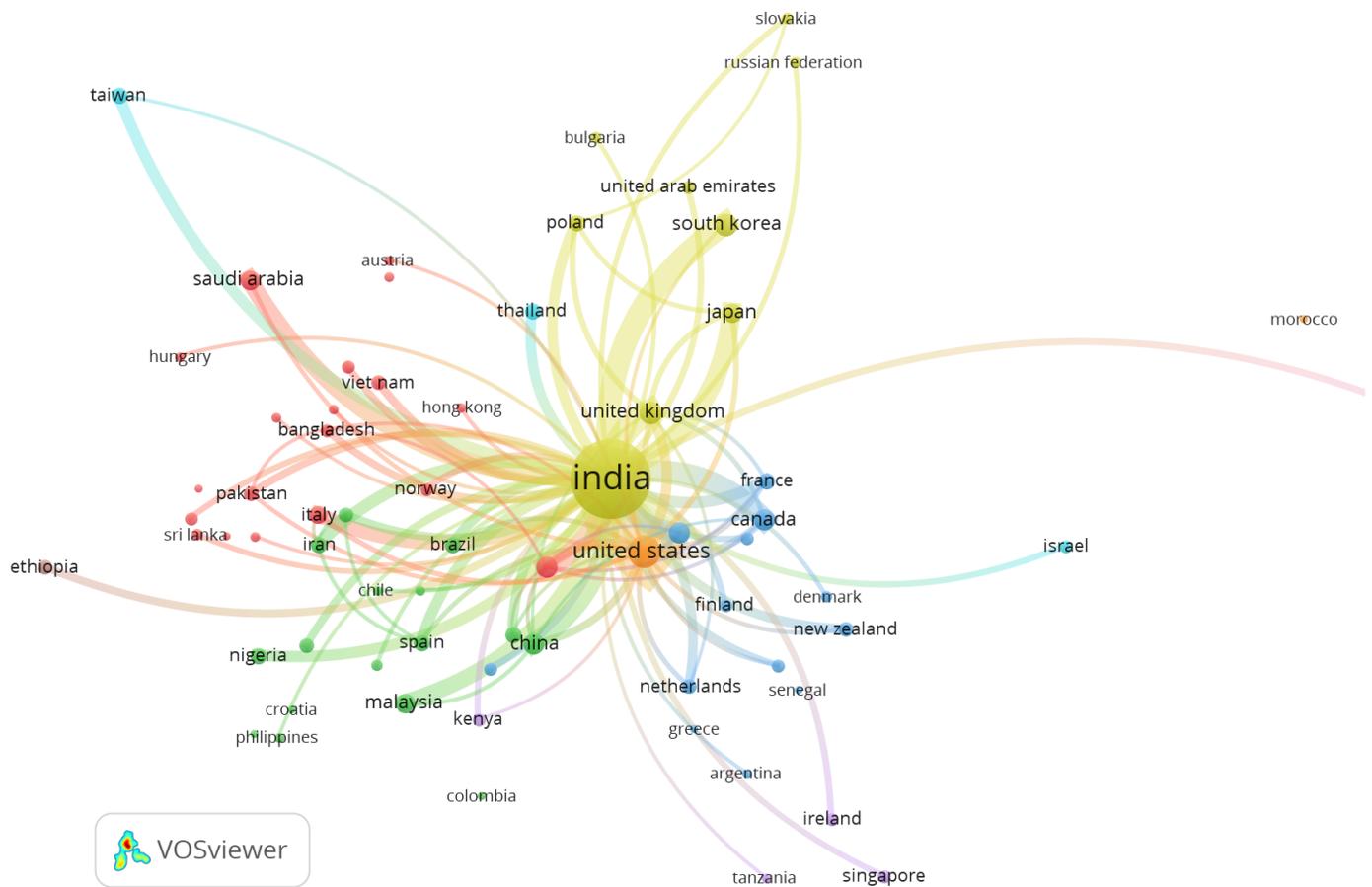
Figure 1b: India's collaboration knowledge network with other countries

Table 3: Most productive journals based on the number of articles published.

Sl. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	19	20
Source Title	Journal of Food Science and Technology	Biocatalysis and Agricultural Biotechnology	Food Chemistry	Indian Journal of Natural Products and Resources	LWT - Food Science and Technology	International Food Research Journal	Journal of Food Processing and Preservation	Agricultural Research	Range Management and Agroforestry	Food and Chemical Toxicology	Journal of Food Measurement and Characterization	Journal of the Science of Food and Agriculture	Journal of Food Process Engineering	Critical Reviews in Food Science and Nutrition	International Journal of Food Properties	Journal of Functional Foods	Journal of Food Biochemistry	Food Research International	Nutrition and Food Science
Articles	1693	791	562	454	450	378	373	353	327	312	288	237	233	204	200	180	175	168	163
Average Article %tage Share	22.45%	10.49%	7.45%	6.02%	5.96%	5.01%	4.94%	4.68%	4.33%	4.13%	3.81%	3.14%	3.08%	2.70%	2.65%	2.38%	2.32%	2.22%	2.16%
Country of Origin	India	Netherlands	UK	India	USA	Malaysia	USA	Switzerland	India	UK	USA	UK	USA	UK	USA	UK	USA	USA	UK

Figure 2: Keyword co-occurrence network of the analysed scholarly knowledge research communications.

India's knowledge networks with other countries signal that of the top contributing countries indicated in Table 1, India is collaborating with over 1/3rd of these countries with over 1% of the percentage share of collaborative papers. However, there are countries like South Korea, Canada, Saudi Arabia, Iran, Malaysia, United Kingdom, Nigeria, Cameroon, Thailand, Spain, Italy, and Brazil with less research frequency with India, where the percentage share of collaborative research is much below 1%. The key observation from this signifies that the collaborative research endeavours with high research productivity countries in the domain need to be further strengthened in areas that can ensure food security, safety and sustainability.

Citation Profile of Top Collaborating Countries

While analysing the citations received by these collaborative countries, it was found that top 4 countries in both cases, in terms of the number of papers or number of citations received maintain their rank (India, USA, Korea, China,), with India capturing 90% of the total citations received by these 20 countries. The data interestingly indicates that there are variations in terms of average citations per article, in which case, India slips down to 16th position, in comparison to its rank at 7th position the world over in terms of research output. Evidences have shown that effective collaboration in research can elicit manifold benefits for researchers by

maximizing the breadth of research,[24] amplifying impact,[25] and drawing more citations. Besides, the descent of impact from international, to national, and institutional collaborative efforts is also discernible in terms of average citation per publication. The reasons could be many. However, this insinuates that the collaborative endeavours need to be strengthened.

Research Knowledge Communication Behaviour

The Indian contribution of 14,649 papers were published in 293 sources. Around 51.47% of these papers are published in the top 20 preferred journals. Of these 20 journals, only 6 journals account for 52.38% of the articles, while only 1 journal of Indian origin represents 22.45% of these papers. Of the top 20 productive journals (Table 3), 4 journals each originated from India, UK and United States, while, others are from the Netherlands (3), Canada (2) and Switzerland (1).

A similar trend evinces from the study [26] for a period of 12 years preceding this study period which analysed 1060 research publications published by Indian scientists from 1998 to 2010, indexed by Web of Science. According to this study, the top ten covered around 55% of the research output. The journal "Food Science and Technology" topped with 179 publications followed by "Food Chemistry" 96 publications and "LWT–Food Science and Technology"

with 60 publications respectively. This broadly indicates the journal preference of Indian researchers in the field, thus their intellectual research pursuit.

Broadly, the core of top 20 preferred journals embrace areas like food packaging and engineering of foods, food quality, food safety, enhancing extended shelf life, food handling and processing, preservation and storage, emerging technology/post-harvest technology, biocatalysis, bioprocesses, biotechnology. Besides, the components of food, food additives, contaminants, food chemistry/biochemistry/microbiology/toxicology, food, beverage and nutrition research, nutritional quality of foodstuffs, food properties -healthy foods and biologically active food ingredients, genetically engineered foods, novel foods and ingredients, sustainable production, impact of climate change, food cultivation are also in their realm. Dairy and animal products, livestock and fishes, fodder production and sources, livestock nutrient management, etc. are other focus areas of these journals.

Co-word Analysis and Keyword Bursts

Identifying emerging research fronts to represent research activities within a scientific area is important. The co-word analysis for mapping the structure of scientific inquiry depicts the state-of-art research in that scientific area by delineating and underscoring the relations between various research themes, using the network of co-occurrences between different words. This allows a quantitative study of the structure of publication contents in terms of the nature and strength of linkages between pairs of words by comparing and classifying publications with respect to the occurrence of similar word-pairs. Studies have successfully used techniques such as co-citation and co-word analysis of data retrieved from various databases (such as Scopus or Web of Science) to investigate emerging or waning research trends. Thus, author and keyword bursts can be considered as indicators for the identification of current research trends.

A total number of 38,333 keywords auto-assigned by the database using text mining techniques and 29361 author assigned keywords were retrieved from these 14,649 papers published during the period for further analysis.

The study also investigated the use of co-word analysis method to understand the micro structure of a research speciality and identify research trends and emerging areas of research. Figure 2 represents co-word occurrence network of keywords in the form of networks of edges and vertices. VOSviewer tool has been used to visualize the network. The size of the node represents frequency and strength of each keyword, edge represents the relationship between two keywords, and thickness and darkness of the lines represents strength of relation. The study includes 394 keywords that

have occurred more than 10 times out of total 29,361 author and 38,333 auto-assigned (by the database) keywords.

The graph (Figure 2) shows that "antioxidant", "response surface methodology", "antioxidant activity", "oxidative stress" has highest number of occurrence and link with other keywords. The links with other keywords by and large depicts the broader research topic areas of food safety, food security, nutrition and nutrients, malnutrition, food fortification and the related aspects. Thus, this elucidates that the research topics addressed by the researchers in general and those who have contributed to the highly cited papers are kindred topic areas, hence of core research importance.

CONCLUSION

The study highlights Food Science and Technology is an active area of research globally. This is unsurprising as this is an area of global concern as world needs more food to feed billions of mouths. The research however is highly skewed with China and USA contributing almost 25% of the global output. India's contribution is about 3.44% of the overall outut being 7th on the world map of FST knowledge research landscape. The study identifies some of the indicators which needs to be strengthened to push Indian research upwards. Firstly, the research needs to be more dispersed as only a few institutions are involved in majority of research output. India also has to expand the journal set as research activity is primarily restricted to a few journals. Increasing volume would not be enough! India needs to focus on the impact of the research output, as in terms of average citations per paper, India has slipped down to 16th position. The top 20 prolific authors have contributed to over 1/5th proportion of the total papers published during the study period. Overall one observes a strong co-authorship pattern. 20 journals have published over 51% papers, of which only 1 journal of Indian origin constitutes about 23% of the papers. This possibly is one indication of Indian papers not making global impact. Expansion of journal set, publishing in high impact journals, and improving international collaboration are factors that help to attract citations.

To understand the micro structure of a research speciality, the content analysis of the highly cited Indian papers reveals that the research topic areas addressed by the authors of these papers primarily deal with antioxidant effects of plant foods, dietary health benefits, food processing, food safety and security, food bioactive compounds, malnutrition, functional foods and the like. Subsequently, the co-word analysis of auto-assigned and author assigned keywords unveils that "antioxidant", "response surface methodology", "antioxidant activity", and "oxidative stress" have highest number of occurrences and link with other keywords based on their internal cohesion. The links with other

keywords by and large depicts the broader research topic areas of food safety, food security, nutrition and nutrients, malnutrition, food fortification and the related aspects. Thus, this elucidates that the research topics addressed by the researchers in general and those who have contributed to the highly cited papers are kindred topic areas, hence of core research importance. Most of these papers are product of collaborative endeavours, whether at the national or international level, the research topic areas in several ways are in sync with the SDGs of the United Nations. Thus, one can also infer that, to reduce the yawning gap of malnutrition and hungry people in the world, addressing issues of food safety, food security, nutrition and nourishment for masses and food sustainability are of key importance for research and development, so as to balance food availability, affordability and supply chain to feed the teaming millions. The finding of this study might be useful for future research, for a more comprehensive understanding of the trends in the discipline of FST.

The majority of the top publication producing countries in the domain are also major contributors to the world economy, besides being food exporters. Is there any correlation between the research output and economic aspect of the country? This research question needs further investigation.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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