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Deciphering the Landscape of Food Science Research Footprints: Scientific Specialties and SDGs

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Due to prevailing milieus, combating hunger, malnutrition, and improving functioning of food systems are now of greater priority to national and international policymakers than they were when the United Nations Sustainable Development Goals (UN SDGs) were announced in 2015. The trade-offs between sustainability, food security, food safety, and making better use of food already produced need to be addressed in the right perspective, using a hierarchy of strategies. One of the strategies could be to analyse research output to divulge the momentum research topics in the domain. This article explores core research specialties using the SCOPUS data due to its comprehensive coverage of the research output in food science from India during 2011–2020. The major outcomes reveal that: (a) research specialties of top topic clusters fall in the worldwide momentum areas and primary focus of Indian researchers lies in finding solutions to the aspects of security, safety, sustainability of food, and addressing the crucial aspects of malnutrition, involving an array of topics ranging from application of processes to enhancement of health benefits of plant food for human consumption; (b) prominence indicator signals that the top worldwide momentum areas have potency to attract more funding; (c) co-relation between prominent topic clusters, research topics of top contributing author's, institutions and in highly cited papers vis a vis SDG's elucidates that the research topics addressed by researchers, in general, are kindred topic areas, hence of core research importance. The study presents a discussion of the outcomes leading to evidence-based inferences, with enduring impact and value-addition to domain knowledge that can aid several stakeholders.

Keywords: Knowledge mapping, Knowledge networks, Performance measurement indicators, Research output, Scientometric tools

Introduction

Food Science (FS) is an active discipline within the realm of scientific research and any improvements in this area may ultimately eradicate hunger while achieving the much-needed food safety. Food for healthy nations and global well being are now increasingly becoming important. Not only its availability, but affordability is also becoming decisive. As a result of the pandemic in 2020, 2.37 billion people are without food or unable to eat a healthy balanced diet on a regular basis as per the UN estimates. While the Sustainable Development Goals (SDG 2) advocate ending hunger and thereby achieving food security and improved nutrition and promoting sustainable agriculture, current research studies have focussed on food safety[1], hygiene, security[2] and sustainability. Several inappropriate practices including cross-contamination, insufficient processing, and poor hygiene are found to cause food-borne diseases (FBD).[3,4] Out of these, food contamination is a severe public health problem around the world, which results in food-borne diseases in humans. Essential aspects of attaining food safety need more research attention, more so with the exponential increase of online food businesses[5–7], that may not be practicing food safety protocols. Thus, there is a dire need to problematize the varied ways of handling food at any given point along the food supply chain to ensure last-mile safety (of consumers). The country-level risks to food security with reference to high prices coupled with reduced incomes, denoting cutting down on both quantity and quality of food consumption[2] by sizeable population, particularly in developing and least developed countries. To feed an estimated 10 billion persons by 2050, the vital trade-offs between sustainability, food security, food safety, and making better use of food already produced need to be addressed in the right perspective, using a hierarchy of strategies for reducing food losses and waste[8], while keeping the SDG 2 of UN (https://www.un.org/sustainabledevelopment/hunger/) in the backdrop. Thus, feasible solutions to sustainability and food security should integrate food safety considerations from the very start.

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The availability of food, its storage, and safety are some of the major issues for the present century, especially in so far as food sustainability issues are concerned.[9] According to Modified Atmosphere Packaging (MAP), the storage of real-time-tested food without synthetic chemical preservations is increasing the demand for the well-being of the human populace.[10,11] Due to insufficiency of food availability, malnutrition coupled with the rising costs[12] of the healthy and quality food[13] leads to an increase in hungry people and thereby disease and poverty that have threatened continuously global public health.[14] Worldwide several organisations are funding research in various core sectors that include food science as well. For instance, UK Research and Innovation (https://www.ukri.org/) in their Gateway to Research portal (https://gtr.ukri.org/) in the Food Science search returns a number of projects that have received fairly good funding. Many of these are in the areas of food security, safety, sustainability, malnutrition, hunger etc. Because of the acute global impacts of climate change and Covid-19, combating hunger and malnutrition, and improving the functioning of food systems, are now an even greater priority of national and international policymakers around the world than they were when the UN Sustainable Development Goals (SDGs) were actually announced in 2015.

In the area of FS, it has been observed that scientific production had rapid growth in the last decade[15] and discerns that the planning, managing, and future course of research in this field will not be completely dominated by the priorities of those countries carrying out most of the research today in FS. There have been very few studies on the application of scientometrics in the field of FS dealing with some aspects of the analytical study using scientometric tools and techniques. For instance, Hinze & Grupp[16] created thematic maps of biotechnology in the area of food science covering a nine-year period using the controlled terms of both the patents and scientific publications and concluded that the less developed EU countries are producing more tools in this field. Similarly, the study[17] focus on the successive framework programmes that have contributed to strengthening European food research through the establishment of networks amongst the research institutions, universities, and companies from various European countries. The disclosure of the structure of scientific fields based on the co-word analysis has been carried out by Jesus Blazquez-Ruiz *et al*.[18] to identify the sub-areas and study their correlation and decipher most specialized themes and their degree of internal cohesion, besides portraying the period of keyword bursts in the area of food science. The scientometric study by Sebastiyan *et al.*[19] while investigating the research performance in the area of food economics using 3213 records from web of science database found that its specific growth in literature is not proportional to the citation impact. Also, the analytical study by Turki and Jalali[20], corroborates that the core papers influencing food technology research are either now focussing on innovative techniques or the old ones are primarily being cited as they are contemplated to be decisive in the field by the research communes.

It is thus an important subject matter to study knowledge resource-base as reflected through the publication output for mapping the sector to decipher trends in research, bearing enduring impact and value-addition to the domain knowledge at large. Therefore, the present study has focussed on the 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 succour policy decision making.[21] Using a set of scientometric and visual analytic tools, metrics, and indicators can highlight potentially significant patterns and trends, and facilitate in exploration and interpretation of visualized intellectual structures and dynamic patterns.[22] From the past studies[11,23] in the domain of FS, it is evident that food safety and hygiene, security, and food sustainability have been one of the major research issues of discussion, and thereby food cross-contamination has a severe impact on public health at large. Identifying emerging research fronts is critical as it aids policy makers and thereby the funding agencies in their decisions in research policies,while at the same time, it is also a useful tool for guiding young researchers' orientation, besides abetting the institutions and individual researchers/academicians to assess their research excellence framework.

Thus, the study is decisive, more so in the backdrop of the public health pandemic COVID-19, wherein public health safety and security coupled with economic aspects have necessitated taking requisite measures on several fronts, including food safety, security, and sustainability. As innovative

thinking in research and development activities leads to domain growth and development, and thus what all do the research front focus on in the FS domain has been analysed to draw evidence-based inferences that can aid several stakeholders, be it the policy makers, researchers, and institutions as well. The finding of this study might be useful for future research, as also for a more comprehensive understanding of the emerging trends in the discipline of FS.

Objectives

The underlying rationale behind taking up this study was to identify and map core research areas in the FS based on the topic clustering of the author and institutional research contributions and using co-word occurrences and keyword bursts based on their internal cohesion, besides tapping other aspects like prominent topic clusters. Thus, the study endeavours to evaluate and understand the research growth patterns and trends in research so as to fathom areas of strengths and weaknesses alike as reflected through the publication output emanating from India during 2011 to 2020. Using the scientometric based indicators to understand the structure and dynamics of food research in India, the study identifies the research trends w.r.t. growth pattern, along with the key institutions and prolific researchers who are contributing significantly to the development of core domain knowledge, thereby understanding the behaviour of the knowledge networks therein. Based on this, it attempts to uncover as to what are the key areas in which research is happening and what are the major areas that still need attention. The study attempts to identify the emerging research fronts using topic clusters, and keyword bursts as indicators for the identification of current research trends and through the use of the co-word analysis method, investigate to understand the micro structure of a research specialty based on their internal cohesion. This is expected to divulge the major areas in which research is happening and thereby gives an indication to draw further a critical discussion on the identified strength and problem areas

Source and Methods

Data Source, Search Strategy and Data Extraction

The research objectives of this study were explored through publications as indexed in Scopus (https://www.scopus.com) and its research evaluation tool SciVal (https://www.scival.com*)*. Benchmarking and research evaluation too are based on Scopus data. To cull out the domain specific data from the database, each core area of science and technology is classified by ASJC subject. ASJC code 1106 for FS has been used to retrieve the data and this code encompasses all the sub-domains of this area holistically. Using the ASJC code a total of 449, 275 papers were retrieved, published from 160 countries of the world and covering the period of 2011–2020. The data was downloaded in December 2021. Out of these papers, a total of 14,709 (i.e. around 3.27%) publications are from India.

For keyword extraction and standardization, the set of unique keywords auto-assigned by the database and assigned to documents by their authors were identified and their frequency has been extracted using VOSViewer and also visualised through Biblioshiny (R package). Also, the top 500 prominent or momentum topic clusters were identified via SciVal.

The basic focus of this study was to analyse and map the available trends of Indian research output in the FS domain and visualize the research performance while benchmarking data relative to peers, measure the researcher's impact, ascertain, and importantly analyse emerging research trends.

To map the core topic related data, assess the researcher's impact, and decipher the subject themes of research being addressed in the present study, while we have analysed research output based on the data downloaded from SCOPUS, the core research topics were decrypted using the following strategy. Firstly, the top 500 topic clusters based on the worldwide prominence percentile were identified via SciVal. Secondly, the top contributing 500 researchers' papers were identified and analysed to figure out the sub-topics of research addressed by them along with their affiliations. Thirdly, analysing the co-word occurrences and keyword bursts to identify the frequently occurring words based on the keywords both auto-indexed by the database and the author keywords; and lastly, the highly cited papers and their areas of research themes were also fathomed. The co-word occurrence to understand the microstructure of a research specialty was attained. Bibliomatrix R Package (An R-tool for comprehensive science mapping analysis) has been used to analyze the data and co-word analysis was analysed and network visualization have been performed using VOSviewer, while Biblioshiny has been used to plot the correlation between entities, besides using Excel for highlighting the emerging trends graphically.

Results and Discussion

Research performance in the food science domain

The research performance indicators as depicted in Table 1 reflect on various key contours of performance related to scholarly research endeavours as echoed in the tangible output based on different parameters.

The random growth trends in the research output are clearly projected in Fig. 1, wherein the expected growth values have been derived and calculated using the Straight line equation Y = mx + c (where, c = y, when, x = 0; c is the y-intercept). The overall scholarly output growth as per observed values is 63.8%, while around 27.47% of this output has been reported in an open access ecosystem. Thus, while on one hand, the growth in the FS knowledge domain is happening, the access barriers are also beginning to ease out, due to gradual progression in open access publishing during 2011–2020. In terms of the publications share growth in percentage, the analysis reveals that there is a huge potential for growth.

As corroborated by earlier studies, in general, the trends in scientific publishing in India show a gradual

Table 1 — Performance indicators at a glance in food science domain

	Overall	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Awards volume (count)	6	—	1	—	1	—	—	—	2	1	1
Awards volume (value)*	38314834	—	793564	—	322094	—	—	—	6186186	23177192	7835798
International collaboration (%)	15.6	14.1	12.8	13.2	12.1	11.8	14	15.1	17.6	21.4	20.5
Academic-Corporate Collaboration (%)	0.6	0.6	0.4	0.4	0.5	1.1	0.9	0.7	0.9	0.6	0.4
Scholarly output	14709	1178	1220	1220	1492	1660	1353	1492	1477	1688	1929
Scholarly output (growth %)	63.8	—	—	—	—	—	—	—	—	—	—
Scholarly output (open access %)	27.47	—	—	—	—	—	—	—	—	—	—
Citations	235909	29608	28304	25308	28656	33797	26406	20540	18375	15459	9456
Field-Weighted Citation Impact	0.94	0.81	0.9	0.9	0.84	0.95	1.02	0.91	0.96	1.02	0.99
Outputs in Top Citation Percentiles (top 10%, field-weighted)	8.4	6.5	6.4	8	7.8	8.6	9.5	8.2	8.9	8.6	10.2
Publications in Top Journal Percentiles (top 10% by CiteScore Percentile)	17.9	20.3	23.6	19	12.3	15.5	19.3	22.4	18.2	17.5	14.8
Citations per Publication	16	25.1	23.2	20.7	19.2	20.4	19.5	13.8	12.4	9.2	4.9
Views	561877	64146	61816	53307	54208	63143	55208	59172	55161	51843	43873
Outputs in Top Views Percentiles (top 10%)	24.2	30.5	29.3	23.9	19.2	20.8	23.9	25.9	26.8	22.2	22.9
Views per Publication	38.2	54.5	50.7	43.7	36.3	38	40.8	39.7	37.3	30.7	22.7
Field-Weighted View Impact	0.96	1.04	1.06	0.95	0.77	0.82	0.97	1.04	1.04	0.97	0.95
Citing-Patents Count (patent office: All Patent Offices)	961	221	178	202	144	126	46	52	22	4	4
Patent-Cited Scholarly Output (patent office: All Patent Offices)	298	62	48	35	48	43	22	20	14	3	3
Patent-Citations Count (patent office: All Patent Offices)	1008	228	178	202	144	128	46	52	22	4	4
Patent-Citations per Scholarly Output (All Patent Offices)	68.5	193.5	145.9	165.6	96.5	77.1	34	34.9	14.9	2.4	2.1
Authors	26484	3003	3253	3308	3952	4198	3721	3899	4229	4871	5598
Authors (growth %)	86.4	—	—	—	—	—	—	—	—	—	—

***Details on awards received in a different currency**

Awards Volume (value in USD)	USD	Native currency	Country/Region
Arts and Humanities Research Council (AHRC)	322094	195398 GBP	United Kingdom
Biotechnology and Biological Sciences Research Council (BBSRC)	23177192	18152563 GBP	United Kingdom
Economic and Social Research Council (ESRC)	2819616	2016743 GBP	United Kingdom
Horizon 2020 Framework Programme (H2020)	11995932	10520465 EUR	European Union

Source: Elsevier SCOPUS (SciVal) database

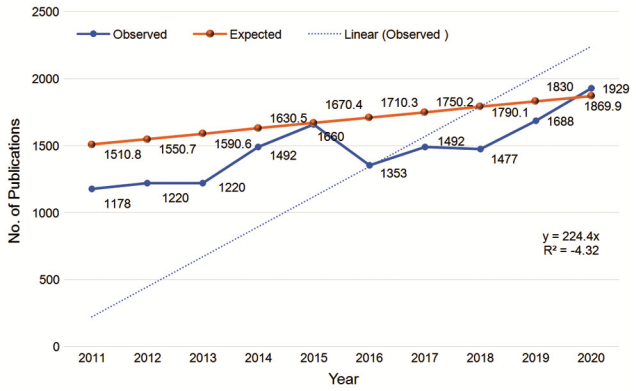

Fig. 1 — Trends in scholarly research output in food science: Observed and expected

increase since 2011. According to the UNESCO Science Report[24], India's response w.r.t. research output on SDG-related topics evolved since 2012, portrays a very decent picture. Indian researchers are publishing more than what would be normally expected on key topics related to agricultural production, health, and sustainable energy, relative to global averages. Output is also more than twice the global average on traditional knowledge, water harvesting, maintaining genetic diversity, and pest-resistant crops, besides various other topics.

Core Research Specialty Topics

To ascertain the subject themes of research being addressed, a quad-pronged approach was charted that includes analysing momentum topic clusters, top contributing authors, co-word occurrences and keyword bursts, and finally the highly cited papers.

Research Portfolio Analysis and Topic Prominence

The identification of emerging topics using various modes and methods, such as retrospective analyses of emerging topics or through nominating emerging topics for consideration is of current interest to decision makers across various sectors whether government or industry to provide a significant indication about the dynamics included in the development of science and signs that may help predict the growth or/and decline of scientific methods, ideas, and even fields. Various taxonomies and classifications of science are used in the macro-organization of science, including for example science policy planning, large-scale research assessments, and grant management. The bibliometric/scientometric researchers tend to favour classifications as developed with bottom-up clustering approaches due to their continuity in institutional practices to decipher the research topics across all of science, wherein many of them have used either or a combination of direct citation, co-citation models and bibliographical coupling mechanisms using the citation databases[25–28], or deep learning based classification schemes.[27,29] The research classifications currently in use require continuous work as new classification techniques become available and as new research topics emerge. Though there are challenges in the validity of topical reconstruction[30], however, notwithstanding that the research portfolio regarding the identification of emerging topics is imperative. The emerging topics have been reported to be of great importance in deriving the nature of award/rewards such as funding, awards, etc. for the decision making by the stakeholders in the science ecosystem to place their bets on.[25,31]

In the present study, the current and emerging research topics were studied to focus on the worldwide momentum topics of research and how researchers in the country (India) are engaging in these prominence areas. Research topic clusters were identified from the SciVal (https://www.scival.com/) clustering of topics based on the scholarly output in the respective topic clusters (https://www.elsevier.com/solutions/scival/features/topic-prominence-in-science).

The top 500 topic clusters for India in the area of food science were analysed on the basis of prominence or momentum indicator vis-a-vis world topic momentum. The prominence indicator (https://www.elsevier.com/solutions/scival/features/topic-prominence-in-science) provides worldwide current momentum or visibility of a topic, which necessarily does not imply its importance. To indicate the momentum of the topic, a topic's prominence is calculated using three metrics that include, (i) Citation count in year *n* to papers published in *n* and *n-1; (ii)* Scopus views count in year *n* to papers published in *n* and *n-1; and (iii)* Average CiteScore for year *n.* It may be pointed out that the prominence is also dependent on the real nature of certain research subject fields.

From the sample of top 500 topic clusters based on the research portfolio analysis of SCOPUS data, wherein the clustering has been constructed on the worldwide topics of prominence in the area of FS. It was observed that 25 such topic clusters (5% of top 500 topic clusters) are in the 99th prominence percentile so far as the Indian research portfolio in

this domain is concerned (Table 2). This means that if you are in the top 1%, you are in the 99th percentile. So, these topics of prominence are in the Indian context of research endeavours with respect to topics of worldwide prominence or momentum areas. As such, the research portfolio shows that there are

Table 2 — Top 25 topic clusters of prominence: based on scholarly output resulting from Indian contributions

Based on worldwide prominence percentile (WPP)				Based on scholarly output in terms of no. of publications			
Topic Cluster	Sch. Out.	FWCI	WPP	Topic Cluster	Sch. Out.	FWCI	WPP
Intestine Flora; Ruminococcaceae; Dysbiosis	360	2.42	99.992	Curcumin; Demethoxycurcumin; Turmeric Extract+	1096	1.45	99.862
Edible Films; Active Food Packaging; Elongation at Break*	412	1.91	99.935	Triphala; Phyllanthus Emblica; Terminalia Chebula	469	0.65	88.163
Curcumin; Demethoxycurcumin; Turmeric Extract +	1096	1.45	99.862	Edible Films; Active Food Packaging; Elongation at Break*	412	1.91	99.935
Galacturonic Acid; Rhamnose; 2-Diethylaminoethanol	132	1.14	99.777	Severe Acute Malnutrition; Child Nutrition Disorders; Stunting~	382	1.04	99.17
Meat Consumption; Food Systems; Livestock Products	62	5.44	99.741	Wild Edible Mushrooms; PleurotusOstreatus; Agaricales	361	0.85	95.638
Retrogradation; Rice Starch; Pasting Properties	328	1.13	99.73	Essential Oils; Thymus Plant; Carvacrol	361	1.22	99.652
Edible Insects; HermetiaIllucens; Stratiomyidae	67	1.13	99.7	Intestine Flora; Ruminococcaceae; Dysbiosis	360	2.42	99.992
Essential Oils; Thymus Plant; Carvacrol	361	1.22	99.652	2 Hydroxypropyl Beta Cyclodextrin; Cyclodextrins; Complexation	338	0.78	98.686
Virgin Olive Oil; Oleuropein; Elenolic Acid	30	0.96	99.606	Biofortification; Zinc Fertilizers; PennisetumGlaucum	329	0.98	96.447
Nanoemulsions; Creaming; Emulsifying Agents	82	1.53	99.557	Retrogradation; Rice Starch; Pasting Properties	328	1.13	99.73
Lactobacillus Amylovorus; Bifidobacterium Animalis; Probiotic Agent	204	1.44	99.469	Thin-Layer Drying; High Temperature Air; Solar Dryers	322	1	99.454
Thin-Layer Drying; High Temperature Air; Solar Dryers	322	1	99.454	Amylases; Glucan 1,4 Alpha Glucosidase; Maltotriose	302	0.46	88.116
Spray Drying; Maltodextrins; Drug Formulations	180	1.43	99.433	Fermented Foods; Bamboo Shoots; SaccharomycopsisFibuligera	283	0.88	84.162
Hyperspectral Imaging; Total Volatile Basic Nitrogen; Freshness	177	1.06	99.388	Punicalagin; Pomegranate Peels; Ellagic Acid	268	0.83	98.941
Food Loss; Waste Prevention; Food Supply Chain	46	1.25	99.343	Bacteriocins; Lactobacillales; Biopreservatives	261	0.61	97.815
Peptidyl-Dipeptidase A; Protein Hydrolysates; Antihypertensive Effect	142	1.32	99.315	Trigonella; 4-Hydroxyisoleucine; Diosgenin	260	0.71	91.983
Protein Hydrolysates; Subtilisins; Foaming Capacity	180	1.1	99.313	Moringa Oleifera; Leaf Extracts; Multipurpose Trees	255	0.91	97.001
Vomitoxin; Zearalenone; 15-Acetyldeoxynivalenol	71	1.69	99.281	Aloe; Acemannan; Alloin	235	0.78	92.521
Fucoidan; Fucosylated Chondroitin Sulfate; Brown Alga	158	1.47	99.276	Shogaol; Gingerol; 6-Paradol	232	1.07	96.542
Quercetin; Flavanols; Tamarixetin	75	2.24	99.267	Piperine; Piper Nigrum; Piperic Acid	229	0.75	89.891
Severe Acute Malnutrition; Child Nutrition Disorders; Stunting ~	382	1.04	99.17	Contract Farming; Smallholders; Market Participation	225	0.52	97.309
Coffee Beans; Coffea Arabica; Melanoidins	36	0.94	99.098	Thymoquinone; Nigella Sativa; Caraway Oil	209	1.15	97.078
Organic Foods; Farmers' Markets; Willingness to Pay	97	1.36	99.097	Lactobacillus Amylovorus; Bifidobacterium Animalis; Probiotic Agent	204	1.44	99.469
Pectins; Rhamnogalacturonan I; Sugar Beet Pulp	92	1.82	99.075	OcimumTenuiflorum; Ayurvedic Medicine; Estragole	204	0.65	73.986
Pesticide Residues; Multiresidue Analysis; Florisil	123	1.04	99.037	Choloylglycine Hydrolase; Probiotic Agent; Lactobacillales	201	1.08	96.902

25 clusters that are in the top 1% of the world; while 215 topic clusters are in the top 10% and the remaining are 20% or above 20% in terms of their prominence. The focus of these top 1% topic clusters deals with the broad domains of food sustainability, food safety, and food security including malnutrition. From this, it is evident that domains reveal the endorsement of the primary goals of the UN SDGs.

At the macro level when we introspect the momentum topics, we find that the primary focus of Indian researchers who are engaged in finding solutions to the aspects of security, safety, and sustainability of food and addressing the crucial aspects of malnutrition involves an array of topics ranging from the application of processes to the enhancement of health benefits of plant food for human consumption. For instance, the antioxidant is being largely addressed primarily in relation to the properties of plant food extracts or their consumption by humans, antioxidant activities of food products or food family members, biological importance of bioactive antioxidants in plant pigments for health benefits, etc. Similarly, processes for stickiness and digestibility of processed foods, use of plant-based (phytopharmaceutical preparations) food preservatives, sustainable food ingredients, probiotics used starter cultures in the fermented foods for health benefits, plant food for cell adhesion, food systems, and livestock products, enzyme-protein for anti-hypertensive effect, food packaging and the like. Application of nano-emulsions in the food industry, use of novel food drying processes, hyper structural imaging for food freshness, increasing foaming capacity of food, consumption of brown algae as foods or food additives, and its development in functional foods. Again, in the area of food safety and malnutrition, the topics like mycotoxins occurrence and toxic effects, food contamination, multi-residue analysis method for determination of pesticides in foods to secure the health of the population, malnutrition, nutrition disorders, and stunting particularly impaired growth and development that children experience from poor nutrition. Organic foods and farmers' markets, and food waste prevention in the food supply chain, were some other observed areas of research. In short, the institutional concern for addressing the core issues including poverty issues through research endeavours in food science is observed.

When we specifically look at 2021 data for worldwide momentum areas, the SCOPUS has identified 112 new topics of prominence that include food security, agriculture, COVID-19 with 538 scholarly research output, 3.08 Field-Weighted Citation Impact (FWCI), and 95.951 worldwide topic prominence percentile (https://scival.com/newtopics). This means that this topic is gaining momentum and thus is getting attention too. Again, the data from Table 2 depicts that 32% of the top 25 topic clusters based on the number of publications fall in the top 1% of the prominence percentile, thereby indicating that the topic clusters with more publications count for globally high momentum topics.

Co-relation between Prominence and Funding

The prominence indicator also signals that the momentum areas in the top worldwide percentile have potency to attract more funding. There is a correlation between the prominence (momentum) of a particular topic and the amount of funding per researcher within that topic.[25] The authors have shown through the topic level model of science that the funding per author increases significantly with topic prominence, thus prominence is an indicator of science demand and emphasized the implications of their results for research planning and portfolio analysis both by the institutions and researchers. The model also showed that the correlation between prominence and future funding is 0.616, thus prominence accounts for 38% (or 0.616) of the variance of future funding. Also, Rahkovsky *et al.,*[32] has suggested an appropriate mix of portfolio-level factors that could positively impact each funding organization's ability to accomplish its mission by analysing the artificial intelligence and machine learning (AI/ML) research portfolios of six large research funding organizations from the United States and briefly described as to how insights such as these could be realistically applied to portfolio management decision-making.

On an average, the higher the momentum, the more money per researcher is available for research on that specific topic. Thus, one can rightfully infer that these 25 clusters are in a position to attract more funding. Also, studies[31] have shown that external evidence, for instance, awards, correlates well with the nature of emerging topics.

Research Performance Impact

The performance impact here is based on the Field-Weighted Citation Impact (FWCI), which represents the ratio of the total citations actually received by the denominator's output, and the total citations that would be expected based on the average of the subject

field. FWCI considers the relative differences in research behaviour across such disciplines.

The FWCI suggests that out of the top 500 topics by scholarly output, 101 topics have a FWCI of over 1, which means that the output is more cited than expected according to the global average. While 1 topic has exactly 1 FWCI indicating that the output performs just as expected for the global average. Simultaneously, the impact in terms of research performance based on FWCI is close to the world average particularly in the later years. However, in terms of outputs in top citation percentiles (top 10%, field-weighted), gradual growth in performance is observed (Fig. 2), thereby indicating better growth in the impact of research on food science. This aspect perhaps could be attributed to the argument that research endeavours are usually centered on prominence themes. Not necessarily, all those topics that have high prominence are included in the high FWCI topics. This corroborates the statement that prominence does not necessarily mean being important. However, currently, those topics have momentum for attracting funding.

The merit of scholarly research output in terms of its impact is also attributed to the research communication source journal. In other words, publishing in top journals has several benefits and is likely to make the author's work stand out[33,34] and thereby is expected to display heightened visibility, research activity, and industry credibility. Good research will get reported in good peer-review journals, as far as the scholarly output communication is concerned. So, in the case of FS, there is no set pattern observed as far as the publications in top journal percentiles in the top 10% by CiteScore percentile is concerned (CiteScore percentile indicates the relative standing of a serial title in its subject field and CiteScore metrics help to measure journal citation impact) and thus needs further investigation before some evidential tangible inference can be actually drawn. However, the data revealed that the mainstream journals representing the most relevant sources were preferred by the researchers in the food science domain for scholarly communications as indicated in Fig. 3.

Scientific Specialties

While prominence topic clusters have revealed current momentum topics, it is only prudent to see what research topics by top 500 authors (identified from the SCOPUS database via SciVal) have addressed during 2011–2020. Similarly, on the identical lines, for the highly cited papers (HCPs), the thematic areas were identified, and also the co-word

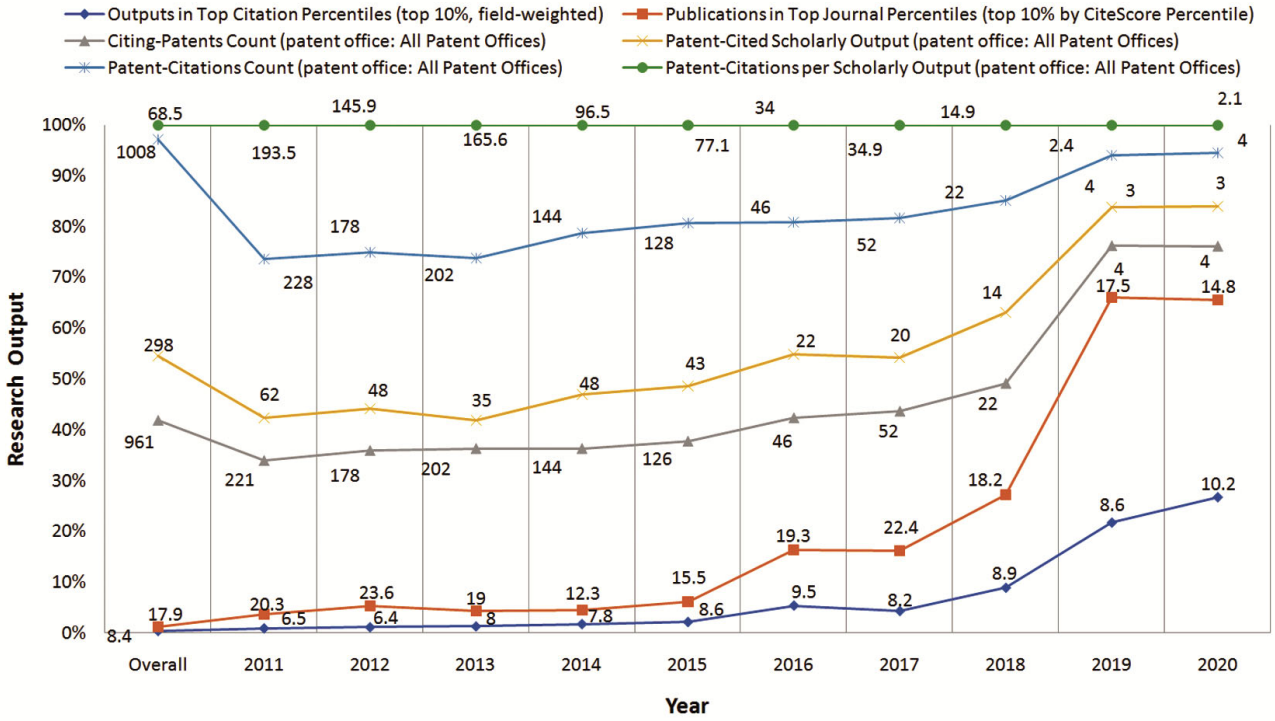

Fig. 2 — Research performance in food science

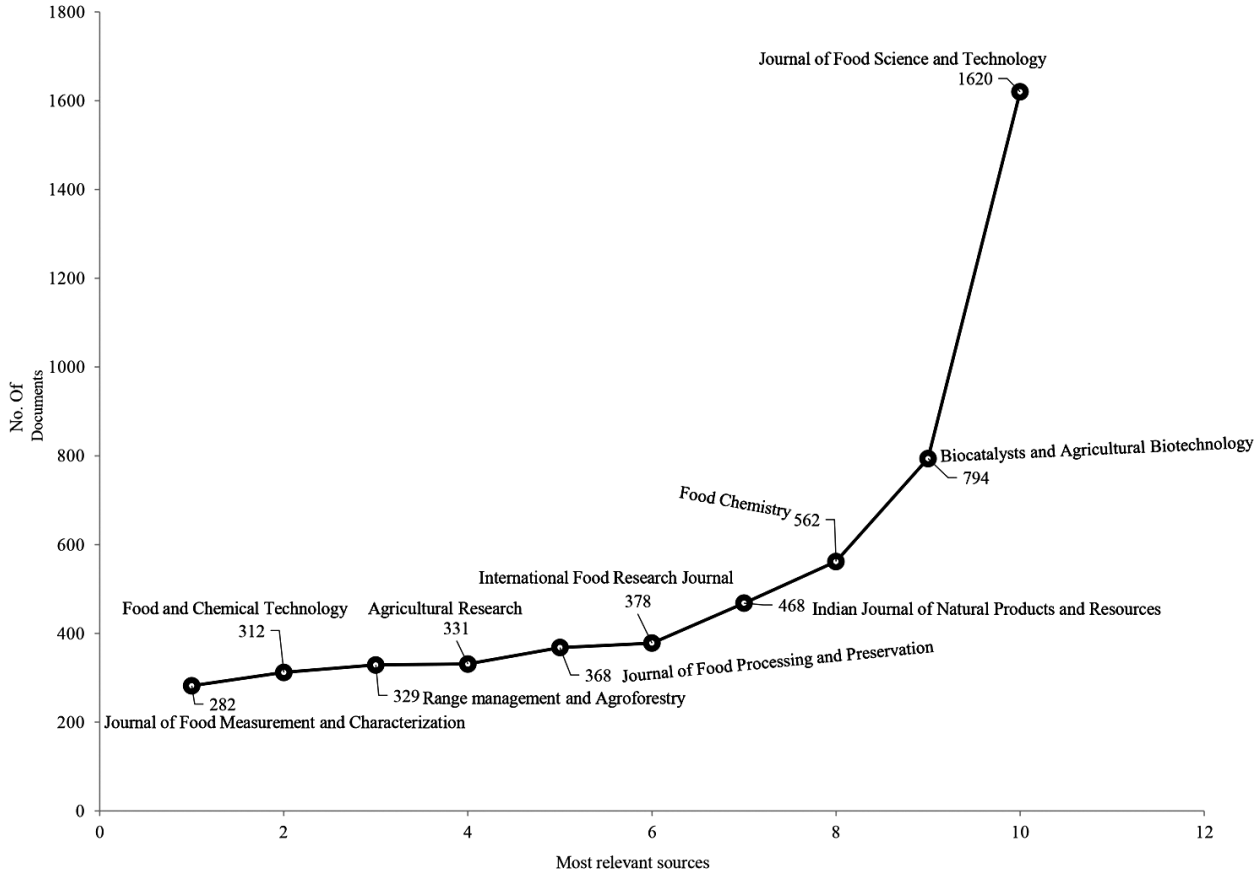

Fig. 3 — Most relevant sources of scholarly research communications

occurrences and the keywords assigned by the authors and auto-assigned by the database were subjected to analysis so as to divulge the prominent topics. Subsequently, the correlation between the top topic clusters (based on prominence percentile), top author (based on the number of publications), research domain topics, and topical areas in HCPs (based on top cited papers) were discerned and equated with co-word occurrences and keyword bursts.

Research Topic Analysis of Top Authors, Institutes and HCPs

Authorship confers credit and thus has important academic, social, and financial implications. In the world of scholarly publication landscape, authorship and publication are crucial measures used to determine the impact that researchers have on their research domain. While authorship can bring great personal and professional rewards, it also insinuates responsibilities and accountability for the published work. From the perspective of measuring the impact of research via its scientific output, researching, mapping, and reporting on trends in the given domain of science, the scientometricians are engaged in a major way.

To measure the researcher's impact in the present study, while the total publication output was considered, firstly, the top contributing 500 researchers' papers were identified and analysed to figure out the sub-topics of research addressed by them along with their affiliations. Secondly, the highly cited papers and their areas of research themes were also fathomed. Thirdly, co-relation amongst the top topic clusters, top author research domain topics, and topic areas in HCPs was discerned. The purpose was to figure out the core areas of research, in addition to the underlying strengths and weaknesses, and also to ascertain whether there is some synchronization with the SDGs of the UN.

From the analysis, it is evident that overall growth in terms of the number of authors engaged in contributing to the scholarly research landscape shows an upward trend (with some deviations in between for a couple of years) during 2011 to 2020, and the authors growth % observed is 86.4% during this period. This indicates that a greater number of scientists are getting engaged in the research domain

of FS. The research study[31] suggests that although nearly all emerging topics contain highly cited papers, the reverse is not true – only 10% of highly cited papers are part of emerging topics. This was by and large found to be of some relevance in this field as well.

The analysis was based on 500 top authors where their research interests are and profiling the subject themes that they are actually working on. The research topics for each of the 500 top contributing authors were identified by navigating through the contributions of each of these researchers' papers in the SCOPUS database for the years 2016–2020. For each of these researchers, the most addressed thematic topics were identified using co-word occurrences and keywords. Thus, for each of these researchers, multiple keywords were identified to figure out the major themes/topics addressed by them. The analysis of the top 500 author's data revealed that these authors are from 219 institutions and broadly the major research areas addressed by these authors fall almost in the similar areas of antioxidants, food security, and safety, food packaging and storage, human health, food processing, etc. Subsequently, a detailed analysis of the top 25 highly contributing authors (contributing over 24.54% of the total contribution of 14,709 papers) was carried out to decipher the core areas addressed by them and their institutional affiliations. The core areas and the correlation amongst the top 25 authors corresponding to their institutional affiliation and research areas are portrayed in Fig. 4.

The top 500 topic clusters also reveal a similar pattern, thus endorsing the momentum areas to be in congruence with the top 500 authors with a major focus on antioxidants, food security & safety, food processing and packaging, food systems, etc.

Research Areas of Top Institutions

While 754 institutions have been observed to be engaged in food science research on various research fronts, however, the domain research concentration is primarily vested in ICAR and its affiliated institutions (94 institutions) contributing 14.81%, followed by 9.87% from CSIR labs (34 labs engaged in the domain in some form with CFTRI, Mysore holding 48.22% from within CSIR labs) and also IITs (17 IITs) contributing 4.16% with major share from IIT, Kharagpur. Primarily three sectors i.e. academic (comprising academic institutions, Universities) contributing the most; Government (comprising central institutions and research organisations) and the Corporate sector has contributed to the scholarly research output.

We tried to decipher the core areas of top collaborating institutes and found that the major areas

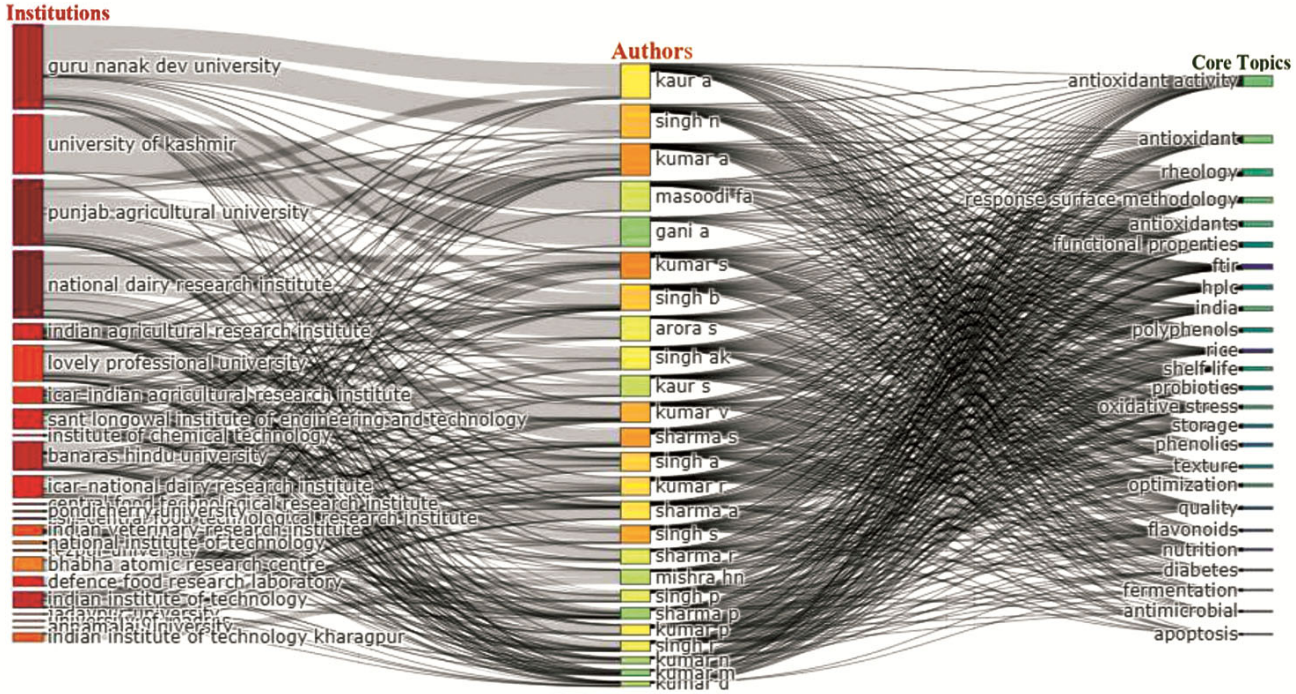

Fig. 4 — Top 25 authors corresponding to their institutional affiliation and the research topic areas

of research of the top collaborating institutes were antioxidants, food processing, packaging and storage, food quality, malnutrition, agriculture and food production, food safety, and health benefits. The top 25 institutions were mapped with the corresponding authors and the research areas that they are engaged in are depicted in Fig. 5. Due to variations in the rendering of names, while auto-identifying the top institutions by the software (Biblioshiny), two institutions have cropped up twice, however, it does not impact the trend. This brought us to another aspect of construing the key research topics of the HCPs.

Research Areas in Highly Cited Papers (HCPs)

Highly cited papers are from 19 institutes and while analysing the top 20 highly cited papers, it was found that the research topic areas addressed by the authors of these HCPs primarily deal with antioxidant effects of plant foods, dietary health benefits, food processing, food safety and security, food bioactive compounds, malnutrition, functional foods etc. It was also observed that of late, food handling aspects are gaining attention. This may be important as many online food aggregators are sharing the market space and are mushrooming. More so due to public health pandemic, food handling is now one of the major aspects of food safety from the health point of view. It may also be pointed out that since most of these papers are an outcome of the collaborative endeavours, whether at the national or international level, the research topical areas in several ways are in accord with the SDGs of the United Nations.

Keyword Bursts and Co-word Occurrences

Identifying emerging research fronts to represent research activities within a scientific area by mapping the structure of scientific inquiry, *and* depicting the state-of-art research in that scientific area is crucial. To map the intellectual structure of the field of FS for the period of 2011–2020, co-word analysis was employed to reveal the prevailing patterns and trends in the field by measuring the association strengths of such terms as are true representative of relevant publications produced in the field based on the SCOPUS data. This allows a quantitative study of the structure of publication contents in terms of the nature and strength of linkages as exist between the pairs of words by comparing and classifying publications with respect to the occurrence of similar word pairs.

A total number of 38,333 keywords auto-assigned by the database using text mining techniques and

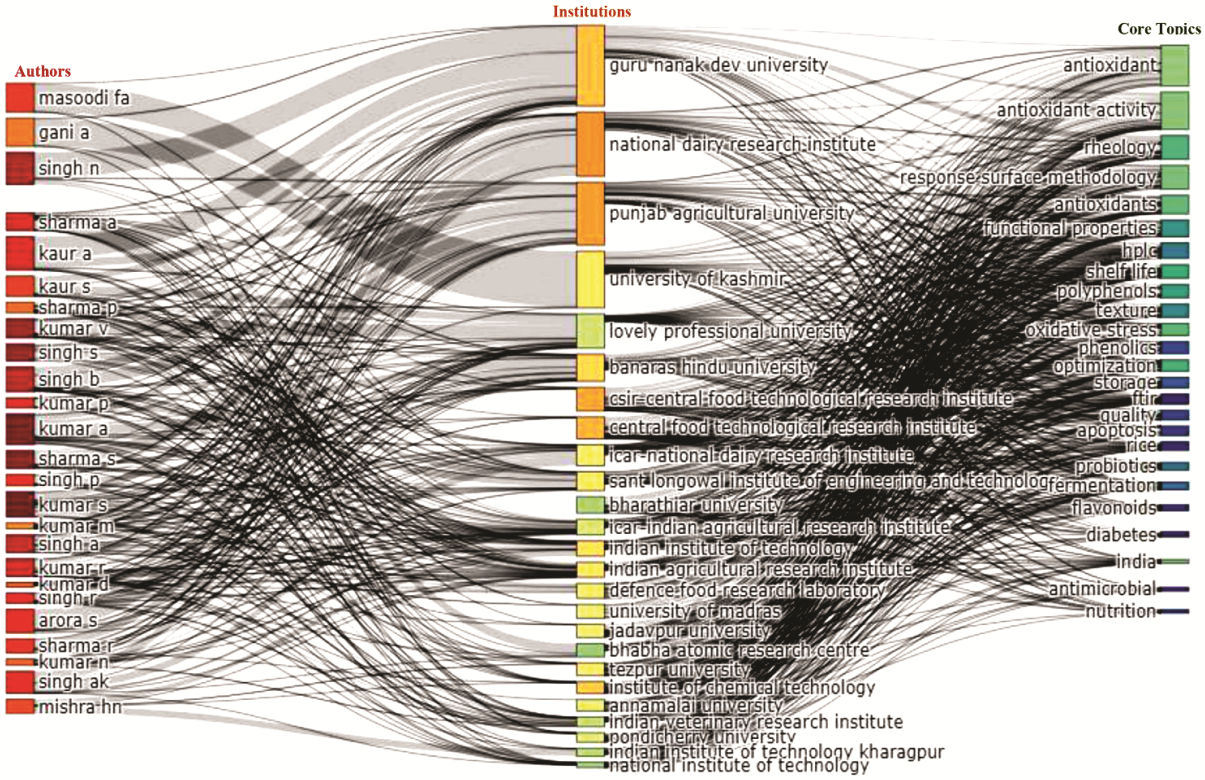

Fig. 5 — Top 25 institutions vis a vis prolific authors corresponding to the core research areas

29361 author-assigned keywords were retrieved from these 14,709 papers published during the period for further analysis. The keywords from authors, besides the keywords auto-assigned by the database, were analysed. In order to trace the dynamic changes in the FS field, the whole10-year period was further separated into two consecutive periods: 2011–2015 and 2016–2020. The results show that the FS field has some established research themes and it also changes rapidly to embrace new themes.

The study also investigated the use of the co-word analysis method to understand the microstructure of a research specialty and thereby identify research trends and emerging areas of research. It was found that "antioxidant", "response surface methodology", "antioxidant activity", "oxidative stress" has the highest number of occurrences and link with other keywords (Fig. 6 a & b). Also corroborated by the research study[18] that evaluated the co-word analysis for research contribution of the food science through

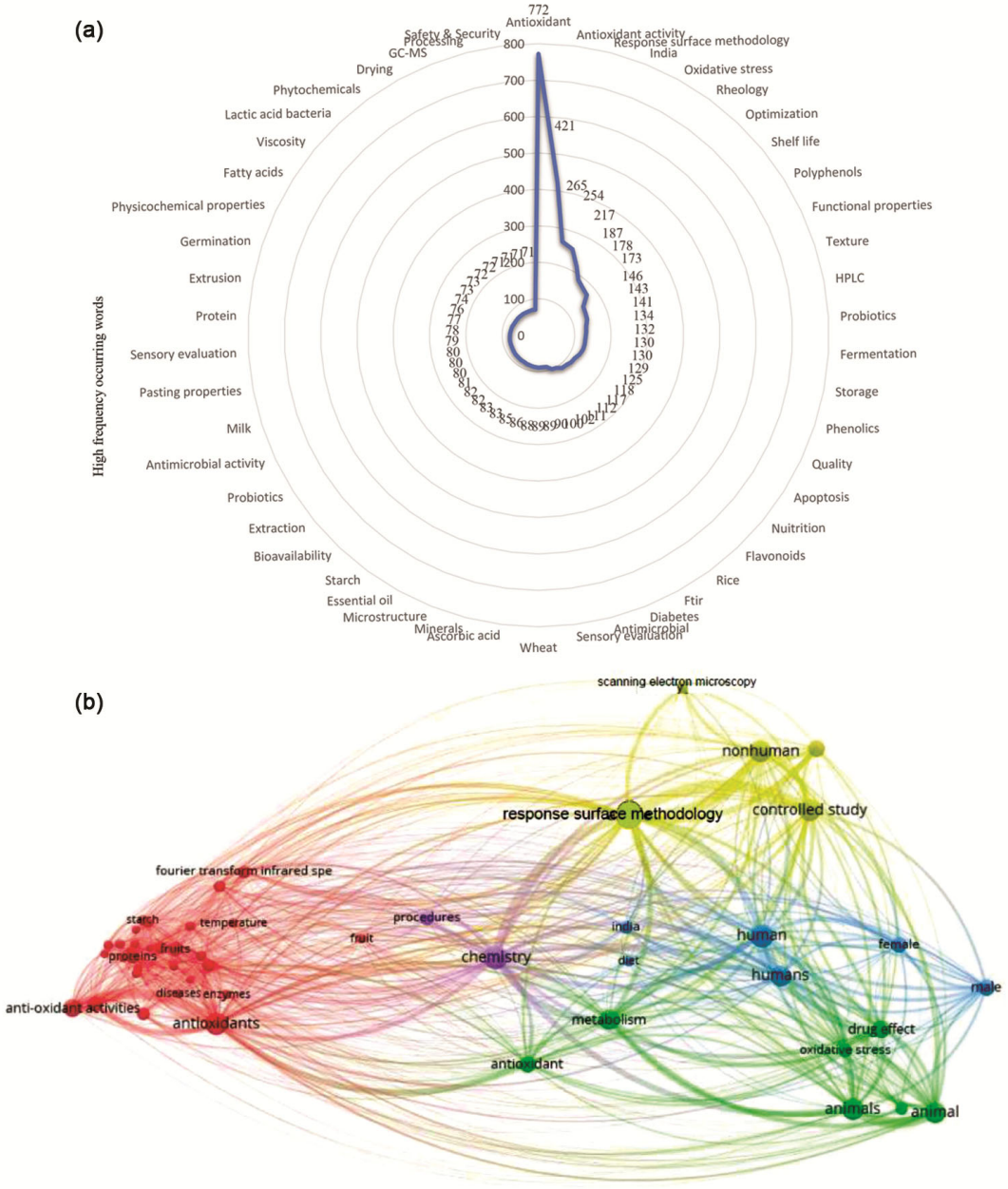

Fig. 6 — High frequency keyword co-occurrence network of the analyzed scholarly knowledge research communications: (a) most prominent 50 keyword co-occurrences (b) most prominent keyword co-occurrence network and its network with other core keywords

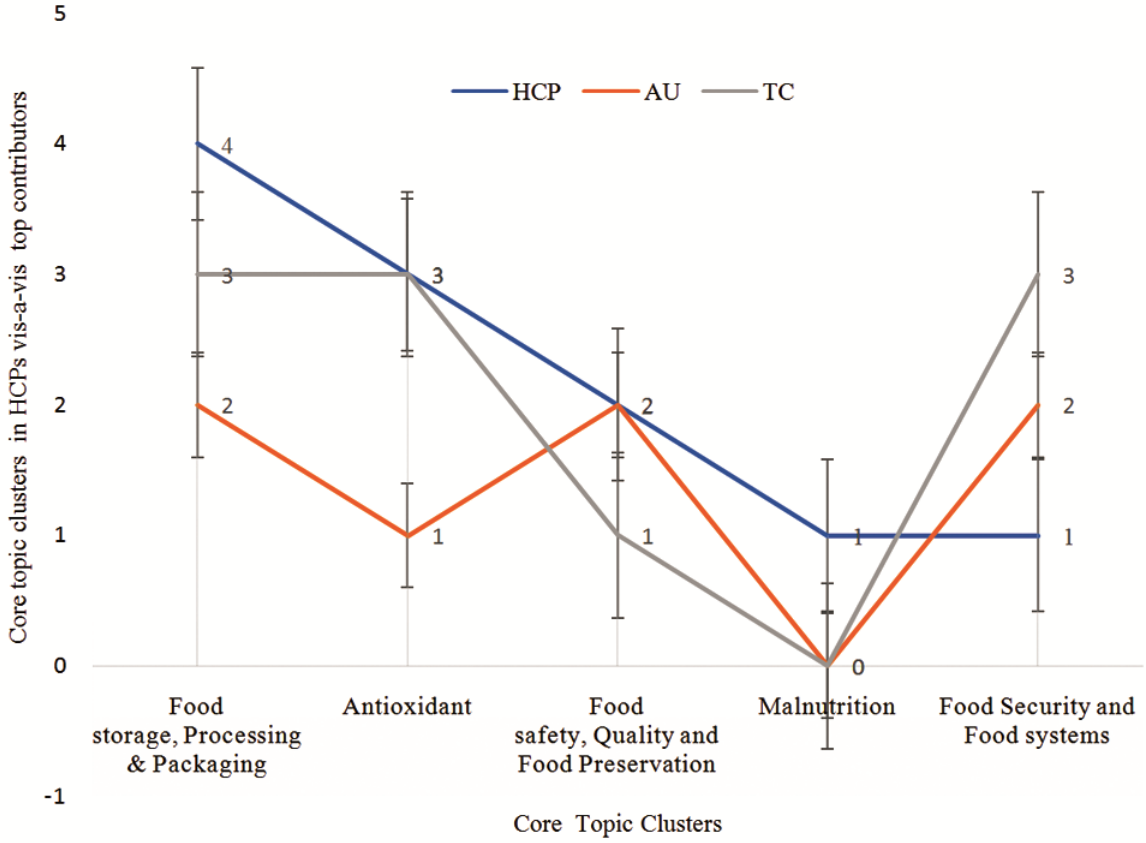

Fig. 7 — Core topics being addressed in the research communications by top contributing authors, in HCPs and in prominent topic clusters (HCP- Highly cited papers, AU- Top contributing authors, TC- Topic clusters)

keywords based on the thematic cluster using scientometric tools, revealed that the structure of the corresponding knowledge map with 'antioxidants' marked the highest occurrences during 2003–2014. The links with other keywords by and large depicted the broader research topic areas of food safety, food security, nutrition and nutrients, malnutrition, food fortification, and the related aspects. Thus, it elucidates that the research topics addressed by the researchers in general and those who have contributed to the highly cited papers and the prominent topic clusters derived via SciVal are analogous topical areas, hence these are of core research importance.

Co-relation Between Prominent Topic Clusters, Top Contributing Author's Research Domain Topics, and Topic Areas in HCPs vis a vis SDGs

The data reveals that in the area of FS, the topics addressed by top contributing authors and institutions, HCPs, and prominent topic clusters primarily fall in the areas such as food sustainability, food security, food safety, improved nutrition /malnutrition issues, besides others, and thus are by and large in cohesion with the SDG's. The Fig. 7 shows the core topics being addressed in the research communications of top contributing authors and within the HCPs and prominent topic clusters. 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 topical areas, hence of core research importance.

Conclusions

The data reveals that global publication output is sizeable and the growth trajectory for India seems to be random in the coming years. The analysis indicates that greater percent of scientists are actually getting engaged in this research domain.

The microstructure of a research specialty shows that "antioxidant", "response surface methodology", "antioxidant activity", "oxidative stress" has the highest number of occurrences and link with other keywords based on their internal cohesion. The links with other keywords depict topical areas of food safety and security, nutrition and nutrients, malnutrition, food

fortification, and related aspects. While the research trend shows that most of the energy is concentrated around antioxidants, the market analysis studies endorse our findings. Research organizations have shown that consumers opt for a high antioxidant diet to reduce the risk of diseases. The market for natural antioxidants is growing which is also evident from this study wherein plant food-based antioxidants are surfing to the top. The outcome of this study is expected to provide researchers with valuable insights into the trends and opportunities alike for the furtherance of research endeavours.

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