



Trend and status of Food Science and Technology category based on the Essential Science Indicators during 2011 – 2021

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Abstract

Based on the Essential Science Indicators database, this study analyzed 2,886 top papers in the subject category of Food Science and Technology from January 2011 to June 2021. The 2,886 top papers include 2,882 highly cited papers and 56 hot papers. All papers written in English, were from 10,698 authors, 2,666 organizations and 115 countries/territories, published in 106 journals and two book series in the field. The top five Journals are *Food Chemistry*, *Food Hydrocolloids*, *Trends in Food Science Technology*, *Critical Reviews in Food Science and Nutrition* and *Journal of Agricultural and Food Chemistry*. The top six countries and regions were Peoples R China, USA, Spain, Italy, Brazil and India. The top six organizations of Jiangnan University, University of Massachusetts, South China University of Technology, Zhejiang University, Jiangsu University and University of Valencia were popular based on contribution of articles more than 45 papers each. The top five authors were McClements David Julian, Sun Da-Wen, Barba Francisco J., Lorenzo Jose M. and Zhang Min. All keywords were separated seven clusters for different research topic. Visualizations offer exploratory information on the current state in a scientific field or discipline as well as indicate possible developments in the future.

Keywords: bibliometric analysis; Essential Science Indicators (ESI); Food Science and Technology; top papers; VOSviewer.

Practical Application: Bibliometric analysis of Food Science and Technology.

1 Introduction

According to category description for Food Science and Technology in Scope Notes of Science Citation Index Expanded, it covers those resources concerning various aspects of food research and production, including food additives and contaminants, food chemistry and biochemistry, meat science, food microbiology and technology, dairy science, food engineering and processing, cereal science, brewing, and food quality and safety. (Clarivate, 2021b).

Bibliometric analysis is a method assessing the status and trends of a particular research field and thus providing ideas and directions for future research. Bibliometrics technique has been adopted in Web of Science category of Food Science and Technology such as, bibliometric analysis of food safety governance research from 1999 to 2019 (Shen et al., 2021), a knowledge domain visualization review of thirty years of halal food research (Mostafa, 2020), Atlas of scientific institutions in food science (Guerrero-Bote et al., 2016), characteristics and trends in global tea research (Wambu et al., 2017), destination food research (Lyu et al., 2020), exploring the scientific interest for olive oil origin (Maléchaux et al., 2020), Food label design (Latino et al., 2020), Innovation, research and development on the passion fruit peel flour (Florêncio et al., 2020), internet of things in food safety (Bouzemrak et al., 2019), Let food be thy medicine and medicine be thy food (Yeung et al., 2018), mapping the scientific research on wine and health (Aleixandre et al.,

2013), recent developments on production, purification and biological activity of marine peptides (Sridhar et al., 2021), research trends in food chemistry (Kamdem et al., 2019), the berries on the top (Yeung et al., 2019), trends in research on durum wheat and pasta (Cecchini et al., 2020), urban food systems (Zhong et al., 2021).

Top papers are the sum of hot papers and highly cited papers, based on Clarivate Analytics' Essential Science Indicators (ESI). The ESI database is widely used to assess scientific outputs. Highly cited paper is a paper that belongs to the top 1% of papers in a research field published in a specified year. The 1% is determined by the highly cited threshold calculated for the research field in the specified year. Hot paper is a paper published in the past two years that received a number of citations in the most recent two-month period that places it in the top 0.1% of papers in the same field. A bibliometric evaluation of highly cited papers with high-level representation was conducted during the period from 1999 to 2009 based on the Essential Science Indicators (ESI) database (Fu et al., 2011), highly cited papers in the field of Economics and Business based on the Essential Science Indicators database (Zhang et al., 2018), highly cited papers in operations research and management science from 2008 to 2017 (Liao et al., 2019), highly cited papers in environmental sciences (Ma et al., 2020), macro-level collaboration network analysis and visualization with Essential Science Indicators:

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A case of social sciences (Yang et al., 2020), and high-impact papers presented in the subject category of water resources in the Essential Science Indicators database (Chuang et al., 2011). Sun and Yuan have analyzed the top papers in world rice research (Sun & Yuan, 2020a), Library and Information Science (Sun & Yuan, 2020b), water Resources (Sun & Yuan, 2020c), Agronomy category (Sun & Yuan, 2021), green and sustainable science and technology (Yuan & Sun, 2019), scientific research on maize or corn (Yuan & Sun, 2020a, 2020b) and wheat (Yuan & Sun, 2021).

The purpose of this paper was to use bibliometric methods to analyze top papers in the subject category of Food Science and Technology during 10 years and 6 months period from January, 2010 to June, 2020 through publication year, category, author, affiliations, country, journals, keywords and other key features. Co-authorship network visualization of author, organizations and countries, co-occurrence network visualization of all keywords were done by VOSviewer. Special attention will be dedicated to research topics and research fronts.

2 Materials and methods

2.1 WoS and Essential Science Indicators (ESI)

Clarivate Analytics's WoS is the world's leading scientific citation search and analytical information platform, and the one of the world's largest and most comprehensive academic information resources covering more than 12,361 core academic journals. The publication counts from the WoS Core Collection were derived from the following databases: The Science Citation Index—Expanded (SCIE)--1900-present, Social Science Citation Index (SSCI)--1900-present, Conference Proceeding Citation Index-Science (CPCI-S)--2015-present, Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH) --2015-present, Current Chemical Reactions (CCR-EXPANDED) --1985-present, Index Chemicus (IC) --1993-present.

Essential Science Indicators (ESI) is a unique compilation of performance statistics and trends extrapolated from counts of articles published in scholarly journals and the citations to those articles. ESI is an analytical tool that helps you identify top-performing research in WoS Core Collection. Article counts for ESI are derived from more than 12,000 journals indexed in WoS Core Collection (SCIE and SSCI only) over a 11-year period. Citation counts for these articles are derived from journals indexed in WoS Core Collection (SCIE, SSCI and Arts & Humanities Citation Index). Each journal is assigned to one of 22 research fields. In ESI a journal can be assigned to only one field. Journals such as Science and Nature are categorized as multidisciplinary since they publish research in many different fields. As a result, papers published in these multidisciplinary journals are assigned to a field based on the representation of the cited journals. For example, if the majority of cited references in the paper are to neuroscience journals, the paper is then categorized as neuroscience (Clarivate, 2021a). Here, the Essential Science Indicators database has been updated as of September 8, 2021, to cover a 10 year and six months period from January 1, 2011 to June 30, 2021. Papers are defined as regular scientific articles and review articles.

2.2 Data collection

Data collection was completed on the single day on September 9, 2021 to avoid the bias. We first conducted a advanced search in the WoS category (WC) of Food Science and Technology and publication year (PY) from 2011 to 2021. The query as following: (WC= Food Science and Technology) AND (PY: 2011-2021)

The results were used to identify the top papers of the highly cited papers and hot papers in field. There are 2,886 top papers from WoS Core Collection. Full record and cited references of the included papers were extracted and imported into VOSviewer (Leiden University, Leiden, the Netherlands) for further citation analysis. The impact factors (IF 2020 and IF 5year) were taken from the Journal Citation Report (JCR 2020) published in 2021, which had the latest data available.

2.3 VOSviewer

Visualizations (network and overlay) using program VOSviewer are conducted on WoS data in order to determine co-occurrence and clusters of connected publications, country input and author collaboration (co-authorship) as well as clusters of interrelated research topics (text data). In this work, we used VOSviewer to show the international collaboration between the authors, organizations, countries and the research trends through all keywords (Van Eck & Waltman, 2010). In this paper, default parameters values of the VOSviewer are usually used in the analysis. Items are represented by a label and a circle. The size of circles reflects the weight of an item. Some items are not displayed in avoidance of overlapping. The colors in network visualization (text maps) represent clusters of similar items as calculated by the program. Distance between the items indicates the strength of relationships.

3 Results and discussion

3.1 Document type and language of publication

Based on Clarivate Analytics's WoS Index, there were total 2,886 top papers of the Food Science and Technology category during the period from January, 2011 to June, 2021. All of 2,886 top papers were identified in SCIE (2,886), SSCI (108), CPCI-S (77), book citation index—Science (31) and index chemicus (6). In the ESI database, papers are defined as regular scientific articles and review articles. The document types of all 2,886 top papers were articles (1,612, 55.856%), reviews (1,274, 44.144%), proceedings papers (77, 2.668%), book chapter (31, 1.074%) and early access (3, 0.104%).

Among the all 2,886 top papers, there are 56 hot papers and 2,882 the highly cited papers that means 52 papers are both the hot papers and the highly cited papers. All papers were published in English, among that, only one paper also was in Estonian. The English was dominating language from the WoS, and scholars tend to publish their articles in English as they want them to be widely accepted. Moreover, most of the published documents were in the form of original research articles written in English language (Khan et al., 2020).

3.2 Publication output

With the aim of knowing the research status and trend, Figure 1 shows the top paper of Food Science and Technology category between 2011 and 2021. The mean publication was 262.36 each year, and the highest value was 385 in 2020, though there is a half year of 2021. An increase in the number of cited references indicates that there are more citing or cited publications. The number of citations to a paper is considered a good quantitative measure of a paper's impact. The *h*-index was initially proposed as a measure of a researcher's scientific output based on counting the number of publications (N) by

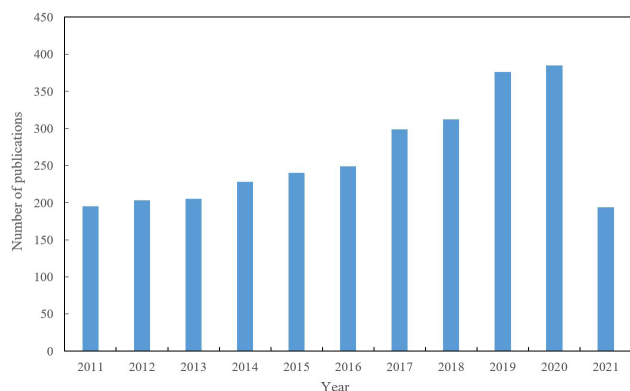


Figure 1. Number of published top papers of Food Science and Technology category per year from January 2011 to June 2021.

that researcher cited N or more times (Hirsch, 2005). For the total 2,886 papers, the *h*-index is 260, and the average citation per item is 131.3.

3.3 Web of Science categories and research areas

Each paper indexed by the WoS belongs to one or more subject categories. There are total 28 WoS subject categories including Food Science and Technology categories in the science edition (total 254 categories) and 21 research areas (Table 1). Among these, the top five categories include Food Science Technology (2,886 papers, 100% of 2,886 papers), Chemistry Applied (1051, 36.417%), Nutrition Dietetics (822, 28.482%), Agriculture Multidisciplinary (202, 6.999%) and Toxicology (96, 3.326%). The top five research areas include Food Science Technology (2,886 papers, 100% of 2,886 papers), Chemistry (1066, 36.937%), Nutrition Dietetics (822, 28.482%), Agriculture (318, 11.019%) and Toxicology (96, 3.326%). Journals or papers may be classified in two or more categories in the WoS, shows the multidisciplinary character of this research field (Elango & Ho, 2017, 2018). Documents are mapped to one or several research areas in WoS. Areas are assigned to publications and then mapped to each document (paper) in a publication. Therefore, publications can be mapped to several different areas. This broad database-specific mapping has several limitations but is nevertheless widely used in bibliometric assessments. In WoS, publications are also mapped to WoS categories which are more detailed than areas (Stopar et al., 2021).

Table 1. WoS categories and research areas for Food Science and Technology category during 2011-2021.

Rank	WoS categories			Research areas		
	Categories	No. papers	% Total papers	Areas	No. papers	% Total papers
1	Food Science Technology	2886	100	Food Science Technology	2886	100
2	Chemistry Applied	1051	36.417	Chemistry	1066	36.937
3	Nutrition Dietetics	822	28.482	Nutrition Dietetics	822	28.482
4	Agriculture Multidisciplinary	202	6.999	Agriculture	318	11.019
5	Toxicology	96	3.326	Toxicology	96	3.326
6	Engineering Chemical	94	3.257	Engineering	95	3.292
7	Biochemistry Molecular Biology	90	3.119	Biochemistry Molecular Biology	90	3.119
8	Microbiology	62	2.148	Microbiology	62	2.148
9	Agriculture Dairy Animal Science	57	1.975	Biotechnology Applied Microbiology	57	1.975
10	Biotechnology Applied Microbiology	57	1.975	Pharmacology Pharmacy	52	1.802
11	Agronomy	38	1.317	Business Economics	16	0.554
12	Chemistry Medicinal	37	1.282	Spectroscopy	14	0.485
13	Horticulture	35	1.213	Mycology	7	0.243
14	Agricultural Economics Policy	19	0.658	Entomology	5	0.173
15	Economics	16	0.554	Behavioral Sciences	4	0.139
16	Chemistry Analytical	15	0.52	Neurosciences Neurology	4	0.139
17	Pharmacology Pharmacy	15	0.52	Physiology	4	0.139
18	Spectroscopy	14	0.485	Immunology	2	0.069
19	Mycology	7	0.243	Environmental Sciences Ecology	1	0.035
20	Entomology	5	0.173	Plant Sciences	1	0.035
21	Behavioral Sciences	4	0.139	Public Environmental Occupational Health	1	0.035

3.4 Core journals

Based on JCR 2020 data (published in 2021), there are 144 journals of the WoS categories for Meteorology and Atmospheric Science. All the 2,886 publications were published in 106 journals and two book series which including *Annual Review of Food Science and Technology* (31) and *Annals of the New York Academy of Sciences* (1). The top 20 core journals were displayed in the Table 2 with total articles each more than 16 top papers, Journal impact factor as IF 2020 and IF 5 year, rank and Quartile in Food Science and Technology category.

The top 5 journals, top 10 journals, top 15 journals and top 20 journals published about 47.817%, 63.202%, 72.453% and 79.487% of the total top papers, respectively. The top five Journals are *Food Chemistry* (556, 19.265%), *Food Hydrocolloids* (272, 9.425%), *Trends in Food Science Technology* (226, 7.831%), *Critical Reviews in Food Science and Nutrition* (166, 5.752%) and *Journal of Agricultural and Food Chemistry* (160, 5.544%), each published more than 160 papers. Based on results of Table 2, among top 20 journals, sixteen journals were in Quartile 1, four journals were in Quartile 2 category. White-Gibson et al. (2019) have also demonstrated the importance of publishing articles in the English language in a high IF journals. Citation analysis is not a measurement of scientific quality, but it is reflective of the importance.

According to the publication data in the citation of 106 journals, there were 57 journals meet the thresholds of 5 publications, and were connected to each other. The network of citation in the field of Food Science and Technology category based on WoS was shown nine clusters with different colors in Figure 2, the size of circles reflects a total number of journal publication records. The nine cluster colors from one to nine are red, green, blue, yellow, violet, light blue, orange, brown and pink. Journals in the same cluster usually suggested that they published the similar content papers and had close relations with each other.

3.5 Authors co-authorship analysis

In general, internationally collaborative articles had the highest visibility and scientific impact, followed by inter-institutional collaborative articles, single-country articles and single-author articles, respectively (Wambu & Ho, 2016). According to the published data analysis results, a total of 10,698 authors have 2,886 publications, and among these, 188 authors met the thresholds of five publications, but only 71 authors were connected with each other. The network of authorship in the field of Food Science and Technology category based on WoS represented in Figure 3, the size of circles reflects a total number of records. Authors in the same cluster usually suggested that

Table 2. Top 20 core Journals on Food Science and Technology category research indexed in the WoS.

Rank	Journal	TP	Ratio	IF 2020	IF 5year	QC	QR
1	<i>Food Chemistry</i>	556	19.265	7.514	7.516	Q1	7
2	<i>Food Hydrocolloids</i>	272	9.425	9.147	9.169	Q1	5
3	<i>Trends in Food Science Technology</i>	226	7.831	12.563	14.466	Q1	3
4	<i>Critical Reviews in Food Science and Nutrition</i>	166	5.752	11.176	11.193	Q1	4
5	<i>Journal of Agricultural and Food Chemistry</i>	160	5.544	5.279	5.269	Q1	24
6	<i>Food Research International</i>	136	4.712	6.475	6.508	Q1	9
7	<i>Comprehensive Reviews in Food Science and Food Safety</i>	91	3.153	12.811	15.365	Q1	2
8	<i>Journal of Food Engineering</i>	81	2.807	5.354	5.144	Q1	23
9	<i>Food Control</i>	70	2.426	5.548	5.498	Q1	19
10	<i>LWT Food Science and Technology</i>	66	2.287	4.952	5.383	Q1	29
11	<i>Journal of Dairy Science</i>	57	1.975	4.034	4.354	Q2	40
12	<i>Molecular Nutrition Food Research</i>	55	1.906	5.914	6.409	Q1	16
13	<i>Foods</i>	53	1.836	4.35	4.957	Q2	37
14	<i>Food Function</i>	51	1.767	5.396	5.534	Q1	22
15	<i>Journal of Functional Foods</i>	51	1.767	4.451	4.907	Q1	35
16	<i>Meat Science</i>	47	1.629	5.209	5.305	Q1	26
17	<i>Food and Chemical Toxicology</i>	43	1.49	6.023	5.844	Q1	14
18	<i>EFSA Journal</i>	39	1.351	3.336	3.268	Q2	53
19	<i>Toxins</i>	38	1.317	4.546	4.8	Q1	32
20	<i>Journal of the Science of Food and Agriculture</i>	36	1.247	3.638	3.802	Q2	47

Note: TP: Total publications; Ratio: Ratio of 2,886(%); IF 2020: journal impact factor in 2020; IF5 year: journal impact factor of 5 years; QC: Quartile in Category; QR: Quartile rank of 144 journals in Food Science and Technology category.

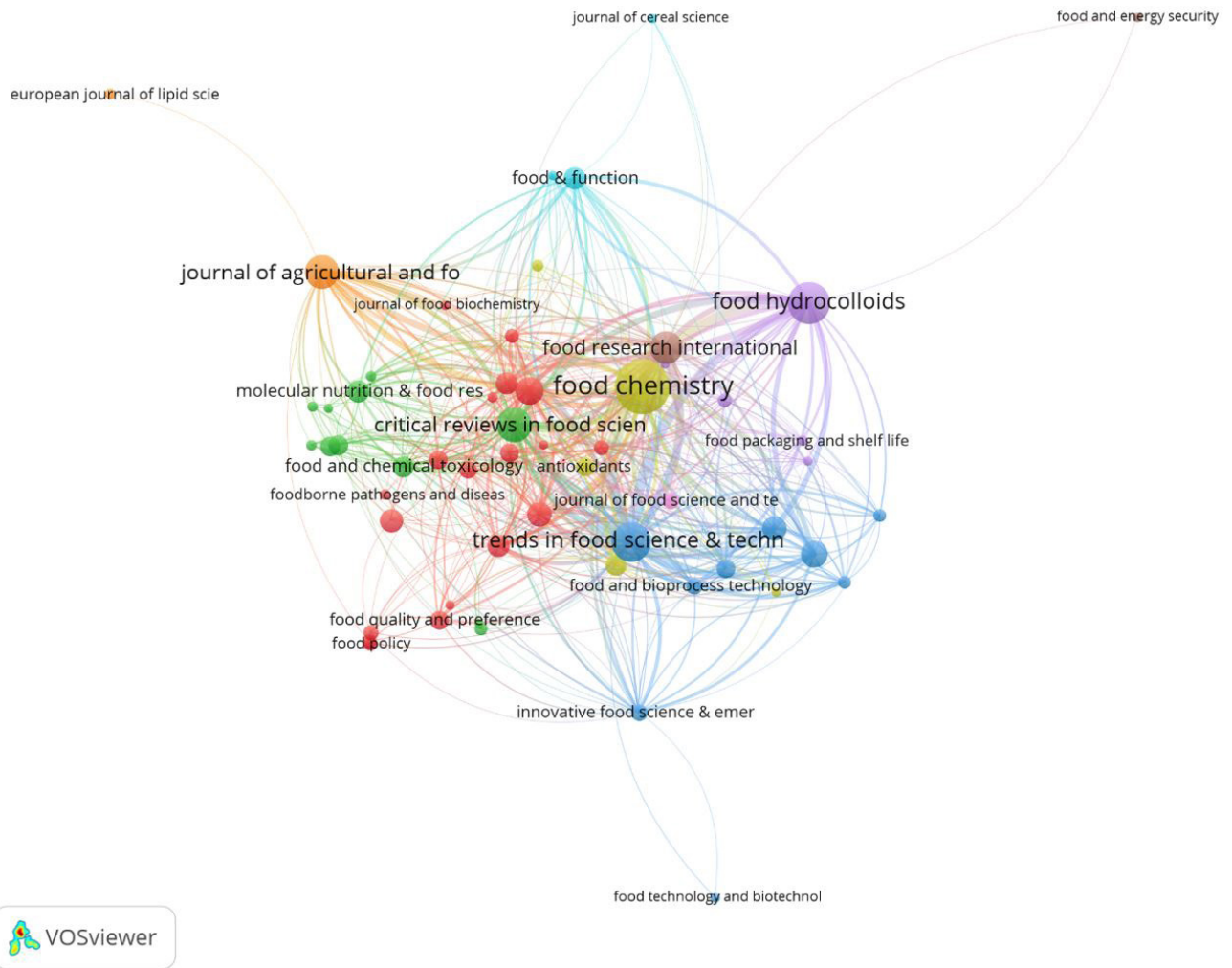


Figure 2. Network visualization maps of citation journals in the field of Food Science and Technology category based on WoS with 57 nodes and 9 clusters.

they studied in a similar field or worked at same institute or had close cooperation with each other.

The detail of author information published articles in the field of Food Science and Technology category from 2011 to 2021 along with citation, average citations, organization-enhenced and countries is provided in Table 3. According to our analysis, the top 14 authors published more than 15 papers. The top five authors were Mcclements, David Julian, Sun, Da-Wen, Barba, Francisco J., Lorenzo, Jose M. and Zhang, Min, each published more than 15 papers. The top five authors with the higher average citations per paper were Ferreira, Isabel C. F. R., Mcclements, David Julian, Granato, Daniel, Sun, Da-Wen and Barba, Francisco J., each paper cited more than 112 times.

3.6 Countries/regions co-authorship analysis

There were 115 countries or regions that contributed 2,886 papers in the field of Food Science and Technology category from January, 2011 to June, 2021. Table 4 represent the list of the top 20 countries or regions that published more than

56 papers, and also shows the cluster, total link strength, citations and average citations. Among the top 20 countries, Peoples R China, USA, Spain, Italy, Brazil and India were the major article contributors. In case of average citations, Netherlands, Germany, England, Belgium and Canada showed the higher citations per paper more than 164 times.

We developed the co-authorship network map using VOSviewer (Figure 4). There are 66 countries or regions that met the requirement threshold as five. The size of circles in Figure 4 reflects a total number of records and the distance between the countries indicate the strength of relationships. The VOSviewer divided these 66 circles into six clusters. The different colors group represent the different clusters formed by sets of countries. Distance between the countries indicates the strength of relationships.

According to Figure 4, the first cluster (red color) consisted of twenty-one countries or regions including Malaysia, India, South Korea, Australia, Peoples R China, Saudi Arabia, Japan, Thailand, Austria, Taiwan, Pakistan, Singapore, South Africa, Egypt, Bangladesh, Indonesia, Nigeria, Vietnam, Ghana, U Arab

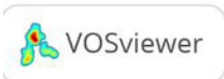
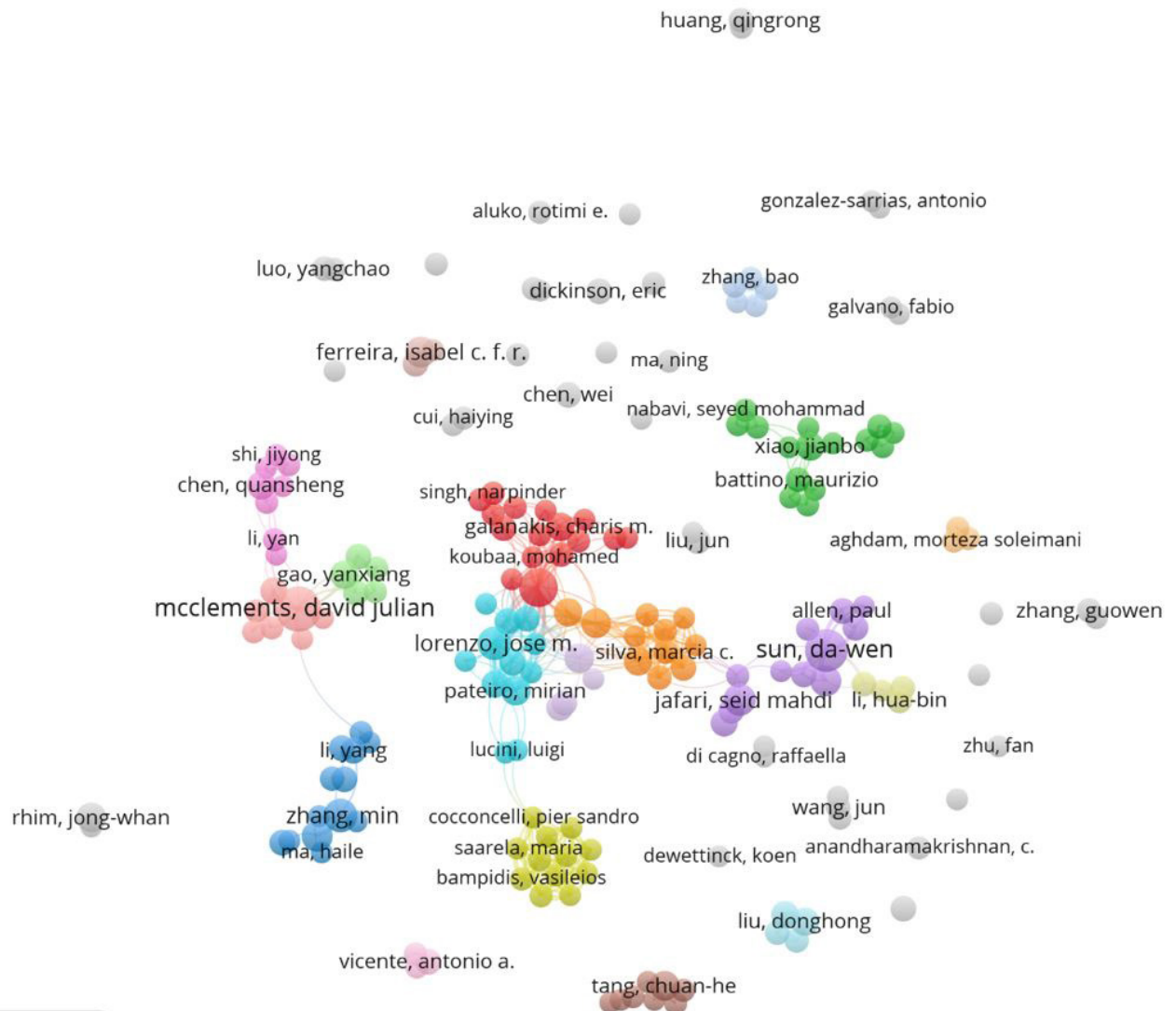


Figure 3. Network visualization map of top authors with more than five papers in Food Science and Technology category from 2011 to 2021. Cooperation based on co-authorship between authors. Network visualization map of authors with minimum productivity of five publications in the studied field and exist within a collaborative research group.

Emirates, Bulgaria. The second cluster (green color) consisted of thirteen countries or regions including Portugal, Turkey, Poland, Greece, Croatia, Norway, Romania, Serbia, Czech Republic, Slovenia, Cyprus, Lithuania, Russia. The third cluster (blue color) consisted of twelve countries including Netherlands, Germany, England, Ireland, New Zealand, Denmark, Switzerland, Sweden, Finland, Scotland, Luxembourg, Wales. The fourth cluster (yellow color) consisted of eleven countries and regions including USA, Spain, Italy, Mexico, Argentina, Israel, Colombia, Chile, Kenya, Ecuador, Philippines. The fifth cluster (violet) consisted of seven countries and regions including Belgium, Canada, France, Tunisia, North Ireland, Algeria, Lebanon. The sixth cluster (shallow blue) consisted of two countries and regions both Brazil and Iran. More cooperation could bring

more advanced achievements in scientific research. Nowadays, increasing concept of international exchanges have promoted academic communications (Tang et al., 2018).

3.7 Organizations co-authorship analysis

According to the publication data, it was revealed that a total of 2,666 organizations have 2,886 publications. Organization co-authorship analysis reflects the degree of communication between institutions as well as the influential institutions in this field (Reyes-Gonzalez et al., 2016). Table 5 represents the top fifteen organizations and institutions ranked by the number of total publications (more than 32 papers), the total link strength, citations, average citations and country.

Table 3. The top fourteen most prolific authors published papers in the field Food Science and Technology category from 2011 to 2021.

Rank	Author	Papers	Citations	Average citations
1	Mcclements, David Julian	65	8934	137.45
2	Sun, Da-Wen	52	6430	123.65
3	Barba, Francisco J.	40	4483	112.08
4	Lorenzo, Jose M.	24	1592	66.33
5	Zhang, Min	23	1867	81.17
6	Jafari, Seid Mahdi	21	1827	87.00
7	Ferreira, Isabel C. F. R.	18	3123	173.50
8	Pu, Hongbin	18	1437	79.83
9	Bhandari, Bhesh	17	1521	89.47
10	Granato, Daniel	15	1931	128.73
11	Pateiro, Mirian	15	925	61.67
12	Rhim, Jong-Whan	15	1201	80.07
13	Sant'ana, Anderson S.	15	1170	78.00
14	Tang, Chuan-He	15	1405	93.67

Table 4. Top 20 countries/regions publishing top papers in the field of Food Science and Technology category from 2011 to 2021.

Rank	Countries/Regions	Records	Cluster	Total link strength	Citations	Average citations
1	Peoples R China	754	1	450	66491	88.18
2	USA	487	4	589	74181	152.32
3	Spain	283	4	463	40863	144.39
4	Italy	210	4	305	24631	117.29
5	Brazil	168	6	190	18196	108.31
6	India	168	1	103	23499	139.88
7	Iran	167	6	124	16104	96.43
8	Canada	150	5	188	24609	164.06
9	England	134	3	264	22100	164.93
10	Australia	132	1	181	16827	127.48
11	France	129	5	293	20007	155.09
12	Ireland	128	3	203	17997	140.60
13	Germany	108	3	258	18330	169.72
14	Portugal	101	2	169	16071	159.12
15	Netherlands	90	3	219	15300	170.00
16	South Korea	83	1	54	10791	130.01
17	Belgium	80	5	156	13149	164.36
18	Turkey	75	2	144	10808	144.11
19	Malaysia	57	1	59	8337	146.26
20	Poland	56	2	88	6080	108.57

These top 15 organizations were mainly based in China (6 organizations), USA (2 organizations), and Spain, Australia, Brazil, Ireland, Belgium, England and Netherlands, each with one organization. Furthermore, the top six organizations of Jiangnan University, University of Massachusetts, South China University of Technology, Zhejiang University, Jiangsu University and University of Valencia were popular based on contribution of articles more than 45 papers each. Similarly in case of citation, the top five organizations of University of Ghent, University of Massachusetts, Wageningen University, Cornell University and University of Leeds showed the higher average citations more than 125.38 times per paper.

Among the total 2,266 organizations, there were 287 organizations met the minimum thresholds of five, and 277 organizations

connected to each other (Figure 5). The VOSviewer software divided these 277 institutes into fifteen clusters with different colors. Within the context of network formation, organizations tend to form bonds with other institutions in the same region. Geographical localization is an important factor for partnership and joint venture. Therefore, there is a heavy presence of intra-institutional relationships within the scientific network on publications.

3.8 All keywords co-occurrence analysis

Using the VOSviewer, the mappings can be made for the author keywords, keyword plus and all keywords. For the author keywords, there were 7,175 keywords, and 490 keywords met

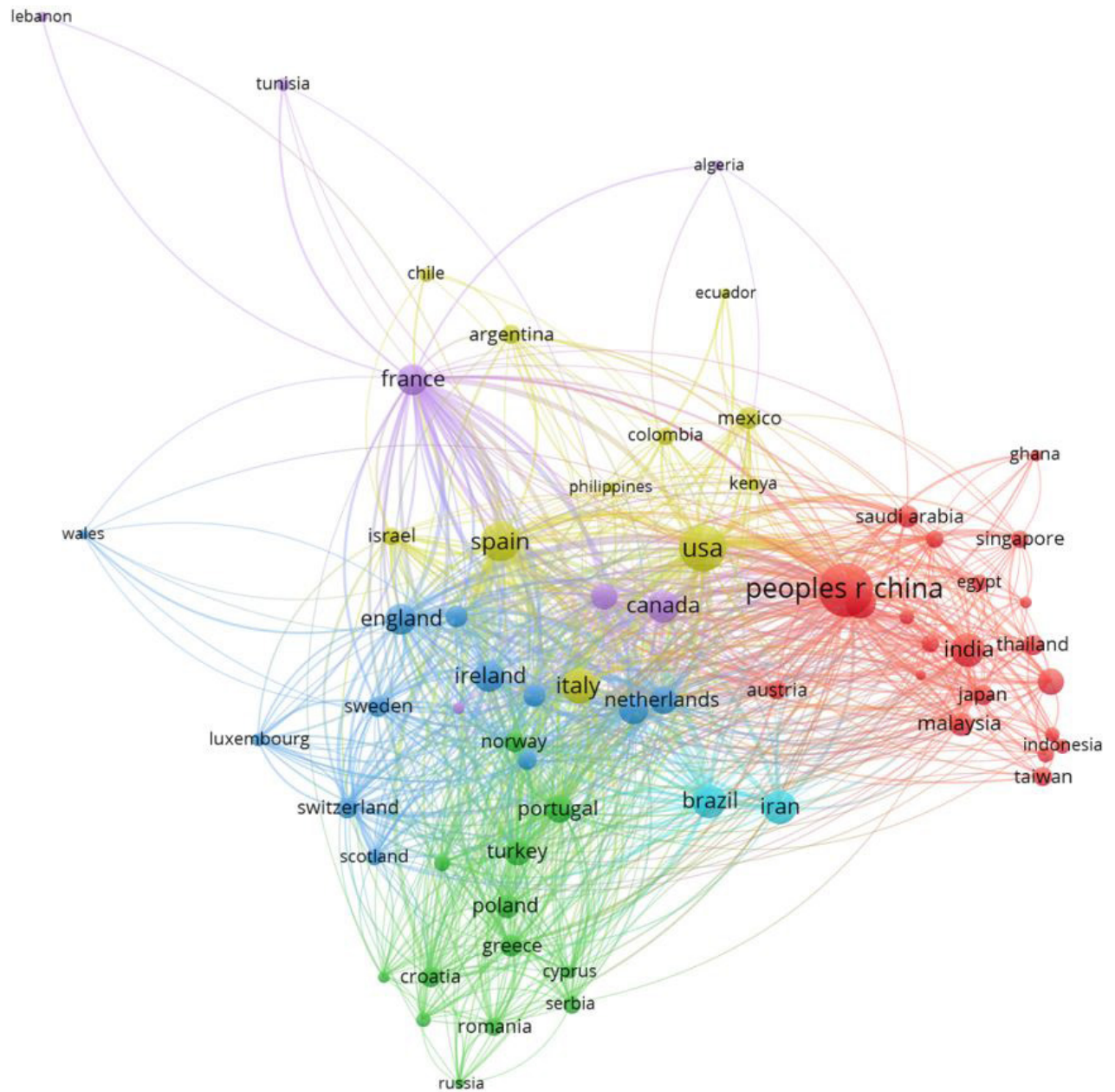


Figure 4. The country co-authorship network of Food Science and Technology related top papers from 2011 to 2021. The country co-authorship network map with 66 nodes and six clusters, the bigger nodes represented the more influential countries in this field. The distance and thickness of links represented the degree of cooperation among countries.

the threshold level of more than five times. The top twenty co-occurrence keywords were antioxidant activity, antioxidant, chitosan, bioavailability, polyphenols, phenolic compounds, food, food safety, curcumin, bioactive compounds, antioxidants, stability, encapsulation, anthocyanins, extraction, health benefits, oxidative stress, bioaccessibility, flavonoids, meat, et al., each keywords occurred more than 39 times. For the keywords plus, there were 9,676 keywords, and 961 keywords met the threshold

level of more than five times. The top twenty co-occurrence keywords were in-vitro, antioxidant activity, phenolic-compounds, quality, physicochemical properties, oxidative stress, stability, shelf-life, food, functional-properties, listeria-monocytogenes, chemical-composition, antioxidant, antimicrobial activity, acid, identification, lactic-acid bacteria, antioxidant properties, escherichia-coli, mechanical-properties, et al., each keywords occurred more than 70 times.

Table 5. Top fifteen organizations publishing papers in the field of Food Science and Technology category from 2011 to 2021.

Rank	Organizations	Records	Total link strength	Citations	Average citations	Country
1	Jiangnan University	77	78	7540	97.92	China
2	University of Massachusetts	76	89	12792	168.32	USA
3	South China University of Technology	61	79	4209	69.00	China
4	Zhejiang University	48	35	3383	70.48	China
5	Jiangsu University	45	27	2502	55.60	China
6	University of Valencia	45	111	5367	119.27	Spain
7	China Agricultural University	43	47	3923	91.23	China
8	University of Queensland	43	33	4594	106.84	Australia
9	Nanchang University	40	37	3632	90.80	China
10	Universidade Estadual de Campinas	39	40	4017	103.00	Brazil
11	National University of Ireland	37	57	4042	109.24	Ireland
12	Cornell University	34	26	4703	138.32	USA
13	University of Ghent	33	47	5781	175.18	Belgium
14	University of Leeds	32	42	4012	125.38	England
15	Wageningen University	32	33	4646	145.19	Netherlands

Figure 6 shows the network map that links the all keywords to the entire sample of the articles analyzed. Among all 15,257 keywords, 951 keywords met the threshold level of more than seven times included in the map. There are seven main clusters that represent different viewpoints on Food Science and Technology category research (Figure 6). The top twenty co-occurrence keywords were antioxidant activity, in-vitro, antioxidant, food, quality, stability, physicochemical properties, oxidative stress, polyphenols, phenolic-compounds, chitosan, bioactive compounds, extraction, antimicrobial activity, shelf-life, encapsulation, bioavailability, nanoparticles, anthocyanins, functional-properties, listeria-monocytogenes, each keywords occurred more than 88 times.

The same data were then arranged by a period of Food Science and Technology category research as overlay map (Figure 7). Blue colors indicate earlier research topics, whereas, yellow and green colors indicate more recent topics of interest. The blue colored topics do not indicate no longer research work on that topics. It usually indicates that, on average, this topic was intensely investigated earlier and now more attention has shifted towards other topics. Yellow and green circles present those research fronts.

Visualizations conducted on large datasets (big data) offer exploratory information on the current state in a scientific field or discipline as well as indicate possible developments in the future. Here, the top twenty keywords were list and ranked in each cluster based on Figure 6.

The first cluster (Red) is focused on in-vitro antioxidant capacity, and include keywords as in-vitro, antioxidant, oxidative stress, polyphenols, bioavailability, acid, antioxidant capacity, flavonoids, antioxidants, gut microbiota, capacity, inflammation, extracts, metabolism, cancer, nf-kappa-b, extract, health benefits, green tea, inhibition, et al., each keywords occurred more than 32 times.

The second cluster (Green) represents the food stability and physicochemical properties, and include keywords as stability, physicochemical properties, encapsulation, nanoparticles, functional-properties, protein, curcumin, rheological properties, starch, microencapsulation, beta-carotene, impact, microstructure, fabrication, in-water emulsions, oxidative stability, proteins, beta-lactoglobulin, bioaccessibility, pectin, et al., each keywords occurred more than 46 times.

The third cluster (blue) is focused on food quality and food safety, and include keywords as quality, food safety, fruit, performance liquid-chromatography, water, milk, liquid-chromatography, toxicity, color, exposure, mass-spectrometry, volatile compounds, mycotoxins, spectroscopy, tandem mass-spectrometry, food quality, solid-phase extraction, beef, olive oil, quantification, et al., each keywords occurred more than 26 times.

The fourth cluster (yellow) represents variety of the microbiology for different organ food, and keywords include as listeria-monocytogenes, lactic-acid bacteria, escherichia-coli, fruits, growth, fermentation, vegetables, storage, escherichia-coli o157-h7, probiotics, ultrasound, staphylococcus-aureus,

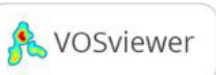
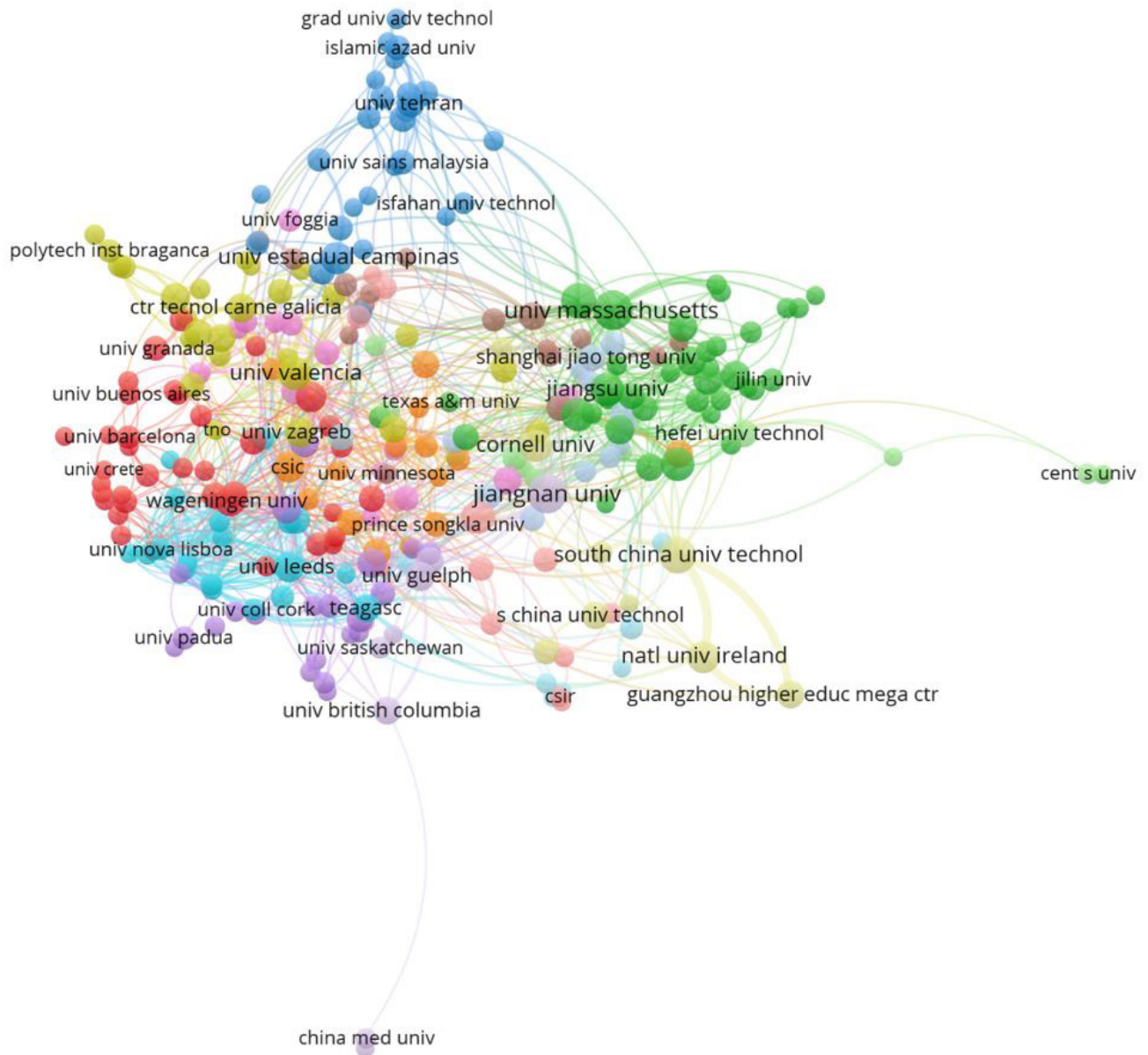


Figure 5. The organizations co-authorship network of Food Science and Technology related publications from 2011 to 2021. The institutions co-authorship network map with 338 nodes and 9 clusters, the bigger nodes represented the more influential institution in this field. The distance and thickness of links represented the degree of cooperation among organizations.

kinetics, high hydrostatic-pressure, ascorbic-acid, lactic acid bacteria, *saccharomyces-cerevisiae*, foodborne pathogens, pulsed electric-fields, functional food, et al., each keywords occurred more than 20 times.

The fifth cluster (violet) is focused on antioxidant activity of phenolic-compounds and bioactive compounds, and include keywords as antioxidant activity, phenolic-compounds, bioactive compounds, extraction, anthocyanins, identification, optimization, phenolic compounds, dietary fiber, purification, temperature,

polysaccharide, polysaccharides, by-products, functional foods, phenolics, antioxidant activities, bioactive peptides, microwave-assisted extraction, nutraceuticals, et al., each keywords occurred more than 32 times.

The sixth cluster (shallow blue) is focused on antimicrobial activity and shelf-life, keywords are ranked as chitosan, antimicrobial activity, shelf-life, chemical-composition, antioxidant properties, lipid oxidation, antibacterial activity, essential oils, mechanical-properties, edible films, physical-properties, essential oil,

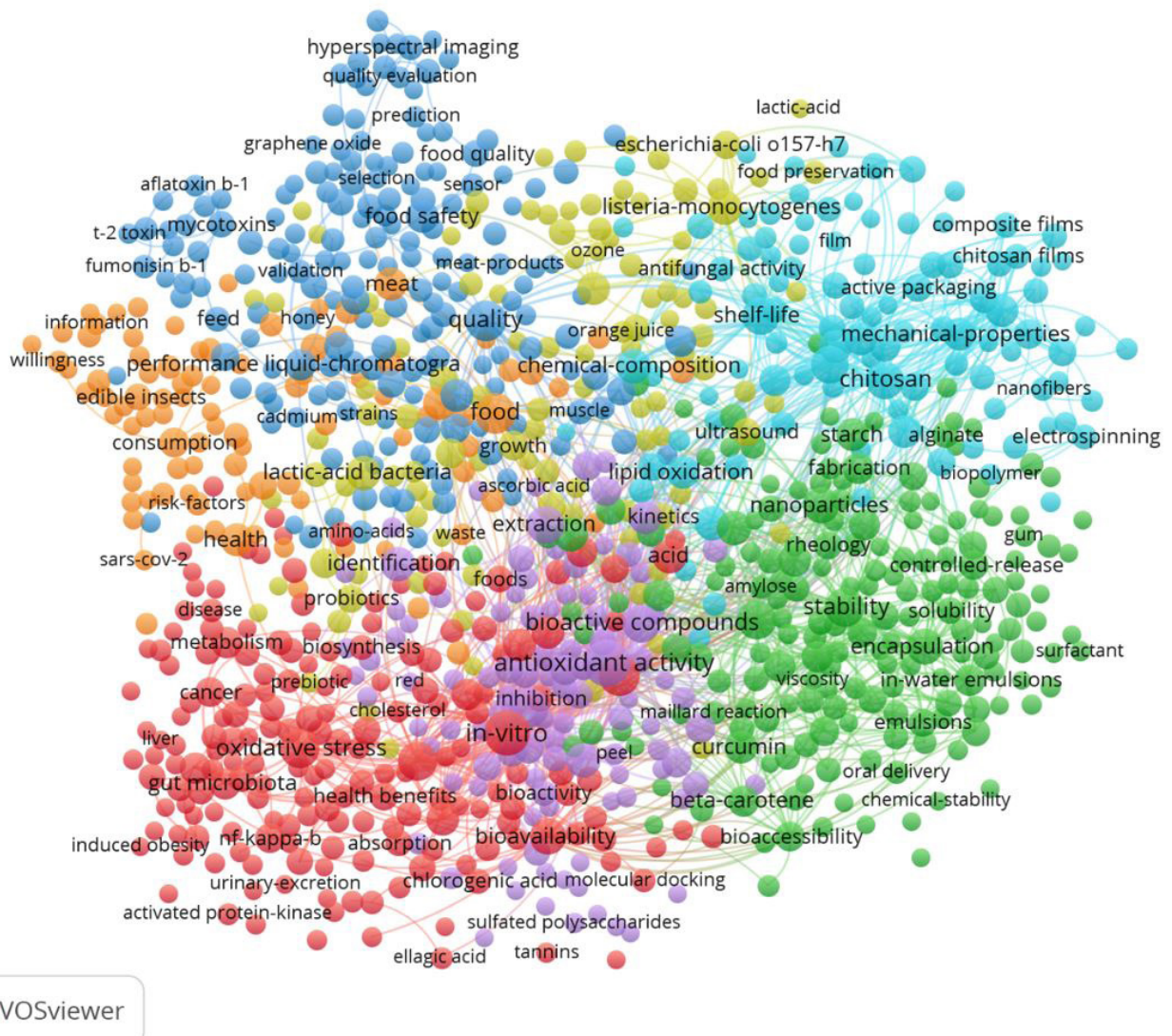


Figure 6. VOSviewer co-occurrence network visualization mapping of most frequent all keywords (minimum of 7 occurrences) in Food Science and Technology. Co-occurrence network of all keywords including author keywords and keywords plus. Of the all 15,257 keywords, there were 951 keywords meet the threshold more than 7 times included in the map. After keywords analysis, there are 7 main clusters that represent 7 different viewpoints on Food Science and Technology.

antibacterial, barrier properties, natural antioxidants, gelatin, release, active packaging, antimicrobial properties, water-vapor permeability, et al., each keywords occurred more than 34 times.

The seventh cluster (orange) is focused on food and health, and keywords are as food, meat, health, products, consumption, nutrition, safety, edible insects, fish, food security, risk assessment, efficacy, nanotechnology, agriculture, model, risk-factors, sustainability, yield, entomophagy, polyunsaturated fatty-acids, et al., each keywords occurred more than 18 times.

3.9 The most frequently cited articles

Citation analysis has been employed as a supplementary index to determine the impact of scientific studies, and to identify studies, researchers and the most renowned institutions

dealing with the theme. Although a great many articles have been published, a relatively small number of individuals account for a large proportion of the citations within the period. The annual citations of the eight papers showed an increasing trend after year of publication (Figure 8).

The most citations eight papers were written by Minekus et al. (2014), Shahidi & Ambigaipalan (2015), Bro & Smilde (2014), Gomez-Guillen et al. (2011), Jeschke et al. (2011), Azmir et al. (2013), Carocho & Ferreira (2013) and Brewer (2011). Here, the total citations for the most frequently cited each paper were 1922, 1018, 966, 895, 892, 891, 813, 792 times, respectively. The time dependence of a single paper is called its history. In the beginning year (zero year here), generally the articles have lower citation because of same year of publication. From the publication year to 2021, the average citation per year of the

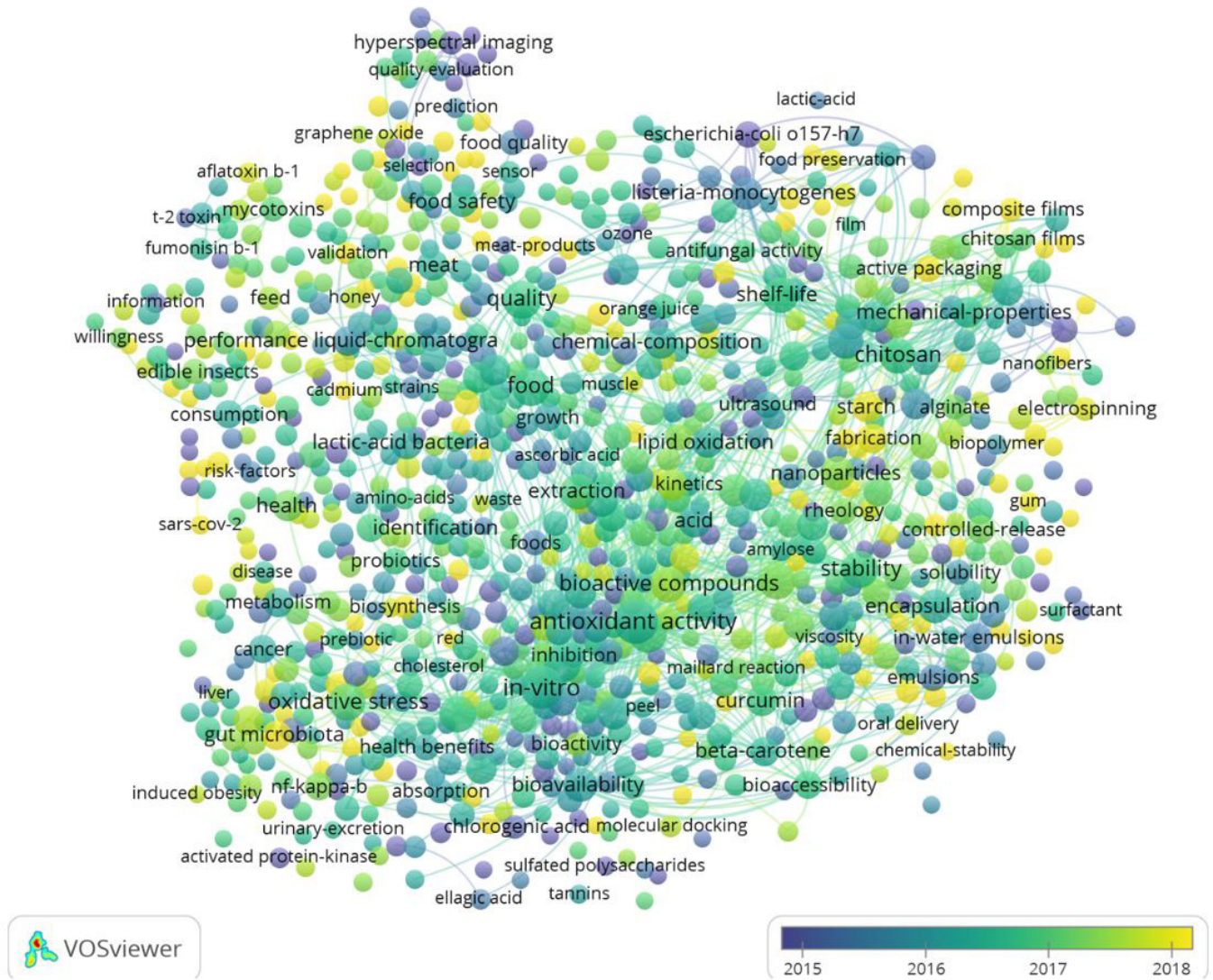


Figure 7. VOSviewer co-occurrence overlay visualization mapping of most frequent all keywords (minimum of 7 occurrences) in Food Science and Technology research from 2011 to 2021.

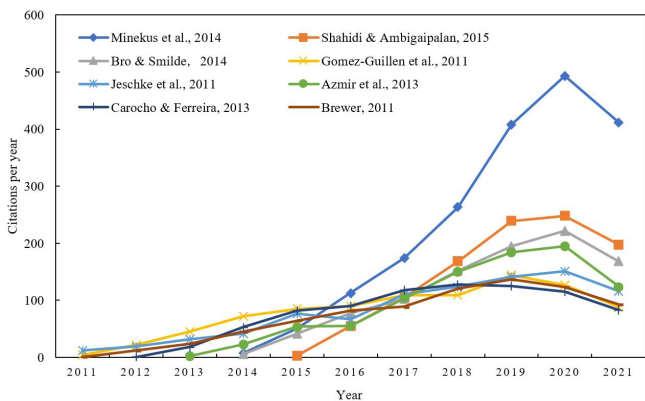


Figure 8. Comparison of the citations per year of the most eight papers from their initial publications to September 9, 2021.

most citation eight papers were 240.25, 145.43, 120.75, 81.36, 81.09, 99, 90.33, 72 times, respectively. From Figure 8, it can be found that the citation per year of the papers increased till to 2020, but the increase rate was different each year. Among eight papers, the highest average citation per year (240.25-blue color) was observed for article of Minekus et al. (2014) published in *Food & Function* (Figure 8).

4 Conclusions

This study analyzed 2,886 top papers in the subject category of Food Science and Technology from January 2011 to June 2021, which include 2,882 highly cited papers and 56 hot papers in the field. All papers written in English, were from 10,698 authors, 2,666 organizations and 115 countries/territories, published in 106 journals and two book series in the field. The top five Journals

are *Food Chemistry, Food Hydrocolloids, Trends in Food Science Technology, Critical Reviews in Food Science and Nutrition* and *Journal of Agricultural and Food Chemistry*. Top six countries and regions were Peoples R China, USA, Spain, Italy, Brazil and India. Top six organizations were Jiangnan University, University of Massachusetts, South China University of Technology, Zhejiang University, Jiangsu University and University of Valencia. The top five authors were McClements David Julian, Sun Da-Wen, Barba Francisco J., Lorenzo Jose M. and Zhang Min. All keywords were separated seven clusters for different research topic. This work is useful for student identifying graduate schools and researchers selecting journals.

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