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BIBLIOMETRIC ANALYSIS OF THE 200 MOST CITED ARTICLES ON ANTIOXIDANT FROM 1976-2020

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ABSTRACT:
Antioxidant helps to reduce various disorders and control pathological conditions such as cancer, aging, cardiovascular disease, cataracts, immune system decline, and brain dysfunction etc. In this study, the top 200 highly cited articles (citations 327,657) with total 647 authors were retrieved from Elsevier's Scopus database (105,440 hits) by the keyword "antioxidant" published across the worldwide for the timespan 1976-2020 years. The data were analysed through bibliometric indicators by using VOSviewer and biblioshiny tools to explore various parameters i.e. keywords co-occurrence, authors contribution, highly cited journals, affiliations/organization engaged and worldwide collaboration. In the year 2001 and 1996, maximum number of articles were published 19 and 17 respectively. In total, 2,312 keywords, most occurrence keyword was polyphenol derivative. Rice-Evans, Prior and Miller were contributed maximum number of articles 9, 8 and 7 respectively. Out of 94, J. Agric Food Chem. was the dominating journal for the study. The higher frequency of collaboration was observed in the USA. This article will confined very prominent and widely covered area on the subject matter on Antioxidant in food science and technology domain. The confined and significant data in this article will definitely useful for research community.

Keywords: Antioxidant; Free Radicals; Reactive Oxygen Species; Bibliometric; VOSviewer; Biblioshiny; Citation Pattern

Introduction

Antioxidant studies are having vital and notable impact in scientific research as most of the diseases are mediated through free radicals and other reactive oxygen species (ROS) that cause oxidative changes to the body cells. Presently antioxidants are directly not only play major role in the human body to reduce oxidative processes and maintain a healthy life but also equally contribute to the food processing industries where they extensively added to many foodstuffs for stabilize food components and preventing spoilage. In human body, antioxidants help to reduce various disorders and control pathological conditions such as cancer, aging, cardiovascular disease, cataracts, immune system decline, and brain dysfunction etc. raised mainly due to formed free radicals as a result of erroneous life style, food habits, pollution, stress, cigarette smoke, UV light, ionizing radiations, and xeno-biotics (Mehta & Gowder, 2015). Antioxidants are substances that neutralize free radicals, slowing down the autoxidation process of essential compounds and alter the biochemical characteristics to support the healthy life. They are generally classified into enzymatic (Superoxide dismutase, catalase, glutathione systems) and non-enzymatic (ascorbic acid, glutathione, melatonin, tocopherols and tocotrienols, uric acid) and are worked through various methods and principles. Numerous *in-vitro* and *in-vivo* antioxidant metabolic studies have investigated via researchers, academician's industrial scientist, policy makers and funding agencies to get rid of various problem associated with foods, dietary supplements, essential oils, pharmaceuticals, medicinal, cosmeceuticals products and other essential commodities.

Research data of antioxidant activities is huge but the same time it has extensively scattered also therefore difficult to get the precise information, which can be utilised further for the supportive research work. Due to day-to-day research finding and data generation through academicians, researchers, industrialists and scientists, it is challenging now to explore existing findings effectively and make available in front of scientific community for sustainable exploitation and current practice. Various bibliometric indicators/tools are the possible auxiliary quantitative exercise, by which enormous data, facts and figures can be replicated, evaluated via methodical/multistep analysis, complemented and represent the precised statistical data in scientific, reliable and systematic manner for its convenient practise (Aria & Cuccurullo, 2017; Broadus, 1987).

Objective of this review article was to be compiled the antioxidant bibliometric data from 45 years and present it in a user friendly way by which it would be assistance to research community and find out the direction for their innovative core research on key word "antioxidant". To the best of our knowledge, very few articles had reported on this direction with very limited metrics database. As this is very vital and widely required topic of research and innovation, so we had collected the antioxidant data from globally accepted larger dataset, analysed with different bibliometric indicators over a span of 45 years and presented in such a way, useful for global readers.

Materials and methods:

The scientific study was mapped according to the standard workflow method as described earlier (Aria & Cuccurullo, 2017; Zupic & Čater, 2015) as follows:

Design of the Study:

As revealed previously that antioxidant study is very immense with their socio-economic impact in day-to-day life, so this had insisted us to focus our studies around the topic “Antioxidants” in the title of research articles. In the design of study, one of the most significant factor known as “time-span of this study” (Kan Yeung et al., 2019) was decided to select over the past 45 years 1976-2020 as most of the research work were addressed and published since 1976.

Sourcing of Data/Data Collection*:*

The Elsevier’s Scopus abstract and citation online database https://www.scopus.com/home.uri was selected as a search tool for this study, by using string TITLE ("antioxidant*") and doctype (ar or re) and pub year < 2022 on January 10, 2021. The keyword antioxidant mentioned in the research and review titles were selected for retrieving the data published in English language only. The comprehensive published literature of 105,440 were retrieved and were shorted by descending order with respect to the highest received citation count. The top 200 highly cited publications concerning above keyword was downloaded in comma-separated values (.csv) file format.

Investigation & data analysis:

To obtain the maximum accuracy in the searched data collection, different bibliometric indicators tools were applied for the further studies. Bibliometrix, an open-source tool for mapping analysis of scientific literature from R statistical package was open in R studio and followed by biblioshiny app. Finally, the shiny app had provided a web interphase http://127.0.0.1:7105 for bibliomatrix tool.

Mapping/Visualization of Data:

The research trends and selected publication features from Scopus file in .csv file format was executed through the shiny app for in-depth bibliometric analysis. Required information was uploaded under the heading “Data” of the above interphase. Selective indicators of matrices e.g. sources, authors, documents, conceptual structures, intellectual structures and social structures were highlighted in this studies. The highly cited 200 publications are presented in the appendix.

Data Interpretation:

All attributes of citation data e.g., author(s), titles, years, source title, cited by, digital object identifier (DOI), affiliations, abstract, keywords and references of documents published from 1976 to 2020 were selected and were exported in .csv format. The maps were created based on bibliographic data by utilizing VOSviewer (http://www.vosviewer.com) and biblioshiny software’s tools e.g. co-authorship, keyword co-occurrences, citations, bibliographic coupling and/or co-citation networks. A holistic approach on top 200 articles on antioxidant studies were designed based on customised requirement. Extensive workflow of the above landscape trends is summarized in Figure 1.

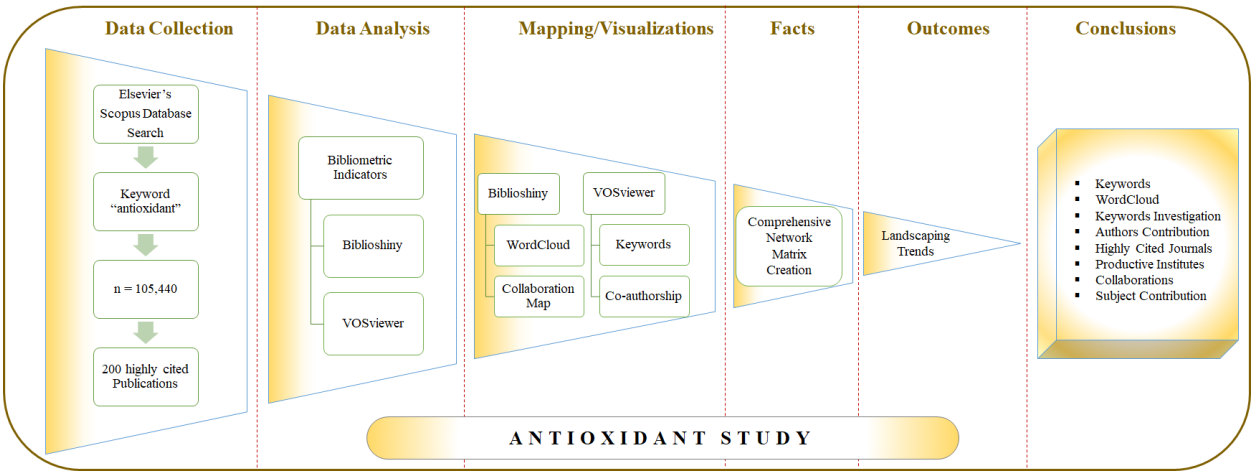

Figure 1: Material and Methods

Results

Bibliometric analysis

Elsevier Scopus database shown total 105,440 hits against the word "antioxidant" for global publications including research and review articles summarized in Table 1. Top 200 highly cited articles with total 647 authors were considered for further analysis. The sources and the corresponding numbers of highly cited articles are presented in the Annexure-1. Most of the articles were have more than one author indicated here as multi-authored articles (>97%), whereas single-authored articles were very less (<3%). Average citation per article (~1638.28) was calculated from total citations (327,657) divided by the number of articles (200). Number of research article per author was found to be 3.23 through total authors (647) dividing by top 200 cited articles. Above calculation was done inversely (200/647) and documents per author was found to be 0.309.

Co-author per article was estimated to the ratio between author appearances and cited articles (200). Average authors per article, average co-authors per article and average number of articles per author suggested that most authors were collaborated with two to three authors. Average number of articles per author is less than one and the number of author appearances is greater than the total number of authors, which shows that some authors have multiple publications. Collaboration index (3.56) was articulated viz total numbers of Authors divided by total numbers of multi-authored articles according to mathematical expression described by Mamdapur (Ghouse et al., 2014). These attributes were indicated strong collaboration between the authors.

Table 1. Holistic representation of global publications on the research keyword "antioxidant" retrieved through window of biblioshiny app.

Description	Counts and rates
Main Information about Data	
Timespan (45 Years)	1976:2020
Sources (Top 200 cited articles from published journals)	94

Articles (Original research Papers/Reviews)	200
Average year from publication	21.4
Average citation per article	1638
Average citations per year per article	78.72
Total References of most-cited 200 articles	16064
Articles	
Article	134
Review	66
Article Contents	
Keywords Plus; Identification (ID)	2312
Author's Keywords; Description (DE)	444
Authors	
Authors	647
Author Appearances	763
Authors of single-authored articles	16
Authors of multi-authored articles	631
Authors Collaboration	
Individual article	23
Article per author	0.309
Authors per article	3.23
Co-Authors per article	3.81
Collaboration Index (CI)	3.56

Citation summary:

Citation pattern are illustrated in Figure 2 (A & B). Citation point of view, articles published in 1996 (total number 17) were received maximum number of citations (34,945). In the year 1999, the articles (total number 8) were received second highest citations (34,623), followed by 23,714 citations received by the 15 numbers of articles, which were published in the year 2002. Single articles that received higher citations were published in a numbers of year's e.g. 1976, 1980, 1985, 2011 and 2013. In the top citation list, an article published in the year 1976 was received a minimum numbers of citations (752).

Number of publication point of view, a maximum number of 19 articles were published in the year 2001, however their total citations were less (20,347; on an average per article 1071) as compared to articles published in 1996, where they received the highest citations (on an average 2056 per article). The number of 15 articles published in the year 2002 were received on an average of 1581 citation per article. Year 1996 and 2002 were followed the rising contribution pattern where the published articles and the citations, both were very high (34945; 17 articles and 23714; 15 articles) respectively as compared to year 1999 and 2001. During the year 1999, articles citations were

second highest however, the number of published article were eight only whereas in year 2001, total citations were less but number of published article were the highest (19).

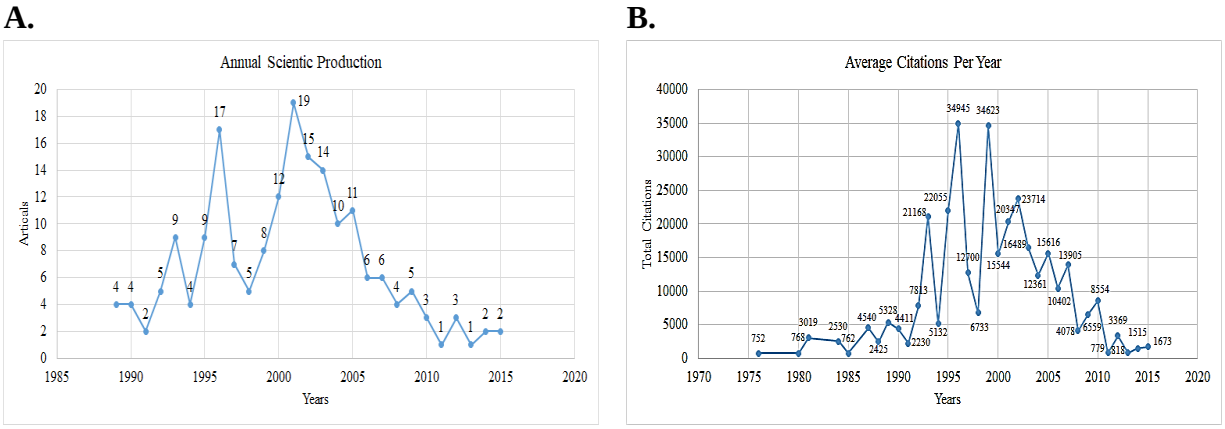

Figure 2: (A). Annual scientific production of articles; (B). Average citation per year

Keywords:

WordCloud:

WordCloud of keywords were developed to understand the difference between Keywords Plus and author's keyword, which are presented in Figure 3. (A).

Keywords investigation:

Keywords Plus of the articles contains words or phrases contained in the titles of an article's references but not in the title of the article itself. Keywords Plus is as effective as author's keywords in investigating the knowledge structure of scientific fields, although it is less comprehensive in representing an article's content (Tijssen & Van Raan, 1994)

The keywords, which are used profoundly by the scientific community in the various disciplinary was selected as a study tool for the in-depth analysis of subject area on antioxidant. In this study, total 2,312 keywords were investigated with minimum occurrence 1. The top 200 keywords, which had maximum strength were selected for the further analysis through VOSviewer tool (van Eck & Waltman, 2010). These keywords were grouped into five clusters to get the knowledge about the keywords co-occurrence in Figure 3. (B). Red coloured cluster 1 was having total 67 (34%) keywords; "*polyphenol derivative*" was the dominated keyword, which had relationship between the occurrences of 133 links (L); total link strength (TLS), which attributes the links of an item associated with other items was the 539. The same pattern was also found for the next two keywords as "*flavonoid*" (L-128; TLS-564) and "*phenol*" (L-125; TLS-439). Green colourd cluster 2 was having total 44 (22%) keywords; "*oxidative stress*" was having L-126; TLS-713 followed by "*reactive oxygen species*" L-121; TLS-500 and "*reactive oxygen metabolite*" L-112; TLS-493. Blue coloured cluster 3 was having total 36 (18%) keywords; "*ascorbic acid*" was having L-143; TLS-818 followed by "*α-tocopherol*" L-135; TLS-719 and "*free radicals*" L-137; TLS-572. Yellow coloured cluster 4 was having total 28 (14%) keywords; "*antioxidant activity*" was having L-142; TLS-1048 followed by "*oxidation-reduction*" L-121; TLS-406 and "*plant extract*" L-90; TLS-282. Purple coloured cluster 5 was having total 25 (13%) keywords; "*antioxidant*" was

having L-154; TLS-1609 followed by "*antioxidants*" L-154; TLS-1415 and "*controlled study*" L-115; TLS-350.

A. **B.**

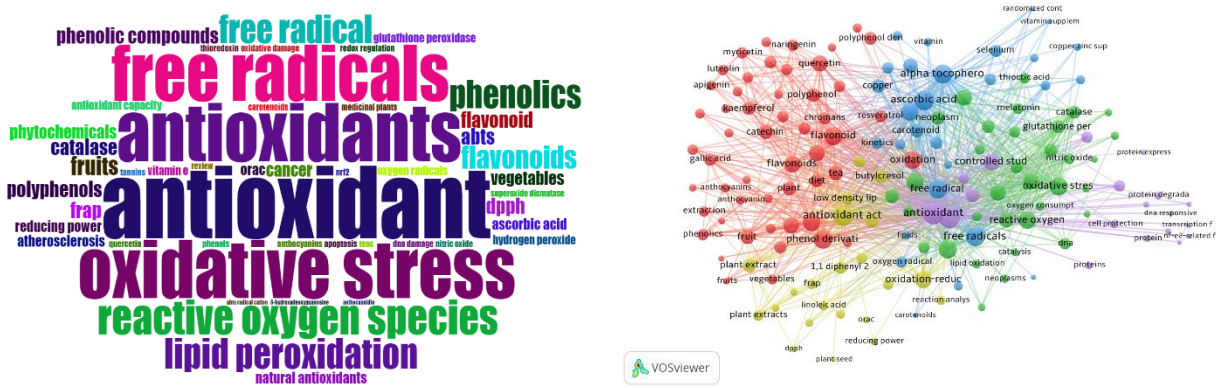

Figure 3.(A): WordCloud of the keywords by using biblioshiny app.; **Figure 3.(B):** Network representing the relationship among the top 200 keywords. Analyses based on the Elsevier's Scopus citation database from 1976 to 2020. An artwork generated by VOSviewer tool. Cluster 1 Red colour; cluster 2 Green colour; cluster 3 Blue colour; cluster 4 Yellow colour and cluster 5 Purple colour.

Above all clusters, cluster 5 had highest links contributing to *"antioxidant"* and *"antioxidants"* 154 each and highest total link strength had *"antioxidant"* and *"antioxidants"* 1609 and 1415 respectively.

Authors contribution:

To study the individual contribution factor, total number of 647 authors, their publication and respective citations (327,657) were analysed by using VOSviewer tool. Figure 4 represents the network map of prominent authors based on their citations values and Total Link Strength (TLS). Figure shows Rice-Evans C.A. leading the top citations (31,300; TLS-34) followed by Miller N.J. (16,536; TLS 22) and Prior R.L. (14,655; TLS-34). Pellegrini N. (14,327; TLS-11) followed by Benzie I.F.F. and Strain J.J. (13,964; TLS-2 each) and Pannala A.; Proteggente A.; Re R. and Yang M. (13,284; TLS-5 each).

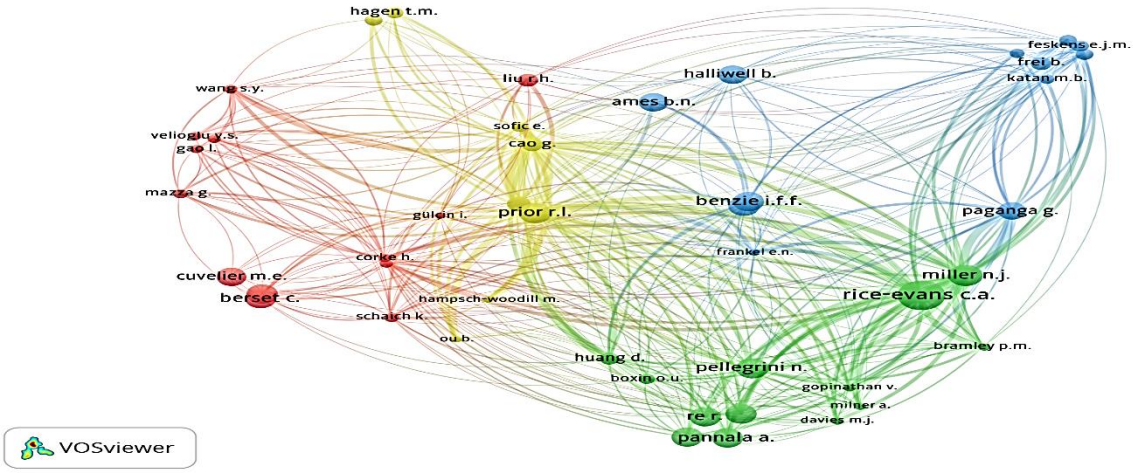

Figure 4: Represent network map of prominent authors based on their citations values and Total link strength.

Further, co-authorship visualization were also investigated, who published more number of the articles (Figure 5). It was noticed that author Rice-Evans C.A. and Halliwell B. contributed the most numbers of articles 9 each with TLS-34 and TLS-6 respectively in a period of 1989 to 2006 followed by Prior R.L. contributed the second highest number of eight articles (with TLS-34) during 1996 to 2005. Co-authorship visualization pattern was clearly indicated that authors Prior R.L. strongly collaborated with the authors Cao G., Sofic E., Huang D. and Wu X. It was also observed that although Rice-Evans C.A. and Halliwell B. have the highest numbers of articles in compared to other authors, their co-authorship network were constraint and therefore unable to visualize in co-authorship pattern.

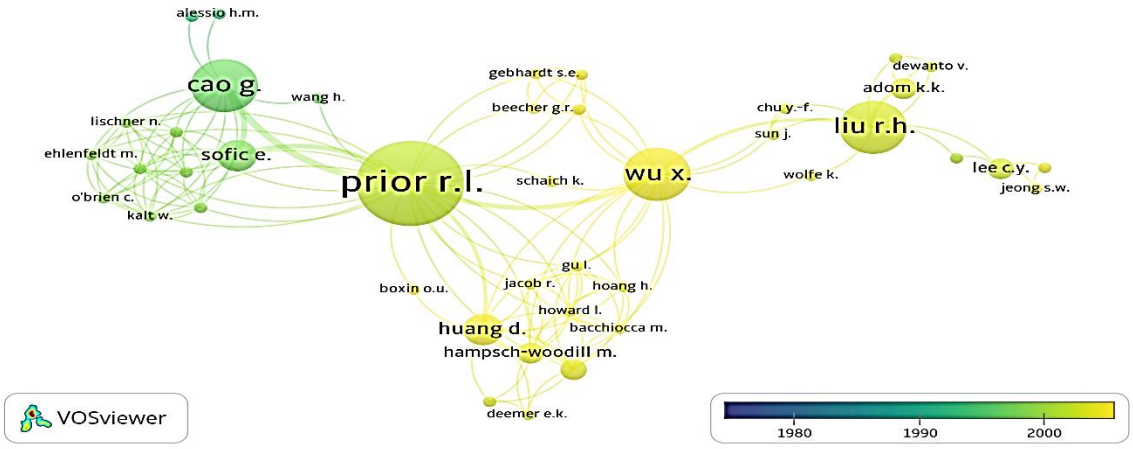

Figure 5: Co-authorship network of articles based on their publications.

Highly cited journals:

In our data analysis, we found that 200 most cited articles were published in the 94 global recognised impact journals. Out of 94, only top 10 journals were selected for the graphical illustration (Figure 6).

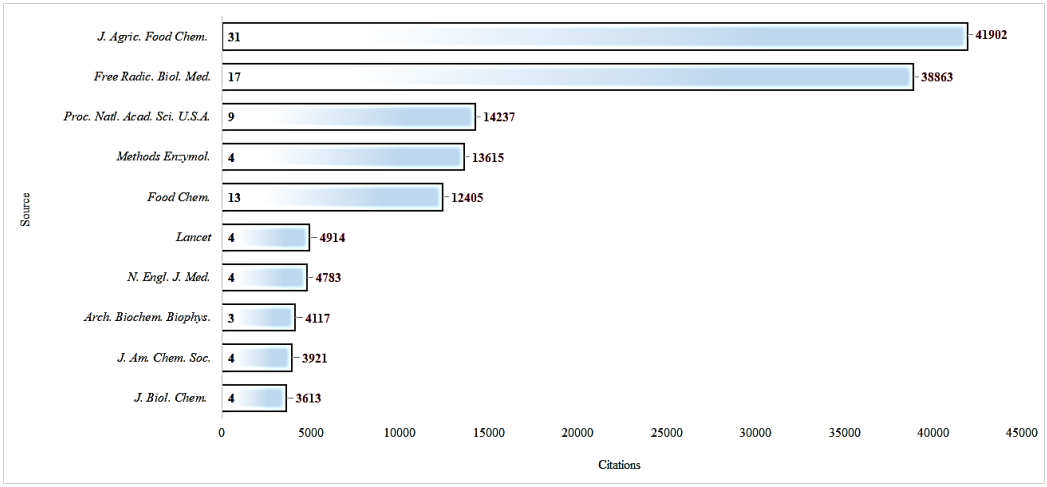

Figure 6: Most relevant top 10 journals about antioxidant research articles

Maximum number of articles (31), which all-together having highest citation (41,902) were published in the *J. Agric Food Chem.* where total contribution factor was 32.98%. *Free Radic. Biol. Med.* was the second highest cited (38,863) journal, which published total 17 articles (contributed 18.09%) followed by *Proc. Natl. Acad. Sci. U.S.A.*, where 9 articles (contributed 9.57%) received the total citation 14,237 times. *Methods Enzymol., Food chem., Lancet, N. Engl. J. Med., Arch. Biochem. Biophys., J. Am. Chem. Soc. and J. Biol. Chem.* are the journals out of all 94, which get maximum number of citations as compared to other journal.

Affiliations/organization engaged:

In all, 216 most relevant affiliations were contributed scientific research on the topic "antioxidant". Out of them, 196 organizations were published 1-5 articles each followed by 15 organizations contributed 6-10 articles and top 5 organizations contributed 11-20 articles each. Among top 20 organizations, 11 (55%) were from the USA, 2 (10%) were from Japan whereas other countries i.e. Canada, Finland, Hong Kong, Italy, Netherlands, Norway and UK were contributed one article each. The affiliations, which were engaged to the contribution for highly productivity research work and data generation, are depicted in Figure 7.

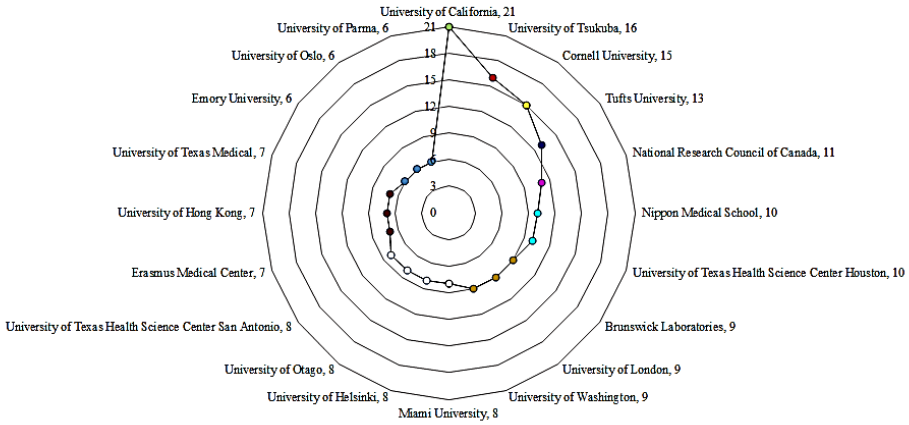

Figure 7: Most significant and highly productivity research universities/institutes contributing to antioxidant.

Collaboration (Worldwide):

The research scholars, academicians, scientists, and subject experts work together for synergies their research knowledge and quality findings, visibility of their publications, and improve the professional prestige together with socio-economic benefits under a common platform. Figure 8 indicates the country wise collaboration (represented through the blue colour) throughout the world map. The higher frequency of collaboration was observed in the USA (dark blue colour) with respect to other active countries like Canada, China, Germany, and United Kingdom followed by the countries that vigorously collaborated with other countries are France, New Zealand, Austria, Malaysia, Italy and India. The map indicates 32 countries were actively engaged in publishing research on the topic "*Antioxidant*" by their collaboration to increase the amount of publications as compared to single country.

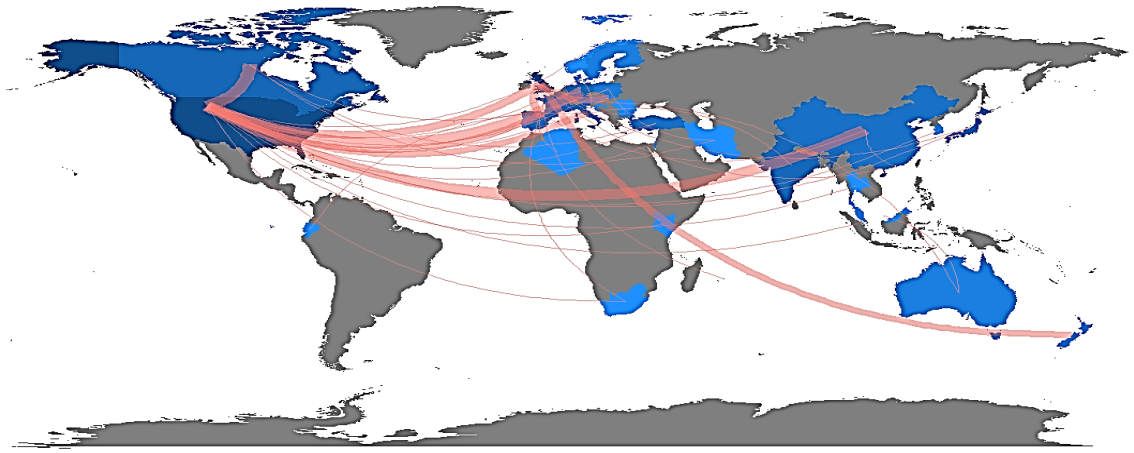

Figure 8: Network map of collaboration among countries resulted from top 200 highly cited articles.

Phytoconstituents in the high citated articles were broadly category included mainly Amino Acids and Peptides; Vitamins, Mineral-Selenium, Alkaloid; Phenolic acids; Anthocyanins; Tannic acid & Ellagitannin; Flavan-3-ols; Flavanones; Flavonols; Curcuminoids; Carotenoids; Essential Oil and Fatty Acids (Figure 9).

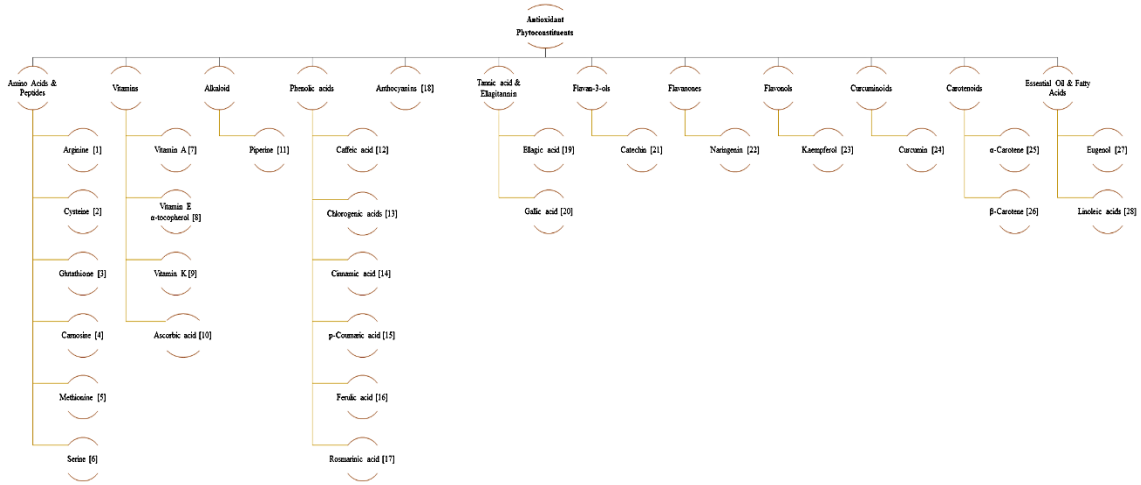

Figure 9: Classification of antioxidants.

Discussion

To assist the research community and to find out the direction of innovative core research relevant to antioxidant, current study explored Elsevier Scopus database, with total number of 105,440 hits for the keyword “antioxidant” considering research and review articles. This study has provided a quantitative and qualitative explanation of worldwide research with top 200 highly cited articles (327,657) on “antioxidant” with compressed timespan 1976-2020. The data were analysed through bibliometric indicators by using VOSviewer and biblioshiny tools to explore various parameters i.e. keywords co-occurrence, authors contribution, highly cited journals, affiliations/organization engaged and worldwide collaboration. In the year 2001 and 1996, maximum number of articles on the topic antioxidant were published 19 and 17 respectively. In total, 2,312 keywords, most occurrence keywords were polyphenol derivative and flavonoids. Rice-Evans, Prior and Miller

were contributed maximum number of articles 9, 8 and 7 respectively about the antioxidant activities with significant research and outcomes. Their novel method for measuring antioxidant capacity over body fluids and drug solutions in premature neonates were contributed to understand that the antioxidant supplementation is very much needed to preterm babies from birth. Further, studies were mainly focused on plant-derived polyphenolic flavonoids in the aqueous and lipophilic phases subsequently with carotenes and xanthophylls. In the succeeding years, the general principles on antioxidant activities with the body fluids analysis, TEAC assay and cell signaling pathway, that influence the metabolism were also evaluated and published in various journals (Miller et al., 1993, 1996; Re et al., 1999; C. A. Rice-Evans et al., 1996, 1997; Rice-evans et al., 1995; C. Rice-Evans & Miller, 1994; Salah et al., 1995; Williams et al., 2004). Another author Ronald L. Prior (8 articles) was also contributed his research which was highly cited in the field of antioxidant with the specified subject on "green tea and black tea". The antioxidant activities were analysed against peroxyl radicals and found that both tea's have much higher antioxidant activities as compared to selective 22 common vegetables. In another studies on 15 fruits, it was found that grape juice was having the highest oxygen radical absorbance capacity (ORAC) activity. Similar assay was used to determine the antioxidant and prooxidant properties of flavonoids Structure-Activity Relationships. One of the publication was dedicated on three standardized metheds relevant antioxidant studies i.e. ORAC, the Folin-Ciocalteu method, and TEAC assays. His multidimensional contribution on antioxidants studies i.e. basic kinetic models and chemical principles of antioxidant capacity assays were published in impact journals (Cao et al., 1996, 1997; Huang et al., 2005; Prior et al., 1998, 2003, 2005; Wang et al., 1996; Wu et al., 2004). Co-authorship visualization pattern is more noticeable and strong for Prior R.L. when compared to the other authors. Total 216 affiliations were dominated in the Antioxidant research and data generation. J. Agric Food Chem. is the dominating one out of 94 journals, where maximum number of articles (31) were published with total citations (41,902). Total 32 countries were actively engaged, where higher frequency of collaboration was observed with the USA. This article confined very prominent and widely covered area on the subject matter on antioxidant in food science and technology domain. The above data useful to the research community to under which country, journal and affiliations were worked in the relevant areas and some data they can utilize for their research work.

Conclusion

The phytoconstituents and herbal medicines have remarkable antioxidants properties, which have been explored since decades. The antioxidants fight against free radicals, oxidative stresses, and various vulnerable deceases due to lifestyle and daily activities and benefits for humankind. This study confined very prominent and widely covered area i.e. keywords co-occurrence, authors contribution, highly cited journals, affiliations/organization engaged and worldwide collaboration to understand how the antioxidant research work was done in the past and which are the domain needs to be focused by scientific community by bridging the gap to enlighten the futuristic outcomes. The confined and significant data of this study definitely will be useful to day-to-day research work by the academicians, researchers, industrialists and scientists. These comprehensive

data, fact and figures can be explored for futuristic methodical/multistep analysis and systematic research with the convenient practises.

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Conflict of Interest
The authors declare no conflict of interest, financial or otherwise.

Author Contributions
Neelesh Kumar Nema- Conceptualization, Methodology, and Writing-original draft; Ghouse Modin N. Mamdapur- Statistical data support, Investigation and analysed the data; Baby Kumaranthara Chacko- Project visualization, Jose Paul-Supervision;

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Annexure-1. List of highly cited 200 articles

Sl No.	Authors	Year	Title	Source title	Citation
1	Re R. et al.,	1999	Antioxidant activity applying an improved ABTS radical cation decolorization assay	Free Radical Biology and Medicine	13284
2	Brand Williams W. et al.,	1995	Use of a free radical method to evaluate antioxidant activity	LWT - Food Science and Technology	12379
3	Benzie I.F.F. & Strain J.J.	1996	The ferric reducing ability of plasma (FRAP) as a measure of 'antioxidant power': The FRAP assay	Analytical Biochemistry	11817
4	Singleton V.L. et al.,	1999	Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent	Methods in Enzymology	9113
5	Valko M. et al.,	2007	Free radicals and antioxidants in normal physiological functions and human disease	International Journal of Biochemistry and Cell Biology	8313
6	Rice Evans C.A. et al.,	1996	Structure-antioxidant activity relationships of flavonoids and phenolic acids	Free Radical Biology and Medicine	6789
7	Mittler R.	2002	Oxidative stress, antioxidants and stress tolerance	Trends in Plant Science	6424
8	Ames B.N. et al.,	1993	Oxidants, antioxidants, and the degenerative diseases of aging	Proceedings of the National Academy of Sciences of the United States of America	5132
9	Gill S.S. & Tuteja N.	2010	Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants	Plant Physiology and Biochemistry	4880
10	Valko M. et al.,	2006	Free radicals, metals and antioxidants in oxidative stress-induced cancer	Chemico-Biological Interactions	4081
11	Huang D. et al.,	2005	The chemistry behind antioxidant capacity assays	Journal of Agricultural and Food Chemistry	3773
12	Hertog M.G.L. et al.,	1993	Dietary antioxidant flavonoids and risk of coronary heart disease: the Zutphen Elderly Study	The Lancet	3748
13	Hockenbery D.M. et al.,	1993	Bcl-2 functions in an antioxidant pathway to prevent apoptosis	Cell	3202
14	Prior R.L. et al.,	2005	Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements	Journal of Agricultural and Food Chemistry	3175
15	Pietta P.G.	2000	Flavonoids as antioxidants	Journal of Natural Products	3093
16	Rice Evans C.A. et al.,	1997	Antioxidant properties of phenolic compounds	Trends in Plant Science	2949
17	Prieto P. et al.,	1999	Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: Specific application to the determination of vitamin E	Analytical Biochemistry	2938
18	Itoh K. et al.,	1997	An Nrf2/small Maf heterodimer mediates the induction of phase II detoxifying enzyme genes through antioxidant response elements	Biochemical and Biophysical Research Communications	2742
19	Stocker R. et al.,	1987	Bilirubin is an antioxidant of possible physiological importance	Science	2682

20	Kähkönen M.P. et al.,	1999	Antioxidant activity of plant extracts containing phenolic compounds	Journal of Agricultural and Food Chemistry	2583
21	Velioglu Y.S. et al.,	1998	Antioxidant Activity and Total Phenolics in Selected Fruits, Vegetables, and Grain Products	Journal of Agricultural and Food Chemistry	2569
22	Blokhina O. et al.,	2003	Antioxidants, oxidative damage and oxygen deprivation stress: A review	Annals of Botany	2524
23	Heim K.E. et al.,	2002	Flavonoid antioxidants: Chemistry, metabolism and structure-activity relationships	Journal of Nutritional Biochemistry	2516
24	Halliwell B.	1994	Free radicals, antioxidants, and human disease: curiosity, cause, or consequence?	The Lancet	2398
25	Itoh K. et al.,	1999	Keap1 represses nuclear activation of antioxidant responsive elements by Nrf2 through binding to the amino-terminal Neh2 domain	Genes and Development	2344
26	Miller N.J. et al.,	1993	A novel method for measuring antioxidant capacity and its application to monitoring the antioxidant status in premature neonates	Clinical Science	2333
27	Benzie I.F.F. & Strain J.J.	1999	Ferric reducing/antioxidant power assay: Direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic acid concentration	Methods in Enzymology	2147
28	Sies H.	1997	Oxidative stress: Oxidants and antioxidants	Experimental Physiology	2088
29	Esterbauer H. et al.,	1992	The role of lipid peroxidation and antioxidants in oxidative modification of LDL	Free Radical Biology and Medicine	2075
30	Ames B.N. et al.,	1981	Uric acid provides an antioxidant defense in humans against oxidant- and radical-caused aging and cancer: A hypothesis	Proceedings of the National Academy of Sciences of the United States of America	2061
31	Halliwell B. et al.,	1992	Free radicals, antioxidants, and human disease: Where are we now?	The Journal of Laboratory and Clinical Medicine	2039
32	Maritim A.C. et al.,	2003	Diabetes, oxidative stress, and antioxidants: A review	Journal of Biochemical and Molecular Toxicology	2030
33	Cao G. et al.,	1997	Antioxidant and prooxidant behavior of flavonoids: Structure-activity relationships	Free Radical Biology and Medicine	1982
34	Velikova V. et al.,	2000	Oxidative stress and some antioxidant systems in acid rain-treated bean plants protective role of exogenous polyamines	Plant Science	1974
35	Shahidi F. et al.,	1992	Phenolic Antioxidants	Critical Reviews in Food Science and Nutrition	1966
36	Pandey K.B. & Rizvi S.I.	2009	Plant polyphenols as dietary antioxidants in human health and disease	Oxidative Medicine and Cellular Longevity	1932
37	Nordberg J. & Arnér E.S.J.	2001	Reactive oxygen species, antioxidants, and the mammalian thioredoxin system	Free Radical Biology and Medicine	1923
38	Stephens N.G. et al.,	1996	Randomised controlled trial of vitamin E in patients with coronary disease: Cambridge Heart Antioxidant Study (CHAOS)	Lancet	1906
39	Dewanto V. et al.,	2002	Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity	Journal of Agricultural and Food Chemistry	1901
40	Buettner G.R.	1993	The Pecking Order of Free Radicals and Antioxidants: Lipid Peroxidation, ?-Tocopherol, and Ascorbate	Archives of Biochemistry and Biophysics	1880
41	Dai J. & Mumper R.J.	2010	Plant phenolics: Extraction, analysis and their antioxidant and anticancer properties	Molecules	1874
42	Uttara B. et al.,	2009	Oxidative stress and neurodegenerative diseases: A review of upstream and downstream antioxidant therapeutic options	Current Neuropharmacology	1855
43	Yen G.-C. & Chen H.-Y.	1995	Antioxidant Activity of Various Tea Extracts in Relation to Their Antimutagenicity	Journal of Agricultural and Food Chemistry	1818
44	Lobo V. et al.,	2010	Free radicals, antioxidants and functional foods: Impact on human health	Pharmacognosy Reviews	1800
45	Birben E. et al.,	2012	Oxidative stress and antioxidant defense	World Allergy Organization Journal	1788

46	Cai Y. et al.,	2004	Antioxidant activity and phenolic compounds of 112 traditional Chinese medicinal plants associated with anticancer	Life Sciences	1774
47	Zheng W. & Wang S.Y.	2001	Antioxidant activity and phenolic compounds in selected herbs	Journal of Agricultural and Food Chemistry	1758
48	Burton G.W. & Ingold K.U.	1984	?-Carotene: An unusual type of lipid antioxidant	Science	1756
49	Balasundram N. et al.,	2006	Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses	Food Chemistry	1729
50	Foyer C.H. & Noctor G.	2005	Redox homeostasis and antioxidant signaling: A metabolic interface between stress perception and physiological responses	Plant Cell	1729
51	Brown B.G. et al.,	2001	Simvastatin and niacin, antioxidant vitamins, or the combination for the prevention of coronary disease	New England Journal of Medicine	1725
52	Sen C.K. & Packer L.	1996	Antioxidant and redox regulation of gene transcription	FASEB Journal	1725
53	Fang Y.-Z. et al.,	2002	Free radicals, antioxidants, and nutrition	Nutrition	1718
54	Rice-evans C.A. et al.,	1995	The relative antioxidant activities of plant-derived polyphenolic flavonoids	Free Radical Research	1707
55	Thaipong K. et al.,	2006	Comparison of ABTS, DPPH, FRAP, and ORAC assays for estimating antioxidant activity from guava fruit extracts	Journal of Food Composition and Analysis	1675
56	Bjelakovic G. et al.,	2007	Mortality in randomized trials of antioxidant supplements for primary and secondary prevention: Systematic review and meta-analysis	Journal of the American Medical Association	1668
57	Frei B. et al.,	1989	Ascorbate is an outstanding antioxidant in human blood plasma	Proceedings of the National Academy of Sciences of the United States of America	1617
58	Packer L. et al.,	1995	Alpha-lipoic acid as a biological antioxidant	Free Radical Biology and Medicine	1577
59	Gil M.I. et al.,	2000	Antioxidant activity of pomegranate juice and its relationship with phenolic composition and processing	Journal of Agricultural and Food Chemistry	1541
60	Erel O.	2004	A novel automated direct measurement method for total antioxidant capacity using a new generation, more stable ABTS radical cation	Clinical Biochemistry	1522
61	Aruoma O.I. et al.,	1989	The antioxidant action of N-acetylcysteine: Its reaction with hydrogen peroxide, hydroxyl radical, superoxide, and hypochlorous acid	Free Radical Biology and Medicine	1510
62	Williams R.J. et al.,	2004	Flavonoids: Antioxidants or signalling molecules?	Free Radical Biology and Medicine	1480
63	Kohen R. & Nyska A.	2002	Oxidation of biological systems: Oxidative stress phenomena, antioxidants, redox reactions, and methods for their quantification	Toxicologic Pathology	1480
64	SIES H.	1993	Strategies of antioxidant defense	European Journal of Biochemistry	1478
65	Bors W. et al.,	1990	Flavonoids as antioxidants: Determination of radical-scavenging efficiencies	Methods in Enzymology	1478
66	Matés J.M. et al.,	1999	Antioxidant enzymes and human diseases	Clinical Biochemistry	1435
67	Ruch R.J. et al.,	1989	Prevention of cytotoxicity and inhibition of intercellular communication by antioxidant catechins isolated from chinese green tea	Carcinogenesis	1426
68	Wang H. et al.,	1996	Total antioxidant capacity of fruits	Journal of Agricultural and Food Chemistry	1364
69	Larson R.A.	1988	The antioxidants of higher plants	Phytochemistry	1351
70	Halliwell B.	1996	Antioxidants in human health and disease	Annual Review of Nutrition	1342
71	Kamal-Eldin A. &	1996	The chemistry and antioxidant properties of tocopherols and tocotrienols	Lipids	1332

	Appelqvist L.-Å.				
72	Wu X. et al.,	2004	Lipophilic and hydrophilic antioxidant capacities of common foods in the United States	Journal of Agricultural and Food Chemistry	1312
73	Higdon J.V. & Frei B.	2003	Tea Catechins and Polyphenols: Health Effects, Metabolism, and Antioxidant Functions	Critical Reviews in Food Science and Nutrition	1304
74	Pulido R. et al.,	2000	Antioxidant activity of dietary polyphenols as determined by a modified ferric reducing/antioxidant power assay	Journal of Agricultural and Food Chemistry	1260
75	Burits M. & Bucar F.	2000	Antioxidant activity of Nigella sativa essential oil	Phytotherapy Research	1249
76	Collins R. et al.,	2002	MRC/BHF Heart Protection Study of antioxidant vitamin supplementation in 20 536 high-risk individuals: A randomised placebo-controlled trial	Lancet	1238
77	Meyer M. et al.,	1993	H2O2 and antioxidants have opposite effects on activation of NF-?B and AP-1 in intact cells: AP-1 as secondary antioxidant-responsive factor	EMBO Journal	1238
78	Reddy A.R. et al.,	2004	Drought-induced responses of photosynthesis and antioxidant metabolism in higher plants	Journal of Plant Physiology	1222
79	Halliwell B.	2006	Reactive species and antioxidants. Redox biology is a fundamental theme of aerobic life	Plant Physiology	1220
80	Pham-Huy L.A. et al.,	2008	Free radicals, antioxidants in disease and health	International Journal of Biomedical Science	1217
81	Cao G. et al.,	1993	Oxygen-radical absorbance capacity assay for antioxidants	Free Radical Biology and Medicine	1216
82	Moure A. et al.,	2001	Natural antioxidants from residual sources	Food Chemistry	1208
83	Diaz M.N. et al.,	1997	Antioxidants and atherosclerotic heart disease	New England Journal of Medicine	1207
84	Gaetke L.M. & Chow C.K.	2003	Copper toxicity, oxidative stress, and antioxidant nutrients	Toxicology	1196
85	Rushmore T.H. et al.,	1991	The antioxidant responsive element: Activation by oxidative stress and identification of the DNA consensus sequence required for functional activity	Journal of Biological Chemistry	1193
86	Apak R. et al.,	2004	Novel total antioxidant capacity index for dietary polyphenols and vitamins C and E, using their cupric ion reducing capability in the presence of neocuproine: CUPRAC method	Journal of Agricultural and Food Chemistry	1191
87	Foyer C.H. & Noctor G.	2005	Oxidant and antioxidant signalling in plants: A re-evaluation of the concept of oxidative stress in a physiological context	Plant, Cell and Environment	1190
88	Sun J. et al.,	2002	Antioxidant and antiproliferative activities of common fruits	Journal of Agricultural and Food Chemistry	1190
89	Ohsawa I. et al.,	2007	Hydrogen acts as a therapeutic antioxidant by selectively reducing cytotoxic oxygen radicals	Nature Medicine	1187
90	Devasagayam T.P.A. et al.,	2004	Free radicals and antioxidants in human health: Current status and future prospects	Journal of Association of Physicians of India	1174
91	Koleva I.I. et al.,	2002	Screening of plant extracts for antioxidant activity: A comparative study on three testing methods	Phytochemical Analysis	1164
92	Wright J.S. et al.,	2001	Predicting the activity of phenolic antioxidants: Theoretical method, analysis of substituent effects, and application to major families of antioxidants	Journal of the American Chemical Society	1157
93	Ho K.-Y. et al.,	2001	Screening of Brazilian plant extracts for antioxidant activity by the use of DPPH free radical method	Phytotherapy Research	1156
94	Halliwell B. & Gutteridge J.M.C.	1990	The antioxidants of human extracellular fluids	Archives of Biochemistry and Biophysics	1135
95	Halliwell B.	2001	Role of free radicals in the neurodegenerative diseases: Therapeutic implications for antioxidant treatment	Drugs and Aging	1125
96	Adom K.K. & Liu R.H.	2002	Antioxidant activity of grains	Journal of Agricultural and Food Chemistry	1124

97	Aruoma O.I.	1998	Free radicals, oxidative stress, and antioxidants in human health and disease	JAOCS, Journal of the American Oil Chemists' Society	1121
98	Young I.S. & Woodside J.V.	2001	Antioxidants in health and disease	Journal of Clinical Pathology	1115
99	Wojdy?o A. et al.,	2007	Antioxidant activity and phenolic compounds in 32 selected herbs	Food Chemistry	1105
100	Salah N. et al.,	1995	Polyphenolic flavanols as scavengers of aqueous phase radicals and as chain-breaking antioxidants	Archives of Biochemistry and Biophysics	1102
101	Boots A.W. et al.,	2008	Health effects of quercetin: From antioxidant to nutraceutical	European Journal of Pharmacology	1097
102	Van Acker S.A.B.E. et al.,	1996	Structural aspects of antioxidant activity of flavonoids	Free Radical Biology and Medicine	1093
103	Frei B. et al.,	1988	Antioxidant defenses and lipid peroxidation in human blood plasma	Proceedings of the National Academy of Sciences of the United States of America	1074
104	Anderson T.J. et al.,	1995	The effect of cholesterol-lowering and antioxidant therapy on endothelium-dependent coronary vasomotion	New England Journal of Medicine	1048
105	Prior R.L. et al.,	2003	Assays for hydrophilic and lipophilic antioxidant capacity (oxygen radical absorbance capacity (ORACFL)) of plasma and other biological and food samples	Journal of Agricultural and Food Chemistry	1047
106	Wolfe K. et al.,	2003	Antioxidant activity of apple peels	Journal of Agricultural and Food Chemistry	1046
107	Erel O.	2004	A novel automated method to measure total antioxidant response against potent free radical reactions	Clinical Biochemistry	1045
108	Jovanovic S.V. et al.,	1994	Flavonoids as antioxidants	Journal of the American Chemical Society	1044
109	Pellegrini N. et al.,	2003	Total antioxidant capacity of plant foods, beverages and oils consumed in Italy assessed by three different in vitro assays	Journal of Nutrition	1043
110	Hagerman A.E. et al.,	1998	High Molecular Weight Plant Polyphenolics (Tannins) as Biological Antioxidants	Journal of Agricultural and Food Chemistry	1042
111	Winston G.W. & Di Giulio R.T.	1991	Prooxidant and antioxidant mechanisms in aquatic organisms	Aquatic Toxicology	1037
112	Kaur C. & Kapoor H.C.	2001	Antioxidants in fruits and vegetables - The millennium's health	International Journal of Food Science and Technology	1024
113	Padayatty S.J. et al.,	2003	Vitamin C as an Antioxidant: Evaluation of Its Role in Disease Prevention	Journal of the American College of Nutrition	1023
114	Ak T. & Gülçin I.	2008	Antioxidant and radical scavenging properties of curcumin	Chemico-Biological Interactions	1011
115	Matés J.M.	2000	Effects of antioxidant enzymes in the molecular control of reactive oxygen species toxicology	Toxicology	1011
116	Sun Y.	1990	Free radicals, antioxidant enzymes, and carcinogenesis	Free Radical Biology and Medicine	1011
117	Ristow M. et al.,	2009	Antioxidants prevent health-promoting effects of physical exercise in humans	Proceedings of the National Academy of Sciences of the United States of America	1010
118	Cao G. et al.,	1996	Antioxidant Capacity of Tea and Common Vegetables	Journal of Agricultural and Food Chemistry	1003
119	Dionisio-Sese M.L. & Tobita S.	1998	Antioxidant responses of rice seedlings to salinity stress	Plant Science	1002
120	Fukumoto L.R. & Mazza G.	2000	Assessing antioxidant and prooxidant activities of phenolic compounds	Journal of Agricultural and Food Chemistry	999
121	Prior R.L. et al.,	1998	Antioxidant Capacity as Influenced by Total Phenolic and Anthocyanin Content, Maturity, and Variety of Vaccinium Species	Journal of Agricultural and Food Chemistry	999
122	Kim D.-O. et al.,	2003	Antioxidant capacity of phenolic phytochemicals from various cultivars of plums	Food Chemistry	986

123	Wang S.Y. & Lin H.-S.	2000	Antioxidant activity in fruits and leaves of blackberry, raspberry, and strawberry varies with cultivar and developmental stage	Journal of Agricultural and Food Chemistry	967
124	Cuzzocrea S. et al.,	2001	Antioxidant therapy: A new pharmacological approach in shock, inflammation, and ischemia/reperfusion injury	Pharmacological Reviews	963
125	Nguyen T. et al.,	2003	Regulatory Mechanisms Controlling Gene Expression Mediated by the Antioxidant Response Element	Annual Review of Pharmacology and Toxicology	958
126	Burton G.W. & Ingold K.U.	1981	Autoxidation of Biological Molecules. 1. The Antioxidant Activity of Vitamin E and Related Chain-Breaking Phenolic Antioxidants in Vitro	Journal of the American Chemical Society	958
127	Djeridane A. et al.,	2006	Antioxidant activity of some algerian medicinal plants extracts containing phenolic compounds	Food Chemistry	950
128	Rao M.V. et al.,	1996	Ultraviolet-B- and ozone-induced biochemical changes in antioxidant enzymes of Arabidopsis thaliana	Plant Physiology	944
129	Machlin L.J. & Bendich A.	1987	Free radical tissue damage: protective role of antioxidant nutrients.	The FASEB journal : official publication of the Federation of American Societies for Experimental Biology	943
130	Marui N. et al.,	1993	Vascular cell adhesion molecule-1 (VCAM-1) gene transcription and expression are regulated through an antioxidant-sensitive mechanism in human vascular endothelial cells	Journal of Clinical Investigation	941
131	Sharma O.P. & Bhat T.K.	2009	DPPH antioxidant assay revisited	Food Chemistry	935
132	Scalbert A. et al.,	2005	Polyphenols: antioxidants and beyond.	The American journal of clinical nutrition	933
133	Carew T.E. et al.,	1987	Antiatherogenic effect of probucol unrelated to its hypocholesterolemic effect: Evidence that antioxidants in vivo can selectively inhibit low density lipoprotein degradation in macrophage-rich fatty streaks and slow the progression of atherosclerosis in the Watanabe heritable hyperlipidemic rabbit	Proceedings of the National Academy of Sciences of the United States of America	915
134	Balla G. et al.,	1992	Ferritin: A cytoprotective antioxidant strategem of endothelium	Journal of Biological Chemistry	906
135	Soobrattee M.A. et al.,	2005	Phenolics as potential antioxidant therapeutic agents: Mechanism and actions	Mutation Research - Fundamental and Molecular Mechanisms of Mutagenesis	904
136	Tiedge M. et al.,	1997	Relation between antioxidant enzyme gene expression and antioxidative defense status of insulin-producing cells	Diabetes	902
137	Eberhardt M.V. et al.,	2000	Antioxidant activity of fresh apples	Nature	892
138	Singh R.P. et al.,	2002	Studies on the antioxidant activity of pomegranate (Punica granatum) peel and seed extracts using in vitro models	Journal of Agricultural and Food Chemistry	888
139	Vivekananthan D.P. et al.,	2003	Use of antioxidant vitamins for the prevention of cardiovascular disease: Meta-analysis of randomised trials	Lancet	885
140	Boaz M. et al.,	2000	Secondary prevention with antioxidants of cardiovascular disease in endstage renal disease (SPACE): Randomised placebo-controlled trial	Lancet	885
141	Jaiswal A.K.	2004	Nrf2 signaling in coordinated activation of antioxidant gene expression	Free Radical Biology and Medicine	881
142	Shahidi F. & Ambigaipalan P.	2015	Phenolics and polyphenolics in foods, beverages and spices: Antioxidant activity and health effects - A review	Journal of Functional Foods	879
143	Siddhuraju P. & Becker K.	2003	Antioxidant properties of various solvent extracts of total phenolic constituents from three different agroclimatic origins of drumstick tree (Moringa oleifera Lam.) leaves	Journal of Agricultural and Food Chemistry	879
144	Koracevic D. et al.,	2001	Method for the measurement of antioxidant activity in human fluids	Journal of Clinical Pathology	879
145	Rice-Evans C. & Miller N.J.	1994	Total antioxidant status in plasma and body fluids	Methods in Enzymology	877

146	Ruby A.J. et al.,	1995	Anti-tumour and antioxidant activity of natural curcuminoids	Cancer Letters	875
147	Ou B. et al.,	2002	Analysis of antioxidant activities of common vegetables employing oxygen radical absorbance capacity (ORAC) and ferric reducing antioxidant power (FRAP) assays: A comparative study	Journal of Agricultural and Food Chemistry	866
148	Venugopal R. & Jaiswal A.K.	1996	Nrf1 and Nrf2 positively and c-Fos and Fra1 negatively regulate the human antioxidant response element-mediated expression of NAD(P)H:quinone oxidoreductase1 gene	Proceedings of the National Academy of Sciences of the United States of America	863
149	Traber M.G. & Atkinson J.	2007	Vitamin E, antioxidant and nothing more	Free Radical Biology and Medicine	848
150	Ruberto G. & Baratta M.T.	2000	Antioxidant activity of selected essential oil components in two lipid model systems	Food Chemistry	844
151	Halvorsen B.L. et al.,	2002	A systematic screening of total antioxidants in dietary plants	Journal of Nutrition	842
152	Burda S. & Oleszek W.	2001	Antioxidant and antiradical activities of flavonoids	Journal of Agricultural and Food Chemistry	841
153	Lenzen S. et al.,	1996	Low antioxidant enzyme gene expression in pancreatic islets compared with various other mouse tissues	Free Radical Biology and Medicine	835
154	Bondet V. et al.,	1997	Kinetics and mechanisms of antioxidant activity using the DPPH• free radical method	LWT - Food Science and Technology	830
155	Frankel E.N. & Meyer A.S.	2000	The problems of using one-dimensional methods to evaluate multifunctional food and biological antioxidants	Journal of the Science of Food and Agriculture	829
156	Dudonné S. et al.,	2009	Comparative study of antioxidant properties and total phenolic content of 30 plant extracts of industrial interest using DPPH, ABTS, FRAP, SOD, and ORAC assays	Journal of Agricultural and Food Chemistry	827
157	Graf E.	1992	Antioxidant potential of ferulic acid	Free Radical Biology and Medicine	827
158	Jayaprakasha G.K. et al.,	2001	Antioxidant activity of grape seed (Vitis vinifera) extracts on peroxidation models in vitro	Food Chemistry	825
159	Engelhart M.J. et al.,	2002	Dietary intake of antioxidants and risk of Alzheimer disease	Journal of the American Medical Association	824
160	Vinson J.A. et al.,	2001	Phenol antioxidant quantity and quality in foods: Fruits	Journal of Agricultural and Food Chemistry	823
161	Carocho M. & Ferreira I.C.F.R.	2013	A review on antioxidants, prooxidants and related controversy: Natural and synthetic compounds, screening and analysis methodologies and future perspectives	Food and Chemical Toxicology	818
162	Shan B. et al.,	2005	Antioxidant capacity of 26 spice extracts and characterization of their phenolic constituents	Journal of Agricultural and Food Chemistry	814
163	Halliwell B.	1994	Free Radicals and Antioxidants: A Personal View	Nutrition Reviews	813
164	Balogun E. et al.,	2003	Curcumin activates the haem oxygenase-1 gene via regulation of Nrf2 and the antioxidant-responsive element	Biochemical Journal	808
165	Kushi L.H. et al.,	1996	Dietary antioxidant vitamins and death from coronary heart disease in postmenopausal women	New England Journal of Medicine	803
166	Keli S.O. et al.,	1996	Dietary flavonoids, antioxidant vitamins, and incidence of stroke: The Zutphen study	Archives of Internal Medicine	802
167	Gülçin I.	2012	Antioxidant activity of food constituents: An overview	Archives of Toxicology	800
168	Levine R.L. et al.,	1996	Methionine residues as endogenous antioxidants in proteins	Proceedings of the National Academy of Sciences of the United States of America	797
169	Pisoschi A.M. & Pop A.	2015	The role of antioxidants in the chemistry of oxidative stress: A review	European Journal of Medicinal Chemistry	794
170	Reiter R.J. et al.,	1995	A review of the evidence supporting melatonin's role as an antioxidant	Journal of Pineal Research	790
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