PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.2396

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REVIEW ARTICLE

Health and commercial relevance of *Garcinia* species: Key scientometric analyses from three decades of research

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OPEN ACCESS

ARTICLE HISTORY

Received: 22 February 2023
Accepted: 04 June 2023

Available online
Version 1.0 : 30 August 2023

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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CITE THIS ARTICLE

Oyenihi O R, George T T, Oyenihi A B, Omotola E O, Ojo O A, Ayeleso A O, Oguntibeju O. Health and commercial relevance of *Garcinia* species: Key scientometric analyses from three decades of research. Plant Science Today (Early Access). https://doi.org/10.14719/pst.2396

Abstract

Garcinia species (*G. indica, G. cambogia, G. kola* and *G. mangostana*) represent some of the most sought-after herbs globally due to their impressive medicinal qualities, hence the ever-growing interest of researchers in not into these plants. In this study, an extensive bibliometric analysis of the available research outputs on the widely-known *Garcinia* species was conducted to appraise the progress made and also highlight the future focus of research on the plants. The published articles (original and conference articles) on the selected species from 1991 to 2021 were retrieved from Scopus® database, scrutinized and further analyzed using the VOS viewer software. Over 2000 research outputs were published posting an annual publication rate of 75 articles, which have altogether garnered almost 37000 citations within the period under review. Of the 85 country affiliations on the publications, 5, which include India, Thailand, Nigeria, Indonesia, and the United States have cumulatively contributed two-thirds of the total outputs. The institutions; the University of Ibadan (97), Prince Songkla University (52) and Mahidol University (50) have the most publications revealing their research focus on herbs. However, in terms of individual influence, Prof E.O. Farombi, of the University of Ibadan, led the pack with an impressive 42 publications (1585 citations) on *Garcinia kola* followed by Prof Y.W. Chin of the Seoul National University, South Korea with 23 publications (452 citations) on *Garcinia mangostana*. The versatility in the health applications of these species especially as sources for new therapeutics, nutraceuticals or functional food ingredients, has been the main driver of the research within the past three decades. Recent research undertakings have demonstrated the potential industrial uses of herbs in the clothing and petroleum industries and these may dominate the research emphases in the immediate future.

Keywords

Garcinia species, health value, commercial value, medicinal plants, therapeutic uses

Introduction

The genus *Garcinia* which belongs to the Clusiaceae family includes about 400 species that are native to Asia and Africa, America, Australia, Brazil, Polynesia and New Caledonia (1, 2). Recently, Garcinia species have received considerable attention worldwide from the scientific as well as industrial sectors, and several potential utilities and novel compounds with diverse bioactivities have been reported. These compounds offer numerous opportunities for pharmaceutical companies in the development of new drug leads. They also represent an excellent source of molecules to produce food additives, functional foods, nutritional products, and nutraceuticals for the growing number of natural products companies. The plants of the genus also have applications in petroleum industries and other diverse industrial fields (3). Fruit-yielding Garcinia trees such as Mangosteen (*G. mangostana* L.), Brindle berry (*G. gummi-gutta* (L.) N. Bobson. Syn. *G. cambogia* (Gaertn.) Desr.) and Kokum (*G. indica* Choisy) are currently gaining commercial, industrial and medicinal importance (4). Edible fruits and vegetables from these Garcinia species play an important role in providing dietary diversity, food security, nutrition and income generation for local communities and the global economy (5).

G. cambogia and *G. indica* are rich in *hydroxyl citric* acid (HCA) – an anti-obesity compound highly marketed by pharmaceuticals as a weight-loss dietary supplement (6-8). The presence of HCA in some Garcinia species is linked to increased fat oxidation, anorexigenic effect, and regulation of endogenous lipid biosynthesis (9). Furthermore, gamboge (or camboge) is the exudate from the bark of several Garcinia species and is used as a pigment in Indian murals and European water paintings. Gamboge is also used for colouring wood, leather, metal and dyeing clothes (10).

In South India, *G. gummi-gutta* and *G. indica* are cultivated for commercial extraction of a variety of products such as bioactive acids, nutraceuticals, fats and condiments. The latter *species* was recently reported to augment synthetic lubricants for the reduction of friction and coating of engine parts and surfaces to protect them from wear (11). Its antioxidant and antimicrobial properties have also been reported (12) and when applied in combination with *G. cambogia*, they enhanced the shelf life of Mackerel fish using a novel icing medium (12). *G. indica* also inhibited the corrosion of mild steel purportedly due to the presence of cyanidin anthocyanins (13). Furthermore, *G. indica* oil has a great demand for the preparation of ointments, face creams and lipsticks in the cosmetic industry while its butter has been utilised as a substitute for cocoa butter (14-15).

G. mangostana also known as Mangosteen is commonly utilized as a functional food and mangosteen-based beverages had a turnover of more than $200 million in 2008 in the USA alone (16). The impressive commercial relevance of the specie stems from its wide applicability ranging from technological and biomedical applications to biomaterial production (17). Xanthones derived from mangosteen have been reported for their wide spectrum of pharmacological and biological properties (18). These properties include but are not limited to antibacterial, antiprotozoal, anti-cancer, antidiabetes, antioxidant and anti-inflammatory activities (19-21). Some clinical trials have also demonstrated the bioavailability of xanthone-rich mangosteen-based supplements and their potent anti -inflammatory and antioxidant effects (22).

G. kola (bitter kola) is one of the most studied Garcinia species. It is highly valued in Africa and used for hospitality purposes during cultural and social ceremonies where the seeds are usually eaten in their crude form as a snack. G. kola is used in African ethnomedicine for prophylactic and therapeutic purposes, especially for inflammatory-related diseases (22). Due to its health benefits, the efficacy and safety of a detox tea containing a mixture of G. kola and other plants (*Andrographis paniculata* and *Psidium guajava*) were investigated as adjuvants to the conventional therapy for COVID-19 in a pilot randomized trial (24). G. kola contains bioactive such as flavonoids, biflavanone, benzophenone derivatives (kolaflavones, Garcinia-flavones 1 and 2), and chromanols (garcinal and garcinoic acid). Of these, the biflavonoid – kolaviron is the most studied and has great potential for clinical use as an antidiabetic agent because it targets multiple abnormalities in the diabetic milieu, specifically by targeting ROS production, bolstering antioxidants and limiting inflammation (25). Pharmaceutical companies from Nigeria and Cameroon have recently focused on the small-scale production of bitter kola syrups and herbal pastes as herbal remedies and food supplements (3).

In this article, a bibliometric study of the dynamics of scientific research on commercially-relevant Garcinia species was investigated. The selection of these five species is based on their general popularity and commercial importance (as indicated by their footprint on the World Wide Web) and their scientific importance (as indicated by the number of research publications). This bibliometric study is instrumental in identifying topical hotspots, research strengths and weaknesses, information gaps and top researchers for collaborations. The information will inform research priorities, identify new research areas and promote further commercialization of these herbs.

Materials and Methods

The scientific data (original articles and conference articles/proceedings) on the research on the selected Garcinia species published within the past 30 years was obtained from Scopus® database on the 1st of February 2022. Scopus was selected because it is the largest scientific journal indexing and citation database administered by Elsevier academic publishers (Amsterdam, Netherlands) (26-27). The data search on Scopus database was limited to research publications from 1st January 1991 to 31st December 2021. This time duration was considered as growth in the use of natural therapeutics and products from plant that became prominent during this period. The search command deployed in this study is defined as follows; TITLE-ABS-KEY ("Garcinia kola" OR “*Garcinia indica*" OR "*Garcinia mangostana*" OR "*Garcinia cambogia*" OR “Garcinia gummi -gutta”) AND PUBYEAR > 1990 AND PUBYEAR < 2022 AND

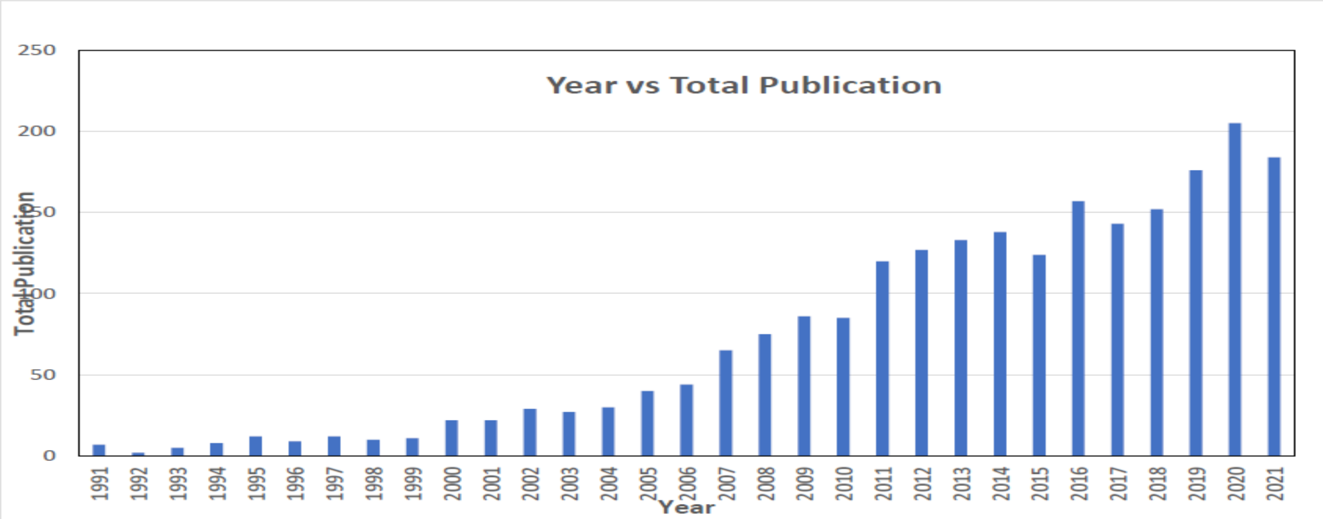

Fig. 1. Global publication trend of commercially relevant *Garcinia* species (1991-2021).

(LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")). The extracted data from Scopus database was carefully checked for correctness and to avoid duplication using Microsoft Excel® spreadsheet (version 2013, Washington, USA). Thereafter, the VOSviewer software (version 1.6.16, Leiden, Netherlands) was employed to establish co-authorship, co-occurrence and co-citation relationships between authors, institutions or countries, as well as the participation of journals in Garcinia research.

Results

Garcinia research publication growth (1991-2021)

In over 3 decades, a total of 2260 original articles and conference publications on the selected *Garcinia* species (Fig. 2) were indexed on Scopus database and have garnered a cumulative 36880 citations. There has been a meteoric rise in the research outputs from just 7 articles published in 1991 to 184 in 2021 posting an average annual publication of 75 in the three decades under review. The research activities on the species in the second decade in particular, were pivotal, as the global research popularity of the use of medicinal plants as potential preventative medicines for many chronic diseases continues to increase. For example, the top-4 most-cited research articles; (28-31), were published during this period. These studies explored the health importance of *Garcinia* species, especially with relation to their antioxidant, antiglycation, biochemical and enzyme inhibition potentials for the management of many diseases. This upward research trend continues into the last decade with the year 2020 being the most productive year to date with 205 published articles. The exponential research growth on these *Garcinia* species over the years indicates continued advances and interest from the international research community as the quest to find novel natural therapies for lifestyle diseases goes on.

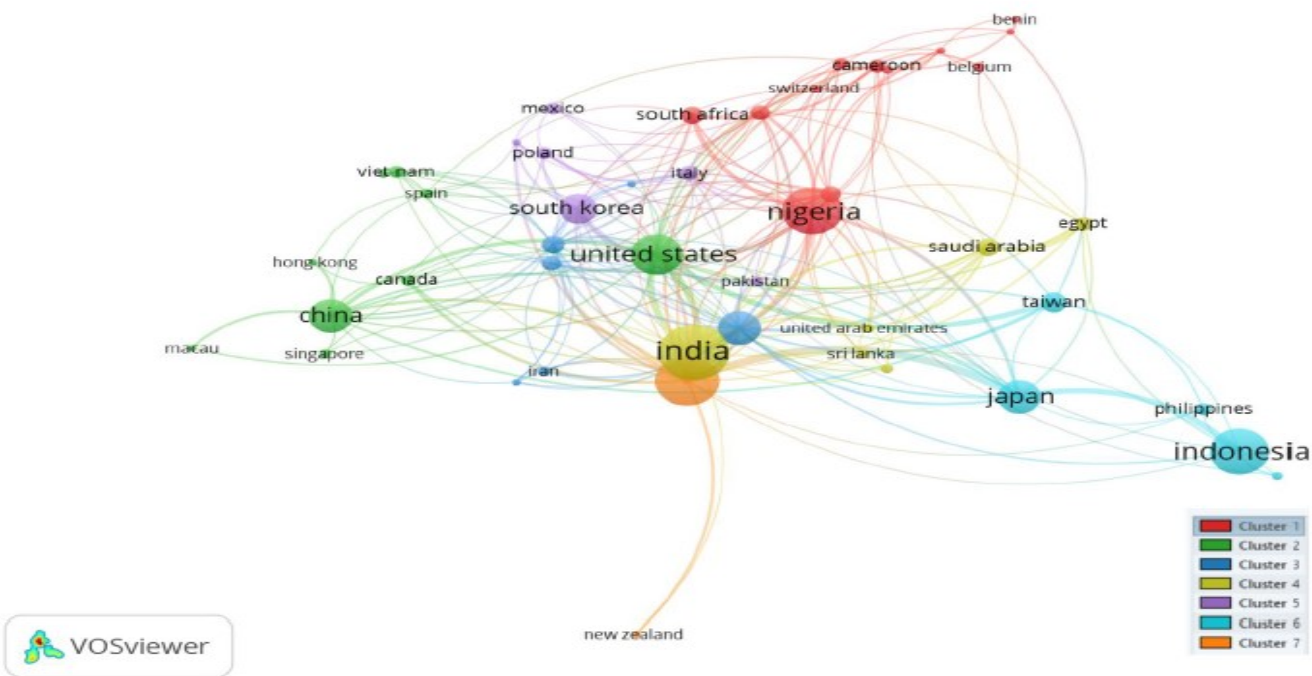

Fig. 2. Network visualization map of co-authorship of countries with at least 5 publications.

Country contribution to *Garcinia* research (1991-2021)

Altogether, 85 countries participated in the research on *Garcinia* species as shown from the clearly-defined affiliations on the publications indexed on Scopus database. Only 10 of these countries published 50 or more research outputs on the subject within this period with India having the most number (396) as depicted in Table 1. Thailand (329), Nigeria (301), Indonesia (273) and the United States (212) complete the top 5 countries with the greatest number of publications on *Garcinia* research and cumulatively represent about 66.9% of the total publications. However, in terms of citations, the publications affiliated with the United States were cited the most garnering a total of 8119 citations and is followed closely by Thailand (7295), India (6020), Nigeria (5093) and Japan (4878). Thus, the United States, Taiwan and Japan may have the highest country influence on *Garcinia* research stemming from their superior citation-to-publication ratios of 38.3, 37.,0 and 33.0 respectively. The research contributions over the years by these countries demonstrate their focus and investment in discovering effective phytotherapeutic strategies for life-long diseases that have plagued the human race. Asian countries are well-known for their age-long beliefs in herbal medicines for example, the Kampo (Japan), traditional (China) (32), or Ayurvedic (India) (33) medical systems have become widely accepted worldwide. Similarly, folkloric use of herbal medicines for disease management by the indigenous North American population has been documented even before the advent of conventional 'orthodox' medicines. In recent times, there has been an upsurge in the popularity of herbal medicines in the United States which can be associated with the amount of scientific research being carried out in this niche (34). The sway of the influence on *Garcinia* research by Nigeria in Africa (Table 1), is not surprising as the country is host to the naturally occurring *G. kola* tree where its seed has been consumed as a recreational snack in cultural settings since times immemorial. The plant was also dubbed "a miracle tree" due to its role as a major component of the traditional medicinal concoctions to manage many ailments such as diarrhea, bronchitis, bacterial infection etc. (35).

this study, VOS viewer was employed to assess the extent of collaboration among the countries that were actively involved in *Garcinia* research in the last 3 decades. Fig. 3 depicts the collaborative networks of countries with at least 5 publications together. The size of the circle

Table 1. Country affiliations on *Garcinia* research publications and citations (1991-2021)

Country	TP	TC	TC/TP	Most cited document
India	396	6020	15.20	(29)
Thailand	329	7295	22.17	(36)
Nigeria	301	5093	16.92	(37)
Indonesia	273	1498	5.49	(38)
United States	212	8119	38.30	(29)
Malaysia	152	2751	18.10	(39)
China	149	2334	15.67	(40)
Japan	148	4878	32.96	(41)
South Korea	118	1831	15.52	(42)
Taiwan	52	1927	37.06	(43)

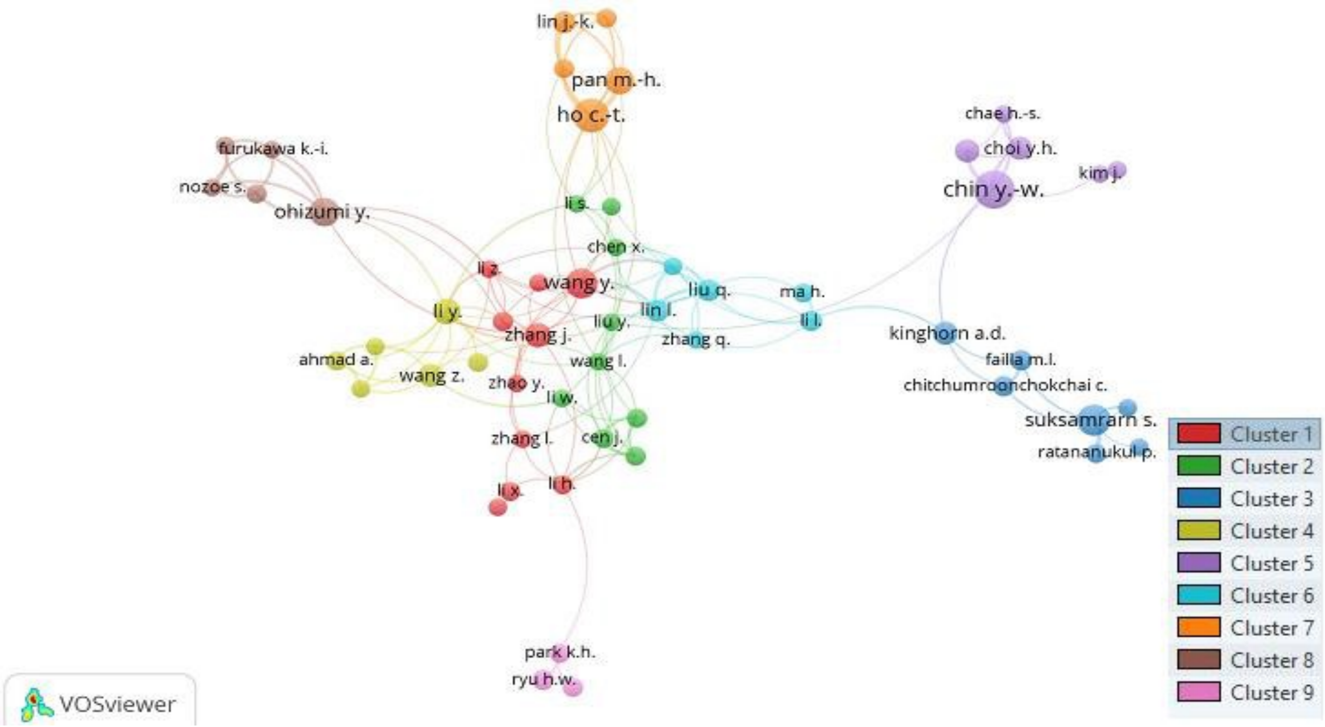

Fig. 3. Network visualization of co-authorship of authors with at least 5 publications in *Garcinia* species research (1991-2021).

(nodes) is a function of the number of publication outputs with inward and outward links uniting or departing from the node while the assembly of individual nodes forms a cluster that is linked together by lines to indicate networks of collaborations and their strengths (44-46). The thickness of links shows the strength of the connections between any 2 nodes in the network (47) Of the total of 85 countries affiliated with the publications on *Garcinia* research, more than half met the selected threshold for inclusion and these were grouped into 7 different clusters. Cluster one had 15 countries including Nigeria which had the highest total link strengths of 86 and 305 documents. In cluster 2 with 11 countries, Australia had the highest total link strengths of 49 and 51 documents and had the highest number of links with other countries (23). There were 8 countries in cluster 3 where India had the highest number of links with other countries (23) as well as the highest total link strengths of 81 and 433 documents. In cluster 4 with 5 countries, South Korea had the highest total link strengths of 40 and 124 documents while the United States had the highest number of links with other countries (27) and a total link strength of 142 and document sent. Clusters 5 and 6 were composed of 6 and 5 countries respectively with Japan having the highest total link strengths of 84 and 147 documents for cluster 6 and South Korea having the highest number of links with 36 countries in cluster 5. Lastly, in cluster 7 with 2 countries, Thailand had a collaborative link with 27 countries and the highest total link strengths of 130 and 296 documents. The United States, therefore, had the most international collaborations on *Garcinia* research while India had the largest node in the country's co-authorship network (Fig. 3) which may have accounted for the high publication number and citations observed for their affiliated publications.

Institutional participation in the research on *Garcinia* species (1991-2021)

It is important to assess the influence of universities and other research centers on the published outputs on *Garcinia* species over the last three decades. The institutions with the highest number of publications, citations and most-cited articles within the period under review were presented in Table 2. The University of Ibadan, Nigeria had the most published outputs (n= 97; 22% of top-10) on *Garcinia* species, predominantly on the potential pharmacological activities of *G. kola*. These publications have amassed a total of 2437 citations averaging at least 25 citations per article. The most cited article (226 citations) from the institution described the possible use of a bioflavonoid compound (kolaviron) isolated from *G. kola* seed to ameliorate the liver injury caused by 2-acetylaminofluorene, a chemical carcinogen (48). The University of Ibadan was distantly followed by Prince Songkla University and Mahidol University, both in Thailand with 52 and 50 publications that were cited 822 and 2143 times respectively. The latter university, however, had the most citation/publication ratio posting an impressive minimum of 42 citations per article among the most influential institutions in *Garcinia* research. Altogether, the top 100 institutions (Table 2) have published almost 20% of the total publications on *Garcinia* research within the period under review. The domination by the Asian institutions is also reflective of the emphasis placed by the continent on the research on herbs for health, food and other applications.

Research Authorship

Author participation and citation

The contributions of leading authors in selected Garcinia publications in the last 3 decades are presented in Table 3. Farombi E.O. affiliated with the University of Ibadan in Nigeria had the highest number of publications (TP: 42) and 1585 citations; and the most cited of his publications was "Chemoprevention of 2-acetylaminofluorene-induced hepatoxicity and lipid peroxidation in rats by Kolaviron – A *Garcinia kola* seed extract", which was published in the year 2000 and cited in about 226 other articles. Also, other leading authors from the University of Ibadan were Adaramoye A.O and Adedara I. A who had 19 and 16 publications on *Garcinia* respectively. However, Adaramoye had a total number of 480 citations from his 19 publications while his work on "Hypoglycaemic and hypolipidaemic effects of fractions from kolaviron, a biflavonoid complex from *Garcinia kola* in streptozotocin-induced diabetes mellitus rats" published in 2006 earned him 67 citations. In contrast, Adedara who had 16 publications from the same University got 460 citations and his publication on "Curcumin and kolaviron ameliorate di-n-butyl phthalate-induced testicular damage in rats", in 2007 garnered him 93 citations making it the leading article on his publication list.

Table 2. Top-10 institutions affiliated with Garcinia research publications (1991-2021)

Institution	Country	TP	TC	TC/TP	Most cited document
University of Ibadan	Nigeria	97	2437	25.12	(48)
Prince Songkla University	Thailand	52	822	15.81	(49)
Mahidol University	Thailand	50	2143	42.86	(50)
Universiti Putra	Malaysia	42	752	17.90	(51)
Institut Pertanian Borgor	Indonesia	41	173	4.22	(52
Kasetsart University	Thailand	36	651	18.08	(53)
Universiti Kebangsaan	Malaysia	33	286	8.67	(54
Khon Khaen University	Thailand	38	506	13.32	(55)
Universitas Padjadjaran	Indonesia	30	257	8.57	(56)
Chulalongkorn University	Thailand	29	290	10.00	(57)

Table 3. Author participation- Top 10 authors with highest publications on selected *Garcinia* species research (1990-2020)

Author name	TP	TC	Affiliation	Country	Most cited publication	Citation number
Farombi E.O	42	1585	University of Ibadan	Nigeria	Chemoprevention of 2-acetylaminofluorene-induced hepatoxicity and lipid peroxidation in rats by Kolaviron – A *Garcinia kola* seed extract (48)	226
Chin Y.W	23	452	Seoul National University	South Korea	Xanthones with quinone reductase-inducing activity from the fruits of Garcinia mangostana (Mangosteen) (62)	89
Adaramoye A.O	19	480	University of Ibadan	Nigeria	Hypoglycaemic and hypolipidaemic effects of fractions from kolaviron, a biflavonoid complex from *Garcinia Kola* in streptozotocin-induced diabetes mellitus rats (63)	67
Ho C.T	18	913	Anhui Agricultural University	China	Induction of apoptosis by garcinol and curcumin through cytochrome c release and activation of caspases in human leukaemia HL-60 cells (58)	199
Muchtaridi M.	17	134	Universitas Padjadjaran	Indonesia	Characterization and antioxidant activity of pectin from Indonesian mangosteen (*Garcinia mangostana* L.) rind (60)	35
Suksamrarn S.	16	913	Srinakharinwirot University	Thailand	Antimycobacterial activity of prenylated xanthones from the fruits of *Garcinia mangostana* (64)	195
Adedara I. A	16	460	University of Ibadan	Nigeria	Curcumin and kolaviron ameliorate di-n-butyl phthalate-induced testicular damage in rats (65)	93
Linuma M.	15	1306	Gifu Pharmaceutical University	Japan	Induction of apoptosis by xanthones from mangosteen in human leukemia cell lines (59)	183
Mohammed G.A	16	350	Al-Azhar University & King Abdulaziz University	Egypt, Saudi Arabia	New xanthones and cytotoxic constituents from Garcinia mangostana fruit hulls against human hepatocellular, breast, and colorectal cancer cell lines (66)	71
Bagchi D.	14	763	Texas Southern University	United States	Effects of a natural extract of (-)-hydroxycitric acid (HCA-SX) and a combination of HCA-SX plus niacin-bound chromium and Gymnema sylvestre extract on weight loss (61)	140

Chin Y.W. from Seoul National University in South Korea had 23 publications to emerge as the top second author with 452 citations. His publication on "Xanthones with quinone reductase-inducing activity from the fruits of *Garcinia mangostana* (Mangosteen)", published in 2008 became the most cited article on his list of *Garcinia* research with 89 citations. Furthermore, Ho C.T. from Anhui Agricultural University in China had 18 publications on *Garcinia* and recorded 913 citations. His co-authored publication on "Induction of apoptosis by garcinol and curcumin through cytochrome c release and activation of caspases in human leukaemia HL-60 cells (58)" had 199 citations to become the most cited of all his works on *Garcinia*.

Also significant was Linuma M. from Gifu Pharmaceutical University in Japan who only had 15 publications on *Garcinia* but got a wider number of citations (1306); out of which, 183 citations came from his work on "Induction of apoptosis by xanthones from mangosteen in human leukemia cell lines (59)", making it the most cited of his work. Muchtaridi M. from Universitas Padjadjaran in Indonesia had 17 publications in all, but only 134 citations. The most cited of his work was "Characterization and antioxidant activity of pectin from Indonesian mangosteen (*Garcinia mangostana* L.) rind (60)" which had 35 citations. Bagchi D. from Texas Southern University in United States had the least number of publications (14) on *Garcinia* with 763 total citations; out of which 140 citations came from "Effects of a natural extract of (-)-hydroxycitric acid (HCA-SX) and a combination of HCA-SX plus niacin-bound chromium and Gymnema sylvestre extract on weight loss (61)".

Conclusively, the study profiled the top 10 institutions and top 10 leading authors with the highest publications research in relation to different studies on Garcinia. In both ways, the University of Ibadan took the topmost position with 97 publications while Farombi E.O was also the leading author with the highest number of publications and citations. The Chulalongkorn University had the least number of publications (29) while Bagchi D was the overall author with the least number of publications (14).

Co-authorship analysis

The VOS viewer Bibliometric Map of the Co-authorship network of researchers with at least 5 publications on selected Garcinia plant research is shown in Fig. 4. Out of 7704 authors, 195 meet the threshold of individuals that has co-authored at least 10 publications. Each of these authors was grouped into 9 clusters. Authors in the same clusters may have been grouped together based on similarities in their research interests and collaborations. It is important to point out that of these 195, only 60 authors are significantly linked and connected together to form

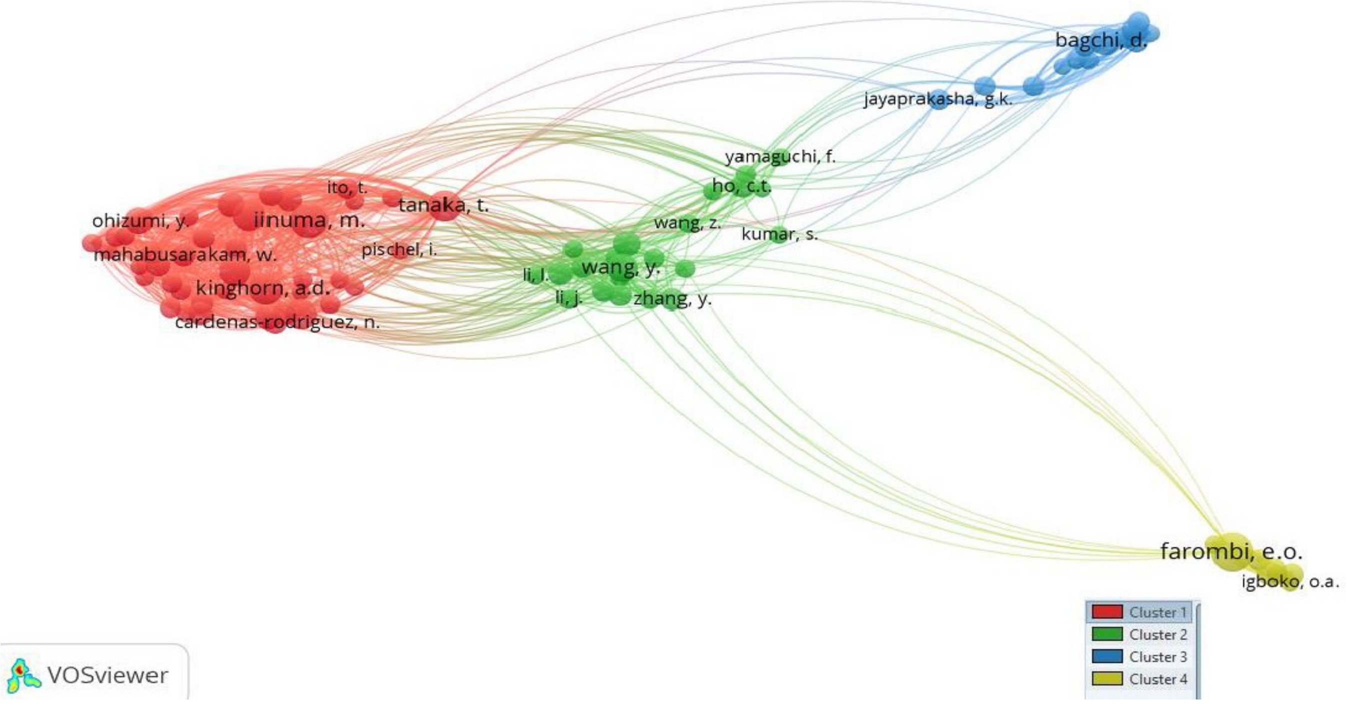

Fig. 4. Network visualization map of co-citation of cited authors in selected Garcinia species research (1991-2021).

this network visualization. Cluster 1 (red) contains 12 authors, cluster 2 (green) has 11 authors grouped together, cluster 3 (blue) and 4 (yellow) has 7 authors linked together, while clusters 5 (purple) and 6 (teal) contains 6 authors respectively, cluster 7 (orange) has 5 authors linked together while 8 (brown) and 9 (pink) contains only 3 authors for both.

Co-citation

In total, the co-citation network of cited authors with a minimum of 150 citations has 83 authors meeting the threshold for co-citing authors. The total link strength of all authors is 211372. The 83 items have been classified into 4 clusters as presented in Fig. 5. In cluster 1 with 41 items grouped together (red), Iinuma has the greatest co-citation network with a total link strength of 17056 and 615 co-citations. In cluster 2 (green), 22 items are grouped together a researcher named Wang Y. has the highest total link strength with 6374 and 374 co-citations. In cluster 3 (blue), 13 items were grouped together, Bagchi D has the highest co-citation strength with a total link strength of 9539 and 402 co-citations. In cluster 4 (yellow), with 7 grouped items, Farombi has the highest TLS of 7733 with 776 co-citations.

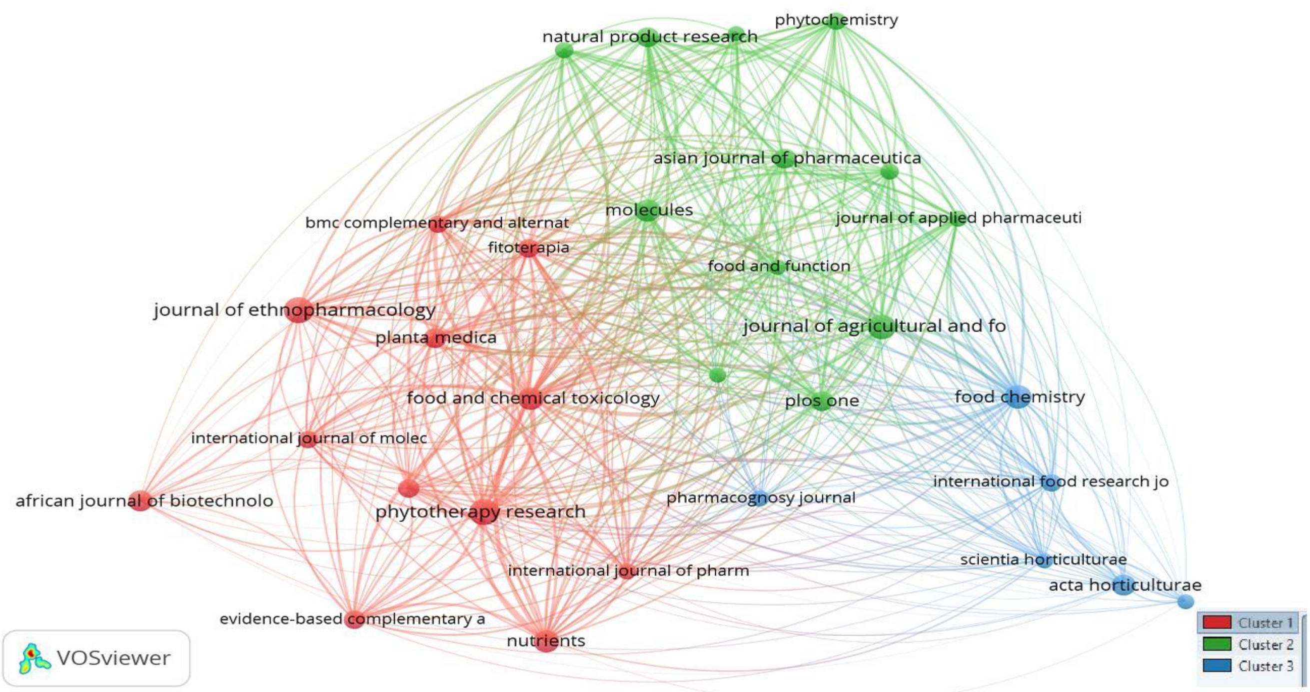

Fig. 5. Bibliographic coupling of Journals in selected *Garcinia* species research (1991-2021).

Journal participation in selected *Garcinia* species research (1991-2021)

A total of 575 journals (sources) have published original research and conference papers on selected *Garcinia* species in the last thirty years. Table 4 presents their contribution in terms of total production, citation, average citation per publication and impact factor. Of the top 10 Journals, Acta Horticulturae is the most prolific journal used by researchers with 83 published articles although it also has the least citation score (TC: TP). Among the top 10 Journals in *Garcinia* species research based on the number of publications, the Journal of Agricultural and Food Chemistry has the highest citation score. The 3 most cited journals are the Journal of Agricultural and Food Chemistry, Journal of Ethnopharmacology and Food and Chemical Toxicology, with a TC: TP ratio of 89.75, 68 and 66.63 respectively. Also, these Journals have an impact factor greater than 4.

Bibliographic coupling of sources analysis provides thematic clusters that are based on those publications that share the same references (67). For bibliographic coupling, the relatedness of documents is relative to the number of references they share (68). Also, the size of the nodes (Journals) is proportional to the number of documents published in the journal, while the relative proximity of the nodes and the thickness of the links symbolize their degree of similarity based on the number of references they have in common (69). Fig. 6 shows the bibliographic coupling of Journals with at least 10 documents. Of the 1024 different journal sources that have been published on *Garcinia*, only 30 met the threshold and were classified into 3 clusters based on the relatedness of subjects of interests. Cluster 1 (red) 12 journals, cluster 2 (green) 12 journals and cluster 3 (blue) 6 items as shown in Fig. 6 (also presented in table 5 for clarity). The total link strength of all 30 journals is 25781. In cluster 1, Phytotherapy Research has the highest total link strength of 2968, in cluster 2, Journal of Agricultural and Food Chemistry has the highest TLS of 3145 while in cluster 3, Food Chemistry has the highest TLS of 2203.

Table 4. Top 10 Journals in *Garcinia* species research (1991-2021)

Journal	TP	TC	TC/TP	Impact Factor (2020)
Acta Horticulture	83	192	2.31	0.26
Journal of Agricultural and Food Chemistry	28	2513	89.75	5.28
Phytotherapy Research	26	900	34.62	4.09
Journal of Ethnopharmacology	27	1836	68.00	4.27
Food Chemistry	25	1595	63.80	6.31
Molecules	21	405	19.30	4.41
Food and Chemical Toxicology	19	1266	66.63	4.68
PlOS One	18	346	19.22	3.84
African Journal of Biotechnology	17	280	16.47	N/A
Natural Research Product	16	255	15.94	2.86

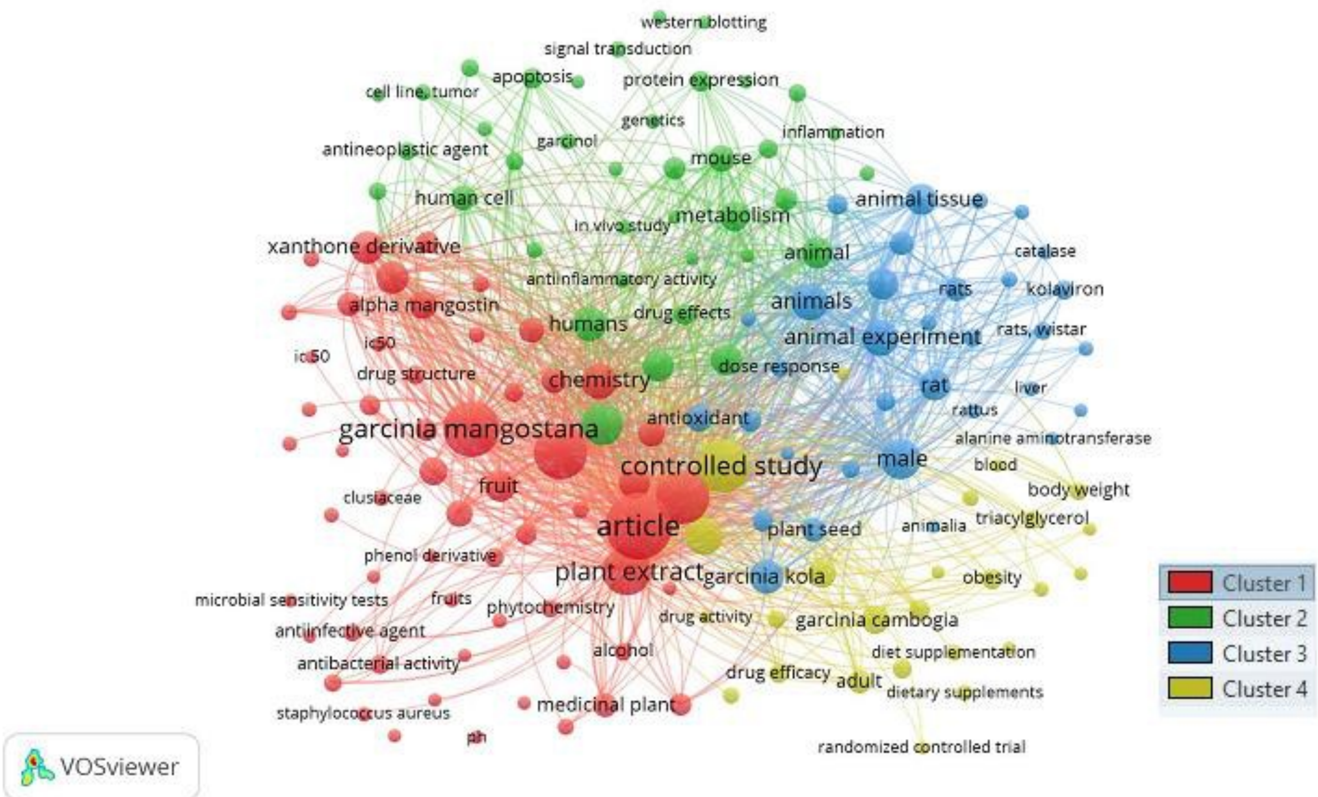

Fig. 6. Network visualization map of co-occurrence of all keywords with at least 50 occurrences (1991-2021).

Table 5. Bibliographic coupling of Journals in selected *Garcinia* species research (1991-2021)

S/N	Cluster 1	Cluster 2	Cluster 3
1	African Journal of Biotechnology	Asian Journal of Pharmaceutical and clinical research	Acta Horticulturae
2	BMC Complementary and Alternative Medicine	Food and Function	Food Chemistry
3	Evidence-Based Complementary and Alternative Medicine	Journal of Agricultural and Food Chemistry	International Food Research Journal
4	Fitoterapia	Journal of Applied Pharmacy	Pharmacognosy Journal
5	Food and Chemical Toxicology	Journal of Natural Products	Postharvest Biology and Technology
6	International Journal of Pharmaology	Molecules	Scientia Horticulturae
7	International Journal of Molecular Sciences	Natural Products Communication	
8	Journal of Ethnopharmacology	Natural Products Research	
9	Journal of Medicinal Food	Phytochemistry	
10	Nutrients	Plos One	
11	Phytotherapy Research	Research Journal of Pharmacy	
12	Planta Medica	Scientific Reports	

Co-occurrence of author keywords in selected *Garcinia* species research (1991-2021)

Co-occurrence of keyword analysis is a powerful tool used to identify, describe and visually present the interactions between keywords in a scientific field (Table 6) (70, 71). This tool analyzes the frequency of co-occurrence of 2 keywords i.e., it quantifies the number of articles in which these words appear together. The network visualization of *Garcinia* species research was carried out and of the 18744 keywords relating to this subject, 154 met the threshold of 50 sets. The keywords used most commonly also gives direction on where research on this subject is currently gaining ground. For instance, the top 10 keywords in Table 6 show the most frequently used keywords in *Garcinia* studies indicating that it is mostly used for its ethnopharmacological importance and as a possible natural remedy for illnesses.

Table 6. Top 10 keywords for Garcinia species research (1991-2021)

Article	1230
Nonhuman	807
Garcinia mangostana	902
Unclassified drug	789
Controlled study	805
Plant extract (s)	1051
Human (s)	799
Male	458
Animal (s)	654
Animal experiment	384

Conclusion

Garcinia species have shown potential to improve a variety of illnesses, including hyperlipidemia, COVID-19, diabetes mellitus and neurodegenerative disorders and have been reported to be safe for consumption. The 3 species understudied (*G. indica, G. cambogia, G. kola* and *G. mangostana)* all have significant impact in the health industry because of the potentials in them to manage different varieties of diseases. Research undertakings have also demonstrated the potential industrial uses of the herbs in the health, pharmaceutical industries, clothing and petroleum industries and these may dominate the research emphasis in the immediate future, however, in terms of isolation of beneficial compounds more studies will be needed to maximize the benefits of these species.

Acknowledgements

We appreciate Cape Peninsula University of Technology, South Africa for funding the article publication.

Authors' contributions

ORO conceived of the study and participated in writing the original draft and coordination. TTG generated the data, performed data analysis, and participated in writing the original draft of the manuscript. ABO reviewed the generated data and participated in writing the original draft of the manuscript. EOO, OAO, AOA participated in writing and reviewing of the manuscript. OO reviewed the manuscript and provided resources for the project. All authors read and approved the final manuscript.

Compliance with ethical standards

Ethical standards were maintained in writing this article.

Conflict of interest: Authors declare that there is no conflict of interests.

Ethical issues: None.

References

1. Chen R, Shi J, Chen Y, Zang B, Guan H, Chen H. Powerlyra: Differentiated graph computation and partitioning on skewed graphs. ACM Transactions on Parallel Computing (TOPC). 2019 Jan 22;5(3):1-39. https://doi.org/10.1145/3298989
2. Espirito Santo BL, Santana LF, Kato Junior WH, de Araújo FD, Bogo D, Freitas KD et al. Medicinal potential of *Garcinia* species and their compounds. Molecules. 2020 Oct 1;25 (19):4513. https://doi.org/10.3390/molecules25194513
3. Maňourová A, Leuner O, Tchoundjeu Z, Van Damme P, Verner V, Přibyl O, Lojka B. Medicinal potential, utilization and domestication status of bitter kola (*Garcinia kola* Heckel) in West and Central Africa. Forests. 2019 Feb 4;10(2):124. https://doi.org/10.3390/f10020124
4. Murthy HN, Dandin VS, Dalawai D, Park SY, Paek KY. Bioactive compounds from fruits of high economic value for food and health. In: Bioactive molecules in food. Springer, Cham. 2019;pp. 1643-70. https://doi.org/10.1007/978-3-319-78030-6_65
5. Khapare LS, Kadam JH, Shirke GD. *Garcinia* a medicinally potential genus in Western Ghats. Journal of Pharmacognosy and Phytochemistry. 2020;9(5):2750-52.

6. Hemshekhar M, Sunitha K, Santhosh MS, Devaraja S, Kemparaju K, Vishwanath BS et al. An overview on genus *Garcinia*: phytochemical and therapeutical aspects. Phytochemistry Reviews. 2011 Sep;10(3):325-51. https://doi.org/10.1007/s11101-011-9207-3

7. Parthasarathy U, Nirmal Babu K, Senthil Kumar R, Ashis GR, Mohan S, Parthasarathy VA. Diversity of Indian *Garcinia*-a medicinally important spice crop in India. In: II International Symposium on Underutilized Plant Species: Crops for the Future-Beyond Food Security. 2011 Jun 27; 979:pp. 467-76. https://doi.org/10.17660/ActaHortic.2013.979.50

8. Apoorva KA, Fakrudin B, Nandini K, Gaurav NC, Sandeep K, Jayashree U et.al. Plasticity for (-)-hydroxycitric acid (HCA) content in ecotypes of *Garcinia indica* (Kokum) of Western Ghats. IJCS. 2020;8(3):1188-95. https://doi.org/10.22271/chemi.2020.v8.i3p.9363

9. Raina R, Verma PK, Taku I, Malik JK, Gupta RC. *Garcinia cambogia*. In: Nutraceuticals. Academic Press. 2021 Jan 1;pp. 975-90. https://doi.org/10.1016/B978-0-12-821038-3.00058-6

10. Aral S, Rameshkumar KB. Gamboge-the bark exudate from *Garcinia* species. Diversity of *Garcinia* species in the Western Ghats: Phytochemical Perspective. 2016;162.

11. Yadav A, Singh Y, Negi P. A review on the characterization of bio-based lubricants from vegetable oils and role of nanoparticles as additives. Materials Today: Proceedings. 2021 Jan 1;46:10513-17. https://doi.org/10.1016/j.matpr.2021.01.046

12. Apang T, Xavier KM, Lekshmi M, Kannuchamy N, Layana P, Balange AK. *Garcinia* spp. extract incorporated icing medium as a natural preservative for shelf-life enhancement of chilled Indian mackerel (*Rastrelliger kanagurta*). LWT. 2020 Nov 1;133:110086. https://doi.org/10.1016/j.lwt.2020.110086

13. Thomas A, AT JR, Joseph A. Extended protection of mild steel in molar HCl using the *Garcinia indica* fruit rind extract (GIW) and iodide ions; electrochemical, thermodynamic and kinetic studies. Journal of the Indian Chemical Society. 2021 Oct 1;98(10):100167. https://doi.org/10.1016/j.jics.2021.100167

14. Swami SB, Thakor NJ, Patil SC. Kokum (*Garcinia indica*) and its many functional components as related to the human health: A review. Journal of Food Research and Technology. 2014 Oct;2(4):130-42.

15. Krist S. Cocoa butter. In: Vegetable Fats and Oils. Springer, Cham. 2020; pp. 239-46. https://doi.org/10.1007/978-3-030-30314-3_37

16. Gutierrez-Orozco F, Failla ML. Biological activities and bioavailability of mangosteen xanthones: A critical review of the current evidence. Nutrients. 2013 Aug 13;5(8):3163-83. https://doi.org/10.3390/nu5083163

17. Aizat WM, Ahmad-Hashim FH, Jaafar SN. Valorization of mangosteen,"The Queen of Fruits," and new advances in postharvest and in food and engineering applications: A review. Journal of Advanced Research. 2019 Nov 1;20:61-70. https://doi.org/10.1016/j.jare.2019.05.005

18. Ahmad I. Recent insight into the biological activities of synthetic xanthone derivatives. European Journal of Medicinal Chemistry. 2016 Jun 30;116:267-80. https://doi.org/10.1016/j.ejmech.2016.03.058

19. Hu D, Li D, Shigeta M, Ochi Y, Okauchi T, Neyama H et.al. Alleviation of the chronic stress response attributed to the antioxidant and anti-inflammatory effects of electrolyzed hydrogen water. Biochemical and Biophysical Research Communications. 2021 Jan 8;535:1-5. https://doi.org/10.1016/j.bbrc.2020.12.035

20. Pinto A, Bonucci A, Maggi E, Corsi M, Businaro R. Anti-oxidant and anti-inflammatory activity of ketogenic diet: new perspectives for neuroprotection in Alzheimer's disease. Antioxidants. 2018 Apr 28;7(5):63. https://doi.org/10.3390/antiox7050063

21. Zhang L, Cheng YX, Liu AL, Wang HD, Wang YL, Du GH. Antioxidant, anti-inflammatory and anti-influenza properties of components from *Chaenomeles speciosa*. Molecules. 2010 Nov 22;15(11):8507-17. https://doi.org/10.3390/molecules15118507

22. Saraswathy SU, Lalitha LC, Rahim S, Gopinath C, Haleema S, SarojiniAmma S, Aboul-Enein HY. A review on synthetic and pharmacological potential of compounds isolated from *Garcinia mangostana* Linn. Phytomedicine Plus. 2022 Mar 11:100253. https://doi.org/10.1016/j.phyplu.2022.100253

23. Wallert M, Bauer J, Kluge S, Schmölz L, Chen YC, Ziegler M et al.. The vitamin E derivative garcinoic acid from *Garcinia kola* nut seeds attenuates the inflammatory response. Redox Biology. 2019 Jun 1; 24:101166. https://doi.org/10.1016/j.redox.2019.101166

24. Attah AF, Fagbemi AA, Olubiyi O, Dada-Adegbola H, Oluwadotun A, Elujoba A, Babalola CP. Therapeutic potentials of antiviral plants used in traditional african medicine with COVID-19 in focus: a Nigerian perspective. Frontiers in Pharmacology. 2021 Apr 26; 12:596855. https://doi.org/10.3389/fphar.2021.596855

25. Ayepola OR, Cerf ME, Brooks NL, Oguntibeju OO. Kolaviron, a biflavonoid complex of *Garcinia kola* seeds modulates apoptosis by suppressing oxidative stress and inflammation in diabetes-induced nephrotoxic rats. Phytomedicine. 2014 Dec 15;21 (14):1785-93. https://doi.org/10.1016/j.phymed.2014.09.006

26. Burnham JF. Scopus database: A review. Biomedical digital libraries. 2006 Dec;3(1):1-8. https://doi.org/10.1186/1742-5581-3-1

27. George TT, Obilana AO, Oyenihi AB, Rautenbach FG. *Moringa oleifera* through the years: A bibliometric analysis of scientific research (2000-2020). South African Journal of Botany. 2021 Sep 1;141:12-24. https://doi.org/10.1016/j.sajb.2021.04.025

28. Yamaguchi F, Saito M, Ariga T, Yoshimura Y, Nakazawa H. Free radical scavenging activity and antiulcer activity of garcinol from *Garcinia indica* fruit rind. Journal of Agricultural and Food Chemistry. 2000 Jun 19;48(6):2320-25. https://doi.org/10.1021/jf990908c

29. Balasubramanyam K, Varier RA, Altaf M, Swaminathan V, Siddappa NB, Ranga U et al. Curcumin, a novel p300/CREB-binding protein-specific inhibitor of acetyltransferase, represses the acetylation of histone/nonhistone proteins and histone acetyltransferase-dependent chromatin transcription. Journal of Biological Chemistry. 2004;279 (49):51163-171. https://doi.org/10.1074/jbc.M409024200

30. Yun JH, Kang JM, Kim KS, Kim SH, Kim TH, Park YW et al. Health-related quality of life in Korean patients with chronic diseases. The Journal of the Korean Rheumatism Association. 2004;263-74.

31. Seeram NP. Berry fruits: compositional elements, biochemical activities and the impact of their intake on human health, performance and disease. Journal of Agricultural and Food Chemistry. 2008 Feb 13;56(3):627-29. https://doi.org/10.1021/jf071988k

32. Teng L, Zu Q, Li G, Yu T, Job KM, Yang X et al. Herbal medicines: challenges in the modern world. Part 3. China and Japan. Expert Review of Clinical Pharmacology. 2016 Sep 1;9 (9):1225-33. https://doi.org/10.1080/17512433.2016.1195263

33. Mukherjee PK, Harwansh RK, Bahadur S, Banerjee S, Kar A, Chanda J et al. Development of Ayurveda–tradition to trend. Journal of Ethnopharmacology. 2017 Feb 2;197:10-24. https://doi.org/10.1016/j.jep.2016.09.024

34. Job KM, Kiang TK, Constance JE, Sherwin CM, Enioutina EY. Herbal medicines: challenges in the modern world. Part 4. Canada and United States. Expert Review of Clinical Pharmacology. 2016 Dec 1;9(12):1597-609. https://doi.org/10.1080/17512433.2016.1238762

35. Emmanuel O, Uche ME, Dike ED, Etumnu LR, Ugbogu OC, Ugbogu EA. A review on *Garcinia kola* heckel: traditional uses, phytochemistry, pharmacological activities and toxicology. Biomarkers. 2022 Feb 17;27(2):101-17. https://doi.org/10.1080/1354750X.2021.2016974

36. Moongkarndi P, Kosem N, Luanratana O, Jongsomboonkusol S, Pongpan N. Antiproliferative activity of Thai medicinal plant extracts on human breast adenocarcinoma cell line. Fitoterapia. 2004 Jun 1;75(3):375-77. https://doi.org/10.1016/j.fitote.2004.01.010

37. Oguzie EE, Njoku VO, Enenebeaku CK, Akalezi CO, Obi C. Effect of hexamethylpararosaniline chloride (crystal violet) on mild steel corrosion in acidic media. Corrosion Science. 2008 Dec 1;50(12):3480-86. https://doi.org/10.1016/j.corsci.2008.09.017

38. Zein R, Suhaili R, Earnestly F, Munaf E. Removal of Pb (II), Cd (II) and Co (II) from aqueous solution using *Garcinia mangostana* L. fruit shell. Journal of Hazardous Materials. 2010 Sep 15;181(1-3):52-56. https://doi.org/10.1016/j.jhazmat.2010.04.076

39. Veerasamy R, Xin TZ, Gunasagaran S, Xiang TF, Yang EF, Jeyakumar N, Dhanaraj SA. Biosynthesis of silver nanoparticles using mangosteen leaf extract and evaluation of their antimicrobial activities. Journal of Saudi Chemical Society. 2011 Apr 1;15(2):113-20. https://doi.org/10.1016/j.jscs.2010.06.004

40. Koh JJ, Qiu S, Zou H, Lakshminarayanan R, Li J, Zhou X et al. Rapid bactericidal action of alpha-mangostin against MRSA as an outcome of membrane targeting. Biochimica et Biophysica Acta (BBA)-Biomembranes. 2013 Feb 1;1828(2):834-44. https://doi.org/10.1016/j.bbamem.2012.09.004

41. Yamaguchi F, Ariga T, Yoshimura Y, Nakazawa H. Antioxidative and anti-glycation activity of garcinol from *Garcinia indica* fruit rind. Journal of Agricultural and Food Chemistry. 2000 Feb 21;48(2):180-85. https://doi.org/10.1021/jf990845y

42. Farombi EO, Shrotriya S, Surh YJ. Kolaviron inhibits dimethyl nitrosamine-induced liver injury by suppressing COX-2 and iNOS expression via NF-κB and AP-1. Life Sciences. 2009 Jan 30;84(5-6):149-55. https://doi.org/10.1016/j.lfs.2008.11.012

43. Chen LG, Yang LL, Wang CC. Anti-inflammatory activity of mangostins from *Garcinia mangostana*. Food and Chemical Toxicology. 2008 Feb 1;46(2):688-93. https://doi.org/10.1016/j.fct.2007.09.096

44. Obileke K, Onyeaka H, Omoregbe O, Makaka G, Nwokolo N, Mukumba P. Bioenergy from bio-waste: a bibliometric analysis of the trend in scientific research from 1998–2018. Biomass Conversion and Biorefinery. 2020 Jul 6;1-6. https://doi.org/10.1007/s13399-020-00832-9

45. Salmerón-Manzano E, Manzano-Agugliaro F. The higher education sustainability through virtual laboratories: The Spanish University as case of study. Sustainability. 2018 Nov 4;10(11):4040. https://doi.org/10.3390/su10114040

46. Van Eck NJ, Waltman L. Citation-based clustering of publications using CitNet Explorer and VOS viewer. Scientometrics. 2017 May;111(2):1053-70. https://doi.org/10.1007/s11192-017-2300-7

47. Bastian M, Heymann S, Jacomy M. Gephi: an open-source software for exploring and manipulating networks. In: Proceedings of the international AAAI conference on web and social media. 2009 Mar 19;3((1): pp. 361-62. https://doi.org/10.1609/icwsm.v3i1.13937

48. Farombi EO, Tahnteng JG, Agboola AO, Nwankwo JO, Emerole GO. Chemoprevention of 2-acetylaminofluorene-induced hepatotoxicity and lipid peroxidation in rats by kolaviron—a *Garcinia kola* seed extract. Food and Chemical Toxicology. 2000 Jun 1;38(6):535-41. https://doi.org/10.1016/S0278-6915(00)00039-9

49. Voravuthikunchai SP, Kitpipit L. Activity of medicinal plant extracts against hospital isolates of methicillin-resistant *Staphylococcus aureus*. Clinical Microbiology and Infection. 2005 Jun 1;11(6):510-12. https://doi.org/10.1111/j.1469-0691.2005.01104.x

50. Moongkarndi P, Kosem N, Kaslungka S, Luanratana O, Pongpan N, Neungton N. Antiproliferation, antioxidation and induction of apoptosis by *Garcinia mangostana* (Mangosteen) on SKBR3 human breast cancer cell line. Journal of Ethnopharmacology. 2004 Jan 1;90(1):161-66. https://doi.org/10.1016/j.jep.2003.09.048

51. Mackeen MM, Ali AM, El-Sharkawy SH, Manap MY, Salleh KM, Lajis NH, Kawazu K. Antimicrobial and cytotoxic properties of some Malaysian traditional vegetables (ulam). International Journal of Pharmacognosy. 1997 Jan 1;35(3):174-78. https://doi.org/10.1076/phbi.35.3.174.13294

52. Yuliana ND, Jahangir M, Korthout H, Choi YH, Kim HK, Verpoorte R. Comprehensive review on herbal medicine for energy intake suppression. Obesity Reviews. 2011 Jul;12(7):499-514. https://doi.org/10.1111/j.1467-789X.2010.00790.x

53. Palapol Y, Ketsa S, Stevenson D, Cooney JM, Allan AC, Ferguson IB. Colour development and quality of mangosteen (*Garcinia mangostana* L.) fruit during ripening and after harvest. Postharvest Biology and Technology. 2009 Mar 1;51(3):349-53. https://doi.org/10.1016/j.postharvbio.2008.08.003

54. Jantan I, Harun NH, Septama AW, Murad S, Mesaik MA. Inhibition of chemiluminescence and chemotactic activity of phagocytes *in vitro* by the extracts of selected medicinal plants. Journal of Natural Medicines. 2011 Apr;65(2):400-05. https://doi.org/10.1007/s11418-010-0492-8

55. Poungchompu O, Wanapat M, Wachirapakorn C, Wanapat S, Cherdthong A. Manipulation of ruminal fermentation and methane production by dietary saponins and tannins from mangosteen peel and soapberry fruit. Archives of Animal Nutrition. 2009 Oct 1;63(5):389-400. https://doi.org/10.1080/17450390903020406

56. Otake T, Mori H, Morimoto M, Ueba N, Sutardjo S, Kusumoto IT et al. Screening of Indonesian plant extracts for anti-human immunodeficiency virus—type 1 (HIV-1) activity. Phytotherapy Research. 1995 Feb;9(1):6-10. https://doi.org/10.1002/ptr.2650090103

57. Chatatikun M, Chiabchalard A. Thai plants with high antioxidant levels, free radical scavenging activity, anti-tyrosinase and anti-collagenase activity. BMC Complementary and Alternative Medicine. 2017 Dec;17(1):1-9. https://doi.org/10.1186/s12906-017-1994-7

58. Pan MH, Chang WL, Lin-Shiau SY, Ho CT, Lin JK. Induction of apoptosis by garcinol and curcumin through cytochrome c release and activation of caspases in human leukemia HL-60 cells. Journal of Agricultural and Food Chemistry. 2001 Mar 19;49(3):1464-74. https://doi.org/10.1021/jf001129v

59. Matsumoto K, Akao Y, Kobayashi E, Ohguchi K, Ito T, Tanaka T et al. Induction of apoptosis by xanthones from mangosteen in human leukemia cell lines. Journal of Natural Products. 2003 Aug 22;66(8):1124-27. https://doi.org/10.1021/np020546u

60. Wathoni N, Shan CY, Shan WY, Rostinawati T, Indradi RB, Pratiwi R, Muchtaridi M. Characterization and antioxidant activity of pectin from Indonesian mangosteen (*Garcinia mangostana* L.) rind. Heliyon. 2019 Aug 1;5(8):e02299. https://doi.org/10.1016/j.heliyon.2019.e02299

61. Preuss HG, Bagchi D, Bagchi M, Rao CS, Dey DK, Satyanarayana S. Effects of a natural extract of (–) hydroxycitric acid (HCA SX) and a combination of HCA SX plus niacin bound chromium and *Gymnema sylvestre* extract on weight loss. Diabetes, Obesity and Metabolism. 2004 May;6(3):171-80. https://doi.org/10.1111/j.1462-8902.2004.00328.x

62. Chin YW, Jung HA, Chai H, Keller WJ, Kinghorn AD. Xanthones with quinone reductase-inducing activity from the fruits of *Garcinia mangostana* (Mangosteen). Phytochemistry. 2008 Feb 1;69(3):754-58. https://doi.org/10.1016/j.phytochem.2007.09.023

63. Adaramoye OA, Adeyemi EO. Hypoglycaemic and hypolipidaemic effects of fractions from kolaviron, a biflavonoid complex from *Garcinia kola* in streptozotocin-induced diabetes mellitus rats. Journal of Pharmacy and Pharmacology. 2006 Jan;58(1):121-28. https://doi.org/10.1211/jpp.58.1.0015

64. Suksamrarn S, Suwannapoch N, Phakhodee W, Thanuhiranlert J, Ratananukul P, Chimnoi N, Suksamrarn A. Antimycobacterial activity of prenylated xanthones from the fruits of *Garcinia mangostana*. Chemical and Pharmaceutical Bulletin. 2003;51 (7):857-59. https://doi.org/10.1248/cpb.51.857

65. Farombi EO, Abarikwu SO, Adedara IA, Oyeyemi MO. Curcumin and kolaviron ameliorate di-n-butylphthalate-induced testicular damage in rats. Basic and Clinical Pharmacology and Toxicology. 2007 Jan;100(1):43-48. https://doi.org/10.1111/j.1742-7843.2007.00005.x

66. Mohamed GA, Al-Abd AM, El-Halawany AM, Abdallah HM, Ibrahim SR. New xanthones and cytotoxic constituents from *Garcinia mangostana* fruit hulls against human hepatocellular, breast and colorectal cancer cell lines. Journal of Ethnopharmacology. 2017 Feb 23;198:302-12. https://doi.org/10.1016/j.jep.2017.01.030

67. Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research. 2021 Sep 1;133:285-96. https://doi.org/10.1016/j.jbusres.2021.04.070

68. Van Eck NJ, Waltman L. Citation-based clustering of publications using CitNetExplorer and VOSviewer. Scientometrics. 2017 May;111(2):1053-70. https://doi.org/10.1007/s11192-017-2300-7

69. Andersen SZ, Čolić V, Yang S, Schwalbe JA, Nielander AC, McEnaney JM et al. A rigorous electrochemical ammonia synthesis protocol with quantitative isotope measurements. Nature. 2019 Jun;570(7762):504-08. https://doi.org/10.1038/s41586-019-1260-x

70. Munoz-Leiva F, Porcu L, Barrio-García SD. Discovering prominent themes in integrated marketing communication research from 1991 to 2012: A co-word analytic approach. International Journal of Advertising. 2015 Aug 8;34(4):678-701. https://doi.org/10.1080/02650487.2015.1009348

71. del Barrio-Garcia S, Munoz-Leiva F, Golden L. A review of comparative advertising research 1975–2018: Thematic and citation analyses. Journal of Business Research. 2020 Dec 1;121:73-84. https://doi.org/10.1016/j.jbusres.2020.08.023