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ORIGINAL ARTICLE

Chemistry journals and research trends in Arab countries: A bibliometric analysis

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Abstract Arab countries have been working hard to establish centers of research excellence and industrial clusters, especially in chemistry, based on the best technologies and practices. It is of utmost importance for decision-makers and academics to estimate the extent of chemistry research progress in Arab countries which differ substantially in economic development and graduate and postgraduate education. This study aims to highlight the current chemistry research trends and analyze chemistry journals in Arab countries. The citation rates, H-Index, SJR (Scimago Journal and Country Rank), and co-occurrence of keywords and authorship were compared between chemistry journals that are published by Arab countries and those published by the rest of the world between 1996 and 2022, referring to SJR report. Saudi Arabia and Egypt are the Arab countries with the largest citations number, published documents, and SJR indicators. Despite Arab countries' efforts to promote scientific research and build industrial clusters, the comparison of Arab countries to the rest of the world revealed that the Arab countries' SJR, H-index, citations per document in the previous two years, and total citations in the last three years are statistically significantly lower than those of the rest of the world. Many topics, such as nanoparticles, graphene, drug delivery, and molecular docking, are addressed by Arab countries as well as by the rest of the world. Arab countries, on the other hand, are more interested in nanoparticles than the rest of the world, which is more interested in catalysis. To strengthen their impact on the chemistry research field, Arab countries should intensify their collaboration with the rest of the world and focus on more centered topics.

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1. Introduction

Chemistry, the science that studies matter and its transformations, describes and predicts the variety and complexity of atomic or molecular assemblies to understand, adjust and optimize their properties. Chemistry has always been enriched by strong interactions with neighboring disciplines such as physics, biology, pharmacy, environment, and ecology. These interactions have been established thanks to modeling and simulation, spectroscopy, and analytical methods and their applications. Research in chemistry covers a whole panorama ranging from basic research to industrial applications and processes, in a thematic continuum that ignores disciplinary boundaries.

Research in Chemistry has evolved rapidly with significant changes in laboratory structures, tools, indicators, objectives, and funding. These developments are driven by each state through laws, funding agencies or evaluation agencies, and research strategies as well as by private institutions. They are implemented by researchers (universities and organizations), engineers, technicians, and departments of the various units. Collaboration with industry is inseparable from basic chemistry research. The research teams conduct numerous bilateral collaborations based above all on personal relationships between researchers and engineers from both the academic and industrial worlds that allows a reciprocal sharing of expertise and knowledge. Academic research laboratories are also involved in schemes geared towards the socio-economic valorization of research results.

Competitiveness and development considerably contribute to the dynamism of research activities and technological innovation. Scientific publications in well-recognized journals play a key role in the diffusion of research results. The methods that can be used for screening the diffusion impact of the research results are mainly the published peer-reviewed articles and the bibliometric analysis (Waast and Rossi, 2010). Scientific production is a powerful indicator used to evaluate scientific and technological development. Bibliometric analysis is a quantitative study of published data. It applies statistics for the quantitative evaluation of literature to analyze the publishing trends in a specific research area and to highlight the impact of scientists, journals, and articles (Gonçalves et al. 2019). This analytical approach assesses research performance, identifies research needs, and allocates resources. It is also utilized to aid in decision-making.

The Arab region consists of 22 countries in the Middle East and North Africa, with a combined population of approximately 456 million people constituting 5.5% of the world's population (World Bank, 2021). Arab countries share cultural and linguistic ties but differ in education, resources, economy, and development (World Bank, 2021). It is of utmost importance to evaluate the chemistry research development in areas where Arab countries prioritize higher education and scientific research and implement several programs to make Arab people internationally competitive, and where disparities in scientific research output between Arab countries are significant (Al-Omari et al. 2022; El Ansari et al. 2022; Rahaman and Ansari, 2022). The disparities in scientific research are due to a variety of factors, including insufficient budgets, poor infrastructure, and limited coordination (Zebakh et al. 2022).

Bibliometric analysis has been discussed in several previous studies, including system soil chemical (Hirawan et al. 2022), green chemistry teaching (Riandi et al. 2022), chemical engineering (Nandiyanto et al. 2021), chemistry industry research (Kurniati et al. 2022), and computational chemistry (Saputra et al. 2022). However, as far as the authors are aware, there have been few studies on bibliometric and mapping analyses in the field of chemical research, particularly in Arab countries. Mapping analysis is necessary for establishing the research trend, quantity, and timeliness of a term. The present work aims to identify the Arab countries that have the largest number of scientific publications and citations in the chemistry area. It aims also to indicate the metrics differences in the publication output between Arab countries and the rest of the world allowing researchers to outline the current research trends in chemistry and helping them to identify the active research areas in chemistry and the most central nations with which they should intensify their collaboration.

2. Methodology

Scimago Journal and Country Rankings were utilized as information sources for data collection in the present work. This freely accessible portal provides scientific journals and national indicators from the Scopus database (Elsevier B.V.). The countries' number of publications and citations, as well as the journals SJR, H-index, citations per document in the previous two years, and total citations over the last three years were selected using the following parameters:

Subject areas: Chemistry.

Subject category: All subject categories (which include Chemistry (miscellaneous), Electrochemistry, Analytical Chemistry, Organic and Inorganic Chemistry, Physical and Theoretical Chemistry, and Spectroscopy).

Region: Arab countries (The results obtained for the Arab countries were compared with those of the rest of the world considering the journals included in Scimago Journal and Country Rankings (SJR) and do not belong to the Arab region).

Period: 1996–2022 (and 2022 for journal rankings)

Types: Journals (we exclude Book Series, Conferences and Proceedings, and Trade journals).

The IBM® SPSS® statistics (version 23.0, 2015, Armonk, NY, USA) software was used to analyze the Kolmogorov-Smirnov normality test, the Levene's test of variance homogeneity, and the Wilcoxon rank-sum test. The Cullen and Frey graphs were created with the free statistics software https://www.wessa.net (Wessa, 2022) to compare the metrics' distributions and to determine the distribution properties when the null hypothesis of the normal distribution was rejected by the appropriate test. We tested the following null hypotheses:

$H1_0$. The H-index does not differ between Arab countries and the rest of the world.

$H2_0$. The SJR distribution does not differ between Arab countries and the rest of the world.

$H3_0$. The number of citations per document does not differ between Arab countries and the rest of the world.

$H4_0$. The number of total citations does not differ between Arab countries and the rest of the world.

Scopus database was utilized to extract the commonly used keywords in chemistry for the co-occurrence network study. The time limit was selected to include years of publication between 1996 and 2022. Only final published studies or review papers in English published in journals in the subject area of chemistry were considered. This means that other document types (such as conference proceedings, book chapters, or books) or languages were excluded. A total of 839,653 document results were collected of which the first 2,000 of the highly cited papers were evaluated. This limit is not considered a problem to determine the H-index and the rate of citations or items of the complete database provided by Scopus (Jacso,

2011). The search for the co-occurrence of keywords in Arab journals was restricted to Arab countries. Arab countries, on the other hand, were omitted from the rest of the world's keyword co-occurrence search. The co-occurrence networks were analyzed using VOSviewer software version 1.6.18 on the first 2000 of the highly cited documents selected with a minimum of five occurrences of a keyword. VOSviewer is a free software used for creating and displaying bibliometric networks which include researchers, journals, and individual articles (Van Eck and Waltman, 2013). These networks can be constructed via bibliographic coupling and citation (i.e., co-citation or co-authorship relationships) collected from the scientific literature.

3. Results

3.1. Volume of published papers and citations

Arab countries, selected from the category SJR-All regions/-countries (Arab countries), ordered according to the volume of papers published and the number of citations between 1996 and 2022 are listed in Fig. 1. Egypt easily took the first position in the top five of the countries that publish the most, with a total of 52,811 published documents, accounting for 29.72% of all Arab countries' total documents (Fig. 1a). Saudi Arabia came in second with a total of 51,551 documents published (29.00%). Algeria and Tunisia came in third and fourth positions, with 11,656 (6.56%) and 11,598 (6.53%) documents, respectively. Morocco was ranked at the last position in the top five, with 11,255 (6.63%) papers. The countries (Algeria, Tunisia, and Morocco) had a regular and homogeneous volume of production. Egypt and Saudi Arabia, on the other hand, stand out with 29.72% and 29.00% of published documents, respectively. It is worth mentioning that Egypt and Saudi Arabia accounted for more than 58% of all documents published, compared to 19.42% of the remaining top five countries. Furthermore, the top five Arab countries (Egypt, Saudi Arabia, Algeria, Tunisia, and Morocco) supplied more than 78% of all Arab documents generated.

Besides the number of citations and the corresponding percent, each Arab country's H-index is also provided in parentheses in Fig. 1b. The H-index is defined as the number of articles (H) in a country having at least (H) citations. In the top five, we found Saudi Arabia in first place with 1,177,794 citations (36.14% of total citations in Arab countries) and an H-index of 314, Egypt in second place with 904,197 citations (27.75%) and an H-index of 208, Tunisia with 188,489 citations (5.78%), and an H-index of 127, Morocco with 187,660 citations (5.76%) and an H-index of 137, and Algeria in fifth place with 171,447 citations (5.26%) and an H-index of 125 (Fig. 1b). The countries ranked from third to fifth place (Tunisia, Morocco, and Algeria) had a regular and uniform volume of citations; nevertheless, Saudi Arabia stands out with 36.14% of total scientific production citations, followed by Egypt with 27.75%. The remaining Arab countries provided 16.8% of the total scientific production citations.

3.2. Chemistry journals in Arab countries

One can find 21 journals from Arab countries from 970 chemistry journals featured in SJR for the year 2022. Three of these 21 journals belong to the first quartile (Q1) which are the Arabian Journal of Chemistry (Open Access, Saudi Arabia), Current Medicinal Chemistry (United Arab Emirates), and Journal of Saudi Chemical Society (Open Access, Saudi Arabia). Table 1 lists the chemistry journals from Arab countries included in Scimago Journal Rankings (1996–2022). In addition, eight journals of the Arab countries are from the Arab Emirates and published by Bentham Science Publishers B.V., four journals belong to Egypt (two are open-access journals published by Hindawi Limited, and two journals are published by Egyptian institutes or research centers). Also, five journals belong to Iraqi universities or societies (the University of Baghdad, the University of Kerbala, and the Iraqi Society for Alternative and Renewable Energy Sources and Techniques) and two journals belong to Morocco (published by the University Mohammed Premier Oujda and Moroccan Institute of Scientific and Technical Information).

3.3. Distributions of the H-index, SJR, citations per document, and total citations

Kolmogorov-Smirnov and Shapiro-Wilk normality tests showed that the distributions of the H-index for the Arab countries and the rest of the world were not normally distributed (i.e., for both cases $p < 0.01$). The Cullen and Frey graph indicates that the H-index distribution of journals from the Arab countries can be described by a beta distribution (Fig. 2a), with min = 2, max = 192, median = 29, mean = 43.98, standard deviation = 45.02, skewness = 1.84, and kurtosis = 3.37. However, the H-index distribution of journals from the rest of the world was close to a gamma distribution (Fig. 2b), with min = 1, max = 790, median = 50.00, mean = 77.81, standard deviation = 86.76, skewness = 2.90, and kurtosis = 13.14.

The homogeneity of variances of the H-index was examined by Levene's test. It was found that the H-index variances of the Arab countries and the rest of the world were not homogeneous ($p = 0.000$). According to the Wilcoxon rank-sum test, the Arab countries' H-index was significantly lower than that of the rest of the world, with $Z = -10.233$ and $p = 0.000$.

SJR indicator is a good option for journal evaluation because it aims to measure the current "average prestige per paper" used in the evaluation processes of journals (Guz and Rushchitsky, 2009). Kolmogorov-Smirnov and Shapiro-Wilk normality tests demonstrated that the SJR distributions for Arab countries and the rest of the world were not normally distributed, where p is lower than 0.01 in both cases. As can be depicted from the Cullen and Frey graph (Fig. 2c), the SJR distribution of journals from Arab countries can be described by a beta distribution, where min = 0.14, max = 0.85, median = 0.26, mean = 0.35, standard deviation = 0.20, skewness = 1.43, and kurtosis = 0.90. However, the SJR distribution of journals from the rest of the world was close to a gamma distribution (Fig. 2d), where min = 0.1, max = 18.91, median = 0.27, mean = 0.63, standard deviation = 1.25, skewness = 8.54, and kurtosis = 106.33.

Levene's test indicated that SJR variances for Arab countries and the rest of the world are different (i.e., $p = 0.001$). In the case where SJR variances are not equal, one can only test for the mean differences. The Wilcoxon rank-sum test proved that the SJR of Arab countries was significantly lower

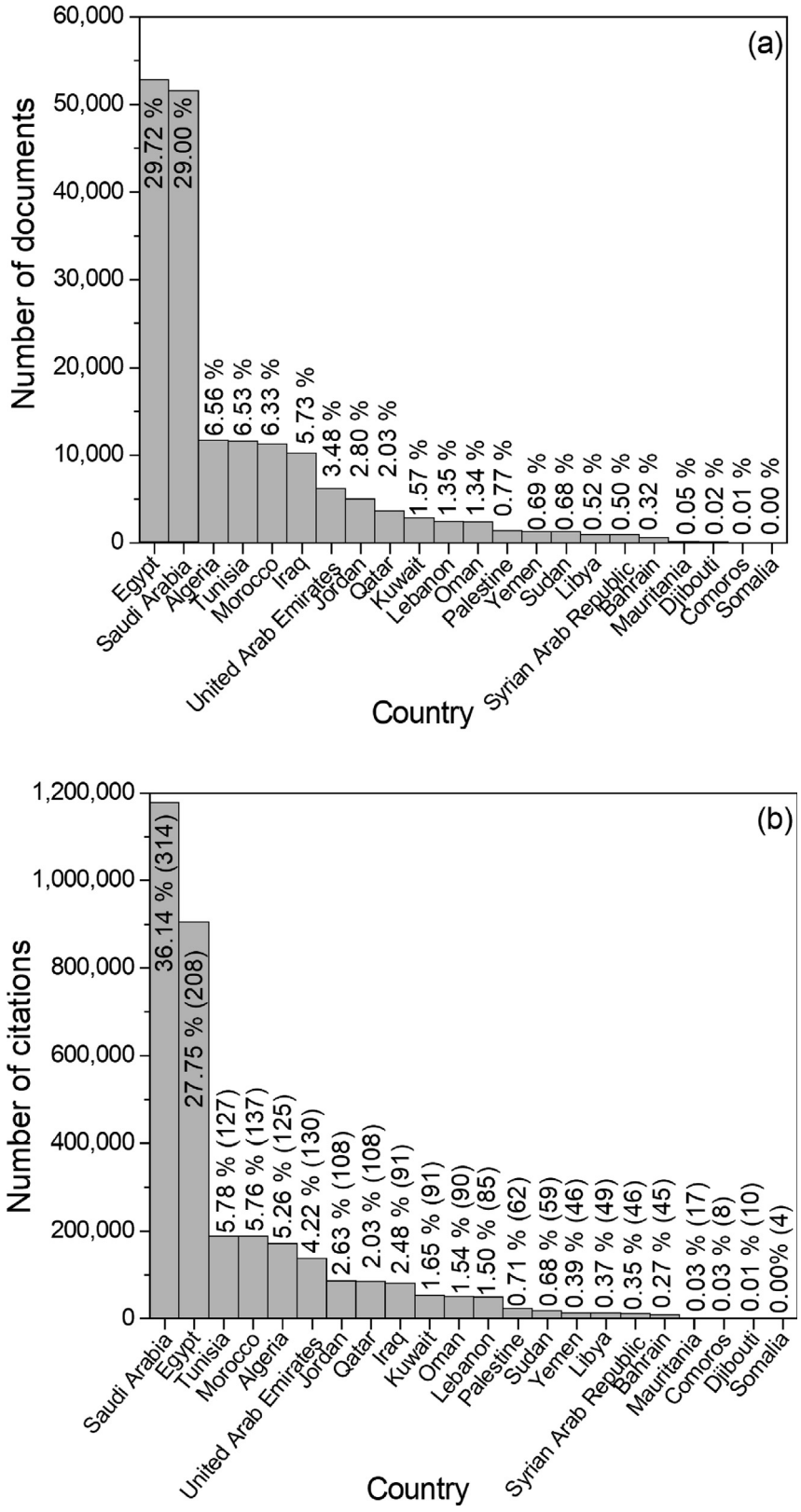


Fig. 1 Arab countries, selected from the category SJR-All regions/countries (Arab countries), ordered according to (a) the volume of papers published and (b) the number of citations between 1996 and 2022. The corresponding percent and the H-index in parentheses are also indicated.

Table 1 Arab countries journals in chemistry area (2022).

Rank	Title	SJR	SJR Quartile	H-index	Total docs. (3 years)	Total citations (3 years)	Country	Publisher
1	Arabian Journal of Chemistry (Open Access)	0.850	Q1	100	1683	11,740	Saudi Arabia	King Saud University
2	Current Medicinal Chemistry	0.776	Q1	192	1214	5194	United Arab Emirates	Bentham Science Publishers B.V.
3	Journal of Saudi Chemical Society (Open Access)	0.742	Q1	67	327	1827	Saudi Arabia	King Saud University
4	Egyptian Journal of Petroleum (Open Access)	0.619	Q2	55	115	516	Egypt	Egyptian Petroleum Research Institute
5	Current Organic Chemistry	0.407	Q3	110	417	1056	United Arab Emirates	Bentham Science Publishers B.V.
6	Current Organic Synthesis	0.377	Q3	53	208	502	United Arab Emirates	Bentham Science Publishers B.V.
7	Mini-Reviews in Organic Chemistry	0.370	Q3	42	191	457	United Arab Emirates	Bentham Science Publishers B.V.
8	International Journal of Analytical Chemistry (Open Access)	0.323	Q3	26	192	379	Egypt	Hindawi Limited
9	Current Analytical Chemistry	0.305	Q3	36	293	566	United Arab Emirates	Bentham Science Publishers B.V.
10	Combinatorial Chemistry and High Throughput Screening	0.271	Q3	68	359	568	United Arab Emirates	Bentham Science Publishers B.V.
11	Journal of Spectroscopy (Open Access)	0.268	Q3	29	129	270	Egypt	Hindawi Limited
12	Egyptian Journal of Chemistry	0.259	Q3	24	1384	2317	Egypt	NIDOC (Nat. Inform. Document. Centre)
13	Moroccan Journal of Chemistry	0.257	Q3	10	239	309	Morocco	University Mohammed Premier Oujda
14	Current Organocatalysis	0.255	Q3	15	82	137	United Arab Emirates	Bentham Science Publishers B.V.
15	Iraqi Journal of Science (Open Access)	0.250	Q3	11	1234	995	Iraq	University of Baghdad
16	Karbala International Journal of Modern Science (Open Access)	0.234	Q3	24	119	188	Iraq	University of Kerbala
17	Baghdad Science Journal (Open Access)	0.230	Q3	10	478	397	Iraq	University of Baghdad
18	Iraqi Journal of Applied Physics	0.186	Q4	2	22	7	Iraq	Iraqi Society for Alternative and Renewable Energy Sources and Techniques
19	Letters in Organic Chemistry	0.186	Q4	32	363	315	United Arab Emirates	Bentham Science Publishers B.V.
20	Iraqi Journal of Pharmaceutical Sciences (Open Access)	0.172	Q4	6	168	129	Iraq	University of Baghdad - College of Pharmacy
21	Arabian Journal of Medicinal and Aromatic Plants	0.141	Q4	2	25	11	Morocco	Moroccan Institute of Scientific and Technical Information

than the SJR of the rest of the world, with $Z = -11.494$ and $p = 0.000$.

Kolmogorov-Smirnov and Shapiro-Wilk normality tests indicated that the citations per document distributions in the previous two years of the Arab countries and the rest of the world were not normally distributed (i.e., $p < 0.02$ in both cases). The Cullen and Frey graph presented in Fig. 2e indicates that the distribution of the citations per document for the Arab countries can be described by a beta distribution, with min = 0.32, max = 6.72, median = 1.66, mean = 2.07,

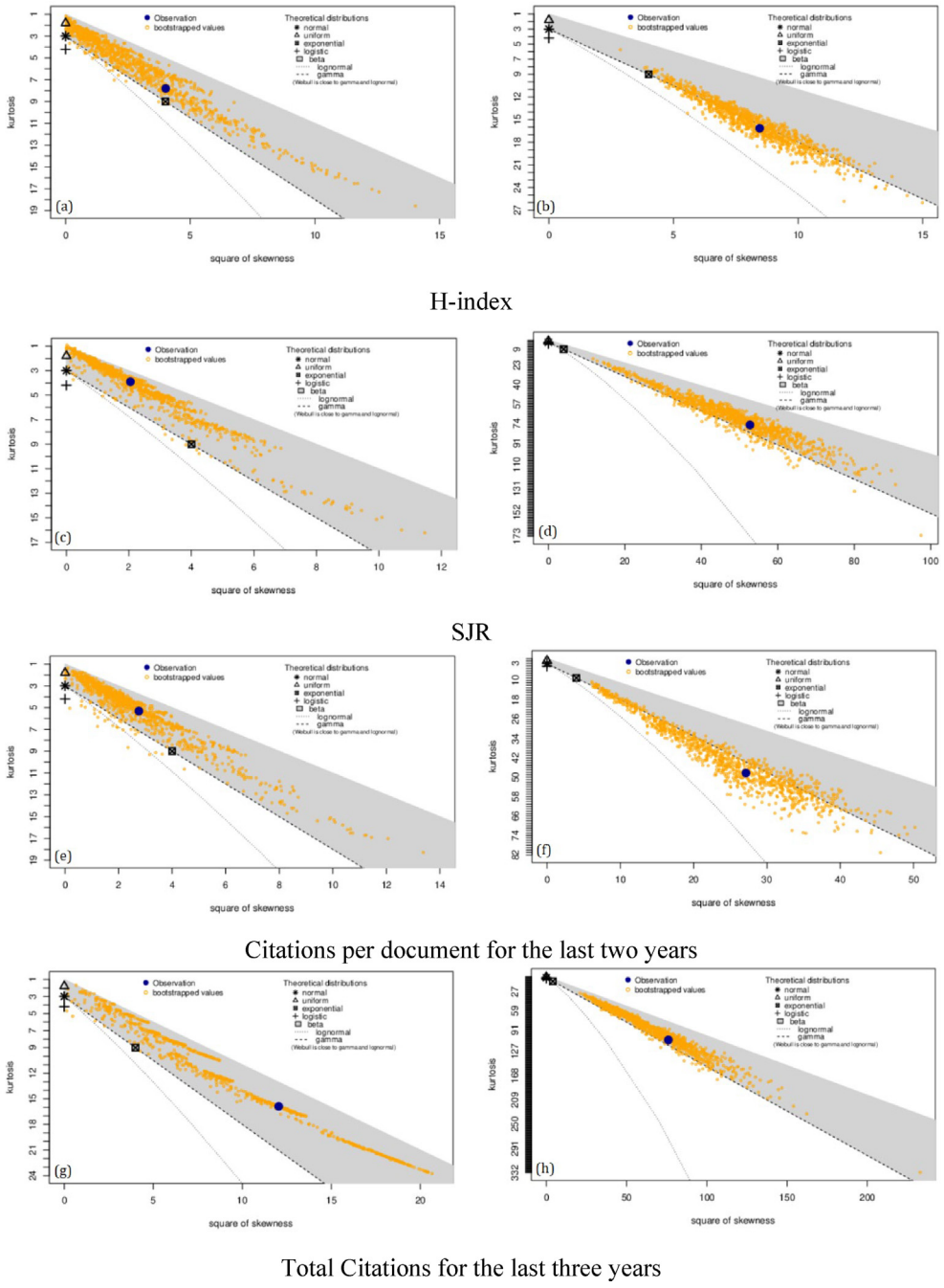


Fig. 2 Cullen and Frey graphs of the (a,b) H-index, (c,d) SJR, (e,f) citations per document and (g,h) total citations of journals from Arab countries (on the left side) and the rest of the world (on the right side).

standard deviation = 1.70, skewness = 1.66, and kurtosis = 2.31. The citations per document distribution of journals from the rest of the world cannot be described by the normal, beta, gamma, or lognormal distribution (Fig. 2f), with min = 0.00, max = 58.37, median = 2.47, mean = 3.45, standard deviation = 4.36, skewness = 5.20, and kurtosis = 45.24.

Levene's test indicated that the variances of the citations per document of the Arab countries and the rest of the world were not homogeneous (p = 0.000). According to the Wilcoxon rank-sum test, the citations per document of the Arab countries were statistically significantly lower than those of the rest of the world, with Z = − 8.592 and p = 0.000.

Kolmogorov-Smirnov and the Shapiro-Wilk normality tests demonstrated that the total citation distributions in the last three years for the Arab countries and the rest of the world group were not normally distributed (in both cases $p < 0.01$). The Cullen and Frey graph presented in Fig. 2g indicates that the distribution of the citations per document from the Arab countries can be described by a beta distribution, where min = 7, max = 11,740, median = 457.00, mean = 1327.61, standard deviation = 2651.53, skewness = 3.47, and kurto-

sis = 12.88. The distribution of citations per document of journals from the rest of the world was close to the gamma distribution (Fig. 2h), where min = 0.0, max = 301,272, median = 743.00, mean = 5389.95, standard deviation = 18,240.72, skewness = 8.71, and kurtosis = 104.94.

According to Levene's test, the variances of the total citations of the Arab countries and the rest of the world for the previous three years were not homogeneous (p = 0.000). The Wilcoxon rank-sum test demonstrated that the total citations of the previous three years of the Arab countries were statistically significantly lower than those of the rest of the world, with Z = -7.816 and p = 0.000.

The distributions of the H-index, SJR, citations per document for the last two years, and total citations for the last three years across Arab countries and the rest of the world and a comparison of these metric parameters between all regions are given in Fig. 3. To conclude, the metric parameters evaluated herein were not normally distributed and the comparison

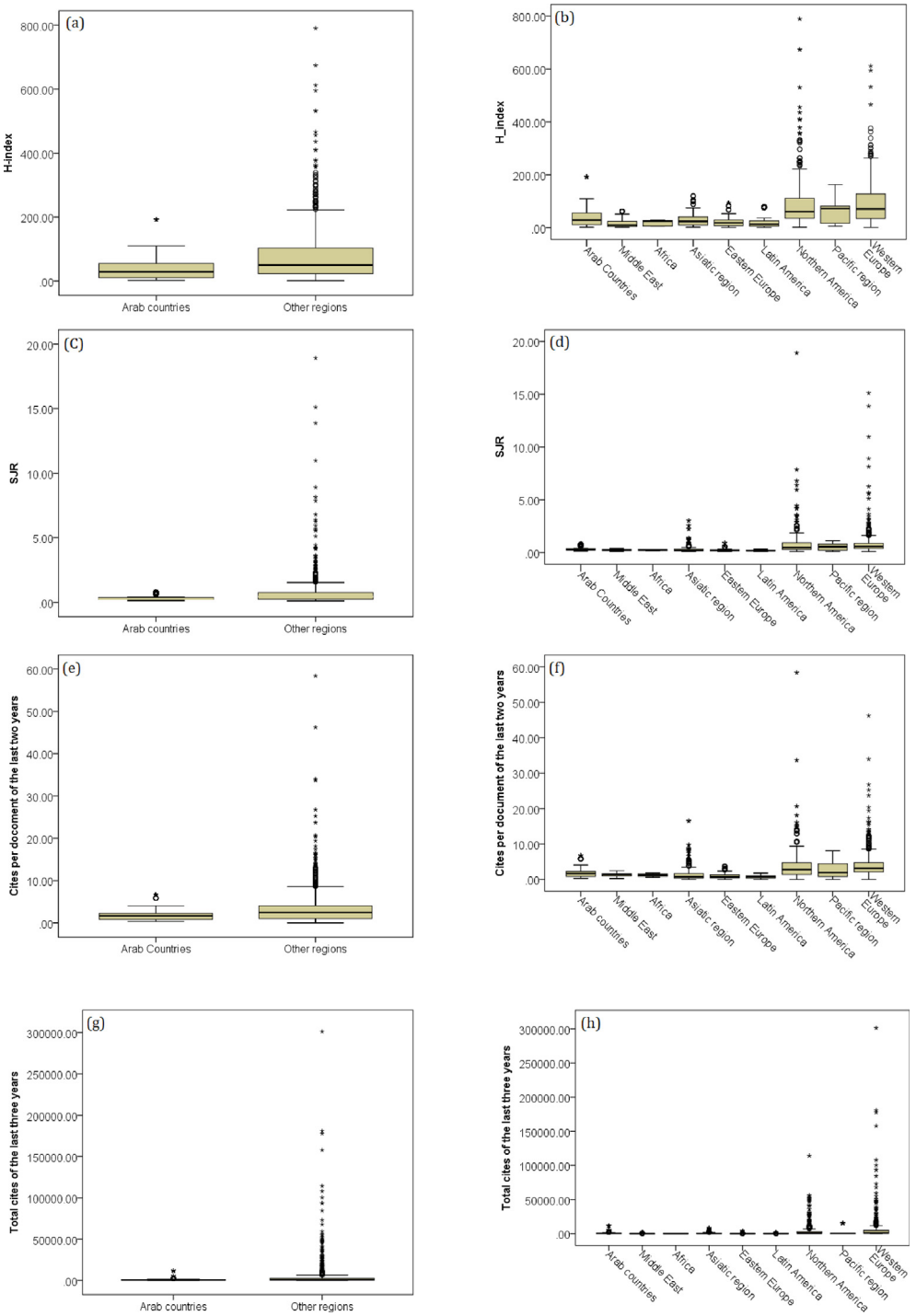


Fig. 3 Distributions (on the left side) and Global comparison between all regions (on the right side) of the (a,b) H-index, (c,d) SJR, (e,f) citations per document and (g,h) total citations of journals of the Arab countries and the rest of the world.

between Arab countries and the rest of the world showed that all these parameters were statistically significantly lower than those of the rest of the world. This indicates that the impact of Arab chemistry journals is less significant than that of journals of the rest of the world.

3.4. Journals published by academic institutions in Arab Countries.

The quality of scientific research and academic activities can be highlighted by the rankings of the publishers when scientific journals are published by academic institutions. Table 2 summarizes the linkages between Arab chemistry journals and academic institutions together with the Academic Ranking of Global Universities (ARWU) 2022, QS 2022 metrics, and QS Arab Ranking 2023. The Arabian's top two chemistry journals in Arab countries belong to Saudi universities ranked in the top 101–150 positions of ARWU 2022, the top 237 of the QS World University Rankings 2022, and the fourth position in QS Arab Ranking 2023.

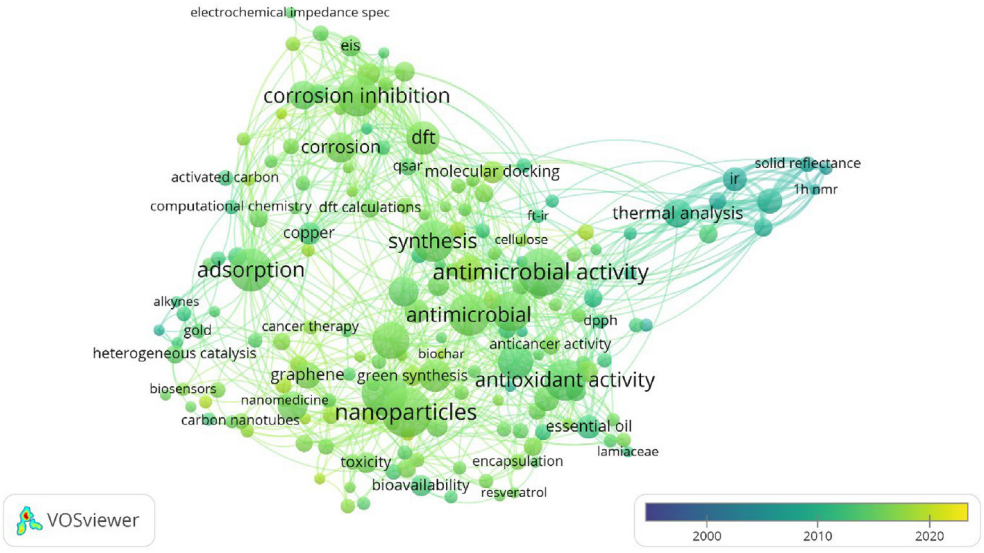
3.5. Co-occurrence of keywords.

Between 1996 and 2022, 4936 author keywords were found in chemical articles from Arab countries. After refining the data in VOSviewer by merging similar words and setting the minimum occurrences to 5, it was found that 181 keywords met the criterion. Chemical publishing keywords in Arab countries were classified into 9 major clusters (Fig. 4a) which were antibacterial and antimicrobial activities, antioxidant activity, adsorption, nanoparticles, corrosion, syntheses, thermal analysis, molecular docking, and DFT calculation. These different clusters linked the most occurred keywords. The term "nanoparticles" was the most frequently occurring, with 40 occurrences and 46 links. 'Antimicrobial activity' was the second-used keyword with 38 occurrences and 58 links. The third important keyword, which was "adsorption", had 32 occurrences and 51 links. The term "antioxidant activity" had 31 occurrences and 48 links. The keyword "synthesis" occurred 30 times and linked 27 keywords, and the term "antibacterial" had an occurrence of 29 and 37 links. The term "silver nanoparticle" occurred 26 times and linked 37 keywords. The keyword "antioxidant" occurred 24 times and linked 30 keywords. The keyword "corrosion" had an occurrence of 20 and 43 links. The terms "drug delivery" and "cytotoxicity" occurred 19 times and linked 22 and 18 keywords, respectively. The keywords "thermal analysis" and "mild steel" occurred 18 times and linked 63 and 48 keywords, respectively. The keyword "anticancer" occurred 17 times and linked 23 keywords, and the keyword "graphene" had an occurrence of 16 and 12 links. The term "phenolic compound" occurred 15 times and linked 17 keywords. The term "essential oil" and "apoptosis" had an occurrence of 14 and had 20 and 19 links, respectively. The keywords "flavonoids" and "gold nanoparticles" occurred 12 times and linked 13 keywords. The terms "biosensor", "dft calculation" and "heterogeneous catalysis" occurred 10 times and had 12, 13, and 11 links, respectively. The keywords "nanotechnology" and "nanocomposite" occurred 9 times and had 13 and 12 links, respectively. The term "metal–organic framework" occurred 8 times and linked 5 keywords. The keywords related to water treatment had fewer occurrences, i.e., the terms "wastewater" and "water treatment" occurred 6 times and had 3 links, and the term "membrane distillation" occurred 5 times and linked 2 keywords.

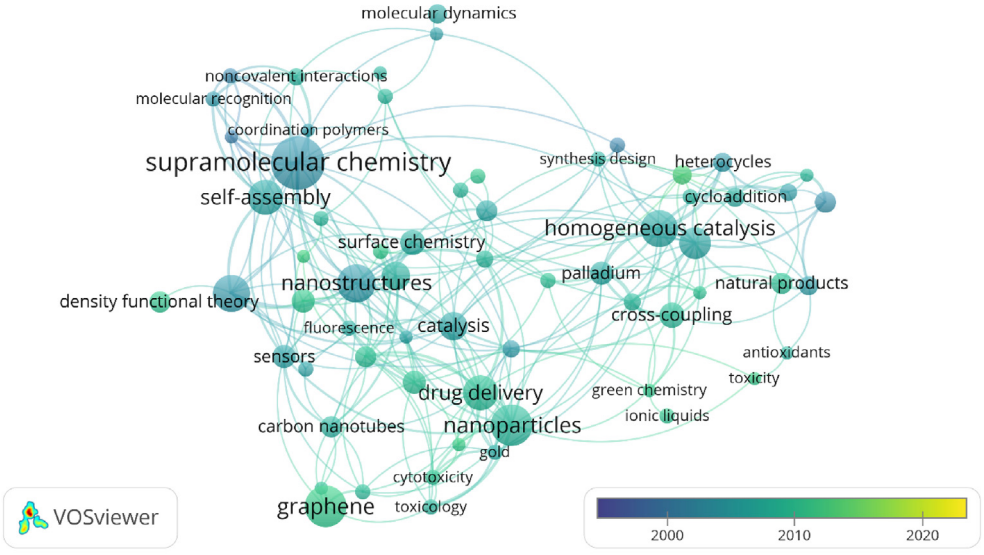
In the rest of the world, a total of 1990 author keywords were detected in chemistry publications. Only 69 keywords reached the threshold of 5 occurrences. These keywords were grouped into 8 main clusters which were catalysis, supramolecular chemistry and molecular dynamics, nanostructure and nanoparticles, graphene, drug delivery, adsorp-

Table 2 Arab chemistry journals together with academic institutions in Arab countries, the Academic Ranking of Global Universities (ARWU) 2022, QS 2022 metrics and QS Arab ranking 2023.

Rank	Title	Country	Publisher	ARWU 2022	QS 2022	QS Arab ranking
1	Arabian Journal of Chemistry (Open Access)	Saudi Arabia	King Saud University	101–150	237	4 (2023)
2	Journal of Saudi Chemical Society (Open Access)	Saudi Arabia	King Saud University	101–150	237	4 (2023)
3	Egyptian Journal of Petroleum (Open Access)	Egypt	Egyptian Petroleum Research Institute			
4	Egyptian Journal of Chemistry	Egypt	NIDOC (Nat. Inform. Document. Centre)			
5	Moroccan Journal of Chemistry	Morocco	University Mohammed Premier Oujda			131–160 (2021)
6	Iraqi Journal of Science (Open Access)	Iraq	University of Baghdad	801–1000		40 (2023)
7	Karbala International Journal of Modern Science (Open Access)	Iraq	University of Kerbala			151–170 (2023)
8	Baghdad Science Journal (Open Access)	Iraq	University of Baghdad	801–1000		40 (2023)
9	Iraqi Journal of Pharmaceutical Sciences (Open Access)	Iraq	University of Baghdad	801–1000		40 (2023)
10	Arabian Journal of Medicinal and Aromatic Plants	Morocco	Moroccan Institute of Scientific and Technical Information			



(a)



(b)

Fig. 4 Network visualization based on the time for author's keywords in chemistry for (a) Arab countries and (b) the rest of the world.

tion, and cross-coupling (Fig. 4b). The term "supramolecular chemistry" was the most frequently occurred, with 29 occurrences and 44 links. The keywords "nanoparticles" and "nanostructure" occupied the second and third places of the most used keywords with respectively, 21 and 19 occurrences and 32 and 31 links. The third place was also occupied by the keyword "graphene" which occurred 21 times and linked 7 keywords. Several keywords related to catalysis had high occurrences such as "homogeneous catalysis" which had 18 occurrences and 24 links, "catalysis" which had 13 occurrences and 13 links, "heterogeneous catalysis" and "asymmetric catalysis" which occurred 9 times and linked to 9 keywords and "organocatalysis" which had 5 occurrences and 7 links. The keywords "drug delivery" and "self-assembly" linked 27 and 26 other keywords, respectively with 17 occurrences. The keyword "synthetic method" occurred 15 times and linked 27 keywords, and the keyword "synthetic design" had an occurrence of 6 and 8 links. The term "polymers" had an occurrence of 13 and 18 links. The keywords "cross-coupling" and "surface chemistry" had 11 occurrences and 19 and 12 links, respectively. The keywords "palladium", "sensors", "phenolics", "semiconductors" and "antioxidant" occurred 10 times and linked to 21, 17, 11, 10, and 8 keywords, respectively. The keywords "natural product" and "antioxidant activity" linked 10 and 4 other keywords, respectively with 9 occurrences. The keyword

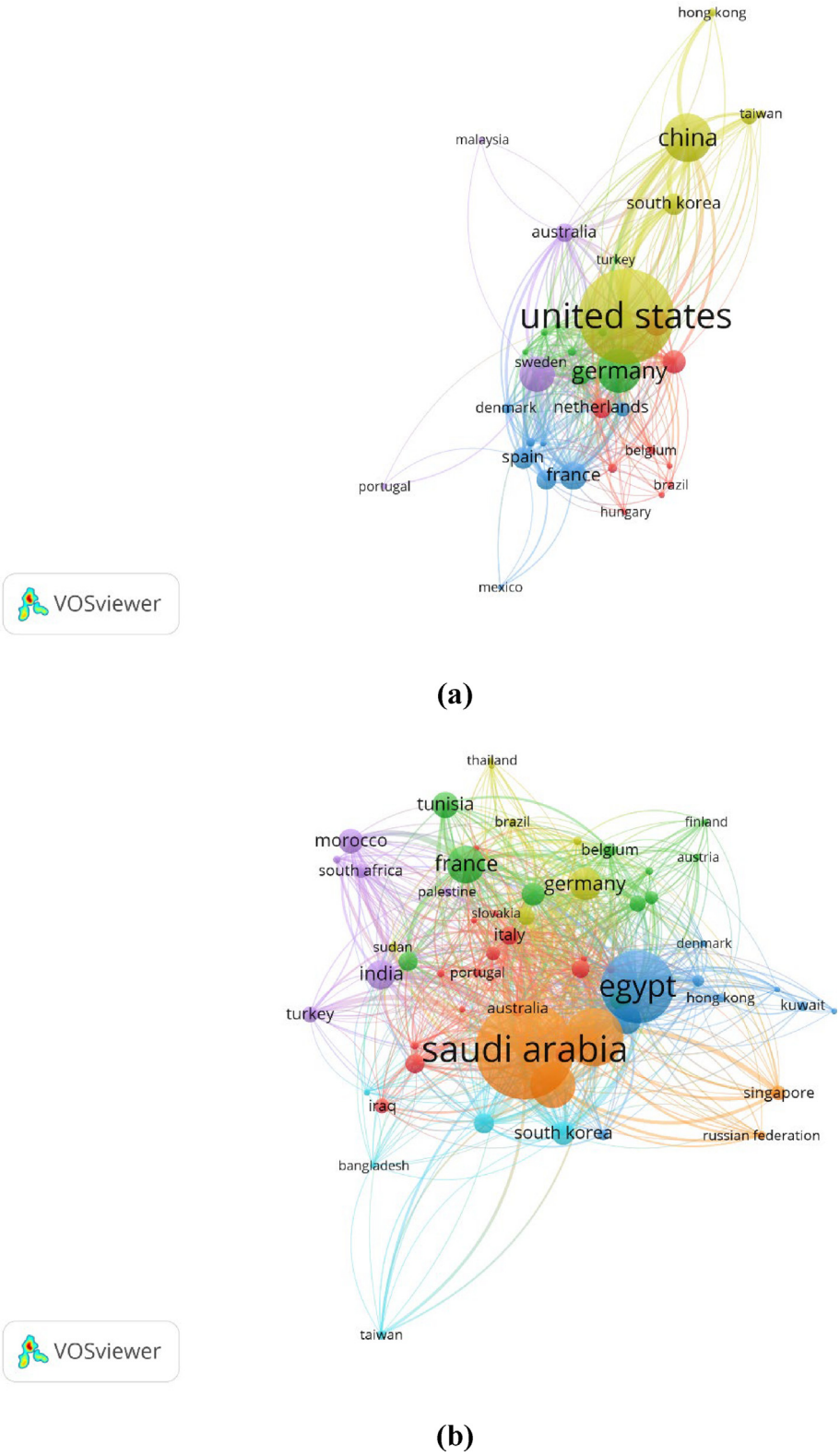


Fig. 5 Network visualization of the co-authorship for (a) Arab countries and (b) the rest of the world.

"molecular dynamics" occurred 8 times and linked one keyword, and the keyword "adsorption" had an occurrence of 6 and 2 links. The keywords "drug design" and "toxicity" had 5 occurrences and 5 and 3 links, respectively.

4. Discussion

Saudi Arabia and Egypt have the largest number of published documents as well as the number of cited documents according

to data collected from SJR. Saudi Arabia currently has 29 public universities and 16 private universities. Of these 45 universities, 14 institutions are included in the QS World University Rankings® 2023. All public universities of Saudi Arabia are present in the QS Arab Region University Rankings, among which three are within the top ten. King Abdulaziz University (KAU) in Saudi Arabia holds the title of the best university in the Arab region. Furthermore, Saudi Vision 2030 intends to showcase the country's skills and strong points to enable the Kingdom to maintain its pioneering position in all sectors, including research and development (R&D), which is expected to play a pivotal role in the Saudi economy. Aligned with this vision, the Saudi national science, technology, and innovation plan holds a robust portfolio of R&D programs, and the Saudi Ministry of Education has created a strategic framework to manage the expansion of the R&D sector. This framework is made up of various pillars that ensure R&D funding is adaptable to national priorities and the appropriate funding is available to provide beneficial outputs and encourage entrepreneurship across Saudi Arabia to help develop demand for R&D. Finally, the Saudi Arabia government collaborates with a wide group of concerned R&D partners such as other government agencies, universities, industry leaders and international partners. On the other hand, higher education has been identified as a priority by the Egyptian government, and a series of measures are being implemented to make Egyptian universities globally competitive. Currently, there are 27 public universities and 27 private universities in Egypt among which 14 were featured in the QS World University Rankings® 2023 and ranked in the top 50 in the QS Arab Region University Rankings. The above-mentioned indicators would explain the volume (number of publications) and the quality (number of citations) of the scientific production in Saudi Arabia and Egypt.

The results of the present work suggest that the Arab Emirates has a hegemonic position in publishing chemistry journals in Arab countries. Despite its hegemony, the Arab Emirates does not rank among the top five Arab countries in terms of the number of publications or the number of citations. This suggests that most Arab Emirates journals, published by a unique and independent publisher (Bentham Science Publishers B.V), are not as well-positioned as those associated with universities or research organizations. It is worth noticing that two journals published by King Saud University (Saudi Arabia) belong to the top five indexed Arab journals. King Saud University occupies relevant positions in the rankings of prestige ARWU and QS, i.e., 101–150 in ARWU, 237 in QS, and 4 in Arab QS ranking. However, there are no journals, indexed in SJR in 2022, that belong to the universities of Algeria and Tunisia despite these two countries being classified in the top five Arab countries with the largest volume of citations or documents published between 1996 and 2022.

The metric parameters evaluated herein (H-index, SJR, citations per document in the previous two years, and total citations in the previous three years) were not normally distributed (Fig. 2). These findings corroborated previous studies indicating that the distributions of the bibliometric parameters did not always follow the normal distribution and may be represented by different models (Ruocco et al. 2017). The Wilcoxon rank-sum tests performed in this work indicated that the H-index, the SJR, the citations per document in the previous two years, and the total citations of the last three years of the Arab countries were statistically significantly lower than those of the rest of the world. Therefore, the impact of Arab chemistry journals is not as important as journals of the rest of the world. This suggests that, despite Arab countries' efforts to establish well-equipped research centers and industrial clusters based on best technologies and practices developed by the R&D sector, these efforts in the chemistry area remain insufficient. Also, the lower number of publications of the Arab countries (with 177,744 publications over the years 1996–2022) compared to the rest of the world (with 6,570,069 publications) and the mother tongue in Arabic countries may constitute a hindrance for Arab scientists to publishing their findings in English and to make these findings globally recognized. This could be overcome by improving international collaboration, especially with the United States of America (USA), China, India, Germany, and Japan which stand in the top five of countries' rankings in the chemistry area. Reinforcing collaboration with these countries would allow for a better mix of knowledge and skills among research teams (Larivière et al. 2015) as well as an increase in research productivity (Shehatta and Mahmood, 2014). This would strengthen the influence of Arab publications on the rest of the world. For this reason, networks were constructed and analyzed for collaborating countries, during the period 1996–2022, using VOSviewer. The worldwide research network in chemistry consists of 53 countries out of 219 countries in the world, which indicates that international collaborative research linkages should be improved. China and the USA were the top two most central nations, as depicted by the big nodes, in terms of overall connection strengths (Fig. 5a), with 39 partner countries each, followed by Germany, India, the UK, Japan, and Saudi Arabia. Considering only Arab countries, Saudi Arabia and Egypt were the top two most central Arab nations, in terms of overall connection strengths, with 36 and 12 partner countries, respectively (Fig. 5b). This would explain why Saudi Arabia and Egypt had the largest numbers of published documents and cited documents in Arab countries and stand out at the top of Arab countries' rankings.

The keywords co-occurrence network gives a rapid way for researchers to perceive the knowledge structure of the analyzed scientific field with keywords as actors. This allows researchers to understand the dynamic development of the analyzed knowledge fields (Rahoveanu et al. 2022; Agnusdei and Coluccia, 2022). After a careful examination of the keywords used by the Arabian authors and the keywords used in the rest of the world, we found that some topics are common such as adsorption, graphene, and nanomaterials. However, researchers in Arab countries are more interested in nanoparticles than researchers in the rest of the world who are more interested in catalysis. The latter subject is not sufficiently treated by the Arab countries.

Many Arab countries have launched nanotechnology research initiatives intended to serve their national interests in several domains such as education, water and energy resources, food supply, transport, and health. These initiatives aimed also to support the transfer of technology to industry to meet the needs of their countries. The interest in nanotechnology falls within the framework of political reforms and economic development in these countries. Indeed, since 2006 in their annual Arab summit, leaders of Arab countries agreed on many initiatives and decisions which aimed to expand funds

Table 3 Top 10 most cited papers on nanotechnology and nanoscience over the years 1998–2022.

Rank	Title	Author names*	Author's Affiliation in Arab countries	Total citations	Ref.
1	Recent developments in phase change materials for energy storage applications: A review	Nazir, H., Batool, M., Bolivar Osorio, F.J., Isaza-Ruiz, M., Xu, X., Vignarooban, K., Phelan, P., **Inamuddin**, Kannan, A.M.	King Abdulaziz University, Saudi Arabia	748	Nazir et al., 2019
2	Recent advances in modelling and simulation of nanofluid flows-Part I: Fundamentals and theory	Mahian, O., **Kolsi, L.**, Amani, M., Estellé, P., Ahmadi, G., Kleinstreuer, C., Marshall, J.S., Siavashi, M., Taylor, R.A., Niazmand, H., Wongwises, S., **Hayat, T.**, Kolanjiyil, A., Kasaeian, A., Pop, I.	Hail University, Saudi Arabia King Abdulaziz University, Saudi Arabia	620	Mahian et al. 2019a
3	A review on $BiVO_4$ photocatalyst: Activity enhancement methods for solar photocatalytic applications	Malathi, A., Madhavan, J., Ashokkumar, M., **Arunachalam, P.**	King Saud University, Saudi Arabia	442	Malathi et al., 2018
4	Recent advances in modeling and simulation of nanofluid flows—Part II: Applications	Mahian, O., **Kolsi, L.**, Amani, M., Estellé, P., Ahmadi, G., Kleinstreuer, C., Marshall, J.S., Taylor, R.A., Abu-Nada, E., Rashidi, S., Niazmand, H., Wongwises, S., **Hayat, T.**, Kasaeian, A., Pop, I.	Hail University, Saudi Arabia King Abdulaziz University, Saudi Arabia	382	Mahian et al. 2019b
5	Remediation of wastewater using various nano-materials	**Anjum, M., Miandad, R., Waqas, M., Gehany, F., Barakat, M.A.**	King Abdulaziz University, Saudi Arabia Central Metallurgical R & D Institute, Egypt	379	Anjum et al., 2019
6	Recent advances in layered double hydroxide-based nanomaterials for the removal of radionuclides from aqueous solution	Gu, P., Zhang, S., Li, X., Wang, X., Wen, T., Jehan, R., **Alsaedi, A., Hayat, T., Wang, X.**	King Abdulaziz University, Saudi Arabia	374	Gu et al., 2018
7	Synthesis, characterization and application of Co/Co_3O_4 nanocomposites as an effective photocatalyst for discoloration of organic dye contaminants in wastewater and antibacterial properties	Yousefi, S.R., **Alshamsi, H.A., Amiri, O.**, Salavati-Niasari, M.	University of Al-Qadisiyah, Iraq University of Raparin, Kurdistan Region, Iraq	354	Yousefi et al., 2021
8	Gold nanoparticle-based colorimetric biosensors	Aldewachi, H., Chalati, T., Woodroofe, M.N., Bricklebank, N., Sharrack, B., Gardiner, P.	University of Mosul, Iraq	350	Aldewachi et al., 2018
9	A comprehensive review on the state-of-the-art of piezoelectric energy harvesting	**Sezer, N., Koç, M.**	Hamad Bin Khalifa University, Qatar	335	Sezer and Koç, 2021
10	Efficient detection and adsorption of cadmium(II) ions using innovative nano-composite materials	**Awual M. R., Khraisheh M., Alharthi N. H., Luqman M.**, Islam A., **Karim M. R., Rahman M.M.**, Abdul Khaleque M.	Qatar University, King Saud University, King Abdulaziz University, Saudi Arabia.	335	Awual et al., 2018

(*) Authors affiliated with an Arab institution are indicated in bold.

allocated to research and development that make the economies of Arab countries based on science and knowledge (Alfeeli et al., 2013). Some Gulf countries like Saudi Arabia and Arab Emirates, have allocated large financial resources to support these initiatives. Some other Arab countries that have fewer economic resources such as Morrocco, Tunisia, and Egypt have bet on human potential to advance nanotechnology research and developments in their countries. Many research centers and funds were created in Arab countries that capitalize on nanotechnology among other advanced technologies. For example, in Saudi Arabia, the King Abdul Aziz City for Science and Technology (KACST) is responsible for the implementation of plans for several research areas including water, oil and gas, petrochemicals, and nanotechnology. Currently, most Saudi universities are conducting research in nanotechnology through the establishment of research centers of excellence devoted to nanoscience and nanotechnology such as the Center of Excellence in Nanotechnology (CENT) at

King Fahd University of Petroleum and Minerals (KFUPM) and the Center of Nanotechnology (CNT) at King Abdelaziz University. These centers support research in nanotechnology for desalination and water treatment, nanotechnology-based renewable energy, nanodevices, nanomaterials, nanobiotechnology, and nano-drug delivery. The industry is also contributing to nanotechnology in Saudi Arabia. For example, local companies, such as the Saudi National Oil Company and the Saudi Basic Industries Corporation (SABIC), have allocated huge resources to conducting research in nanotechnology areas. In the Arab Emirates, many research centers are devoted to nanotechnologies such as the Center of Excellence for Applied Research and Training (CERT) which has been invested in superfast computer calculations used in nanotechnology among other technologies, and the Ras Al Khaimah Center for Advanced Materials (RAK-CAM) which established many research areas including nanomaterials for water purification and energy storage. In Egypt, one can find the Yousef Jameel Science and Technology Research Center (YJ-STRC) and the Center of Nanoelectronics and Devices (CND) at the American University in Cairo (Egypt), the Nanoelectronics Integrated Systems Center (NISC) at Nile University and the Center for Nanotechnology (CNT) at the Zewail City of Science and Technology. For Tunisia, Algeria, and Morocco, nanotechnology is one of their national research priorities, including but not limited to water resources and management, energy, environment, biotechnology, materials, and microelectronics. Indeed, Morocco gave attention to nanotechnology by launching the National Initiative for Nanoscience and Nanotechnology, Tunisia established the National Strategy for Nanotechnology Sciences and Algeria established the Research Unit in Nanotechnology and Science. These initiatives focus on the application of nanotechnology in industrial development and fund research in nanotechnology with respect to education, training, and infrastructure. That is, funding for several nanotechnology research projects has been made available in collaboration with other Arab countries as well as European countries (Alfeeli et al., 2013).

The top 10 highly cited research papers in the nanotechnology field are listed in Table 3. As it can be easily noticed, three of the 10 top-cited papers were related to the use of nanomaterials in water and wastewater treatment, two papers were related to energy storage, two papers were related to nanofluids, two papers were related to photocatalysis, and one paper was related to biosensors. Therefore, Arab countries through their universities and research centers have been working vigorously to promote research and development of nanotechnology applications, especially those related to nanomaterials for water treatment, energy, and electronics. Other than this, governmental support in many vital sectors enhances the demand for nanotechnology. This would encourage more researchers to be involved in these subjects and the local industry to take more risks and invest in these areas, consequently expanding the markets of nanomaterials in Arab countries.

Although some subjects are treated more extensively in Arab countries than in the rest of the world such as adsorption, corrosion, and water treatment, there have been several challenges that slow down the development of science and technology related to some significant topics, such as catalysis, in Arab countries, i.e., the shortage of helpful governmental policies and limited funding, a small scientific research community compared to the rest of the world and a limited transfer of technology to the local industry, which, in turn, does not take the risk of investing in such research fields. To meet these challenges, Arab governments should adjust their policies by including those topics among their research priorities and providing more funds. Governmental support encourages researchers to be involved in these subjects and the local industry to take more risks and invest in these areas.

5. Conclusion

In the present work, the countries in the category SJR-All regions/-countries (Arab countries) arranged by the volume of publications in chemistry between 1996 and 2022, journals, H-index, SJR, and citations were systematically summarized. Saudi Arabia and Egypt had the largest volumes of published and cited documents and most chemistry journals in Arab countries are published by the Arab Emirates. The comparison between Arab countries and the rest of the world showed that the H-index, the SJR, the citations per document in the last two years, and the total citations of the last three years of the Arab countries were statistically significantly lower than those obtained for the rest of the world, which reject the $H1_0$, $H2_0$, $H3_0$, and $H4_0$ null hypotheses. This suggests that the impact of the Arab chemistry journals is not as significant as journals of the rest of the world and, despite Arab countries making efforts to establish centers of research excellence and industrial clusters based on best technologies and practices developed by the R&D sector, these efforts in the chemistry area remain insufficient. After a careful examination of the keywords used by the Arabian authors and the keywords used in the rest of the world, we found many topics that are treated by Arab countries and the rest of the world, such as drug delivery, molecular docking, graphene, and nanomaterials. However, Arab countries are more interested in nanoparticles than the rest of the world which is more interested in catalysis. To strengthen their impact on the chemistry research field, Arab countries should increase their collaboration with mainly the USA, China, Germany, India, the UK, and Japan. Also, Arab researchers should focus on more centered topics such as catalysis.

Author contributions

A.K. was involved in the methodology, data analysis, supervision, and writing and editing of the work. I.S. was involved in data curation and results analysis. F.T. was involved in ensuring resources and data curation. All authors have read and agreed to the published version of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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