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ORIGINAL

Characterization of the scientific output on lithium batteries through SciVal topic analysis

Caracterización de la producción científica sobre baterías de litio mediante análisis de tópicos de SciVal

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ABSTRACT

Introduction: in the context of the depletion of fossil fuels and the threat of climate change, countries are betting on a change in the energy paradigm, where lithium-ion batteries are at the technological frontier and their production has become widespread in recent decades.
Objective: to characterize the scientific output on lithium-ion batteries by analyzing SciVal topics.
Method: bibliometric study on the scientific output published in Scopus concerning lithium batteries between 2017 and 2021. SciVal was used to analyze articles clustered in the topic “Lithium-ion Batteries; Lithium Ion; Electrodes”. Production, citation and collaboration indicators were determined.
Result: 98 articles were published in this topic, where the most productive year in papers and citations was 2017 (%Ndoc=25,51 %; %Ncit=46,53). 65,3 % of the articles were registered in the area “Materials Science” and 51 % within the area “Chemistry”. 2 % of the articles were found in the top 1 % of the most cited articles, 27,5 % presented international collaboration. China (Ndoc=64), Japan (Ndoc=)20 and the United States (Ndoc=8) concentrated most of the scientific output, with China Three Gorges University being the most productive institution (Ndoc=11).
Conclusions: the scientific output on lithium batteries was mainly concentrated in first quartile journals, with articles in the areas of materials science and chemistry. There was a high rate of international collaboration, however, a low University - Company collaboration.

Keywords: Lithium Ion; Lithium-Ion Batteries; Chemical Engineering.

RESUMEN

Introducción: en el contexto del agotamiento de los combustibles fósiles y la amenaza del fenómeno del cambio climático, los países apuestan por un cambio en el paradigma energético, donde las baterías de iones de litio se encuentran en la frontera tecnológica y su producción se ha masificado en las últimas décadas.
Objetivo: caracterizar la producción científica sobre baterías de litio mediante análisis de tópicos de SciVal
Método: estudio bibliométrico sobre la producción científica publicada en Scopus referente a las baterías de litio entre 2017 y 2021. Se empleó SciVal para analizar los artículos conglomerados en el tema “Lithium-ion Batteries; Lithium Ion; Electrodes”. Se determinaron indicadores de producción, citación y colaboración.
Resultado: se publicaron 98 artículos en este tema, donde el año más productivo en documentos y citas fue 2017 (%Ndoc=25,51 %; %Ncit=46,53). El 65,3 % de los artículos se registró en el área “Ciencia de los Materiales” y el 51 % dentro del área “Química”. El 2 % de los artículos se encontraron en el 1 % de los más citados, el 27,5 % presentó colaboración internacional. China (Ndoc=64), Japón (Ndoc=)20 y Estados

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Unidos (Ndoc=8) concentraron la mayor parte de la producción científica, siendo la China Three Gorges University la institución más productiva (Ndoc=11).
Conclusiones: la producción científica sobre baterías de litio se concentró principalmente en revistas de primer cuartil, respondiendo los artículos a las áreas ciencia de materiales y Química. Existió un elevado índice de colaboración internacional, sin embargo, una baja colaboración Universidad – Empresa.

Palabras clave: Ion Litio; Baterías de ion de Litio; Ingeniería Química.

INTRODUCTION

The energy produced by hydrocarbons, such as oil, natural gas, and coal, has historically been humanity's primary energy source. However, as the world's population has increased and the energy demand has grown, it has become increasingly apparent that these energy sources could be more sustainable in the long term. On the other hand, lithium is an element found in nature and is more abundant than hydrocarbons. It is also an element that can be recycled and reused, which makes it more sustainable in the long term than hydrocarbon-based energy sources.

Lithium-ion batteries (Li-ion batteries) (LiB) are rechargeable batteries that use lithium ions to store and release energy. These batteries have a much higher energy density than conventional lead-acid and nickel-cadmium batteries, which means they can store more energy in a smaller space and with less weight.[1]

The transition from conventional batteries to LiB began in the 1990s when lithium-ion battery technology became more advanced and cheaper. Since then, lithium-ion batteries have become the preferred choice for various portable electronic devices, including mobile phones, tablets, and laptop computers.[2]

They have also been used in larger applications such as electric vehicles and energy storage systems in the home and industry. Lithium-ion batteries have a longer lifespan, are lighter, have higher performance, and are more energy efficient than conventional batteries. In addition, they do not contain toxic heavy metals, which makes them safer and less harmful to the environment.[3]

This makes lithium a strategic resource in the energy transition and the emerging technological paradigm based on sustainable energy and, consequently, present in the geopolitical dispute between industrial countries to guarantee access to and control of the resource.

In the last decade, the demand for lithium has increased exponentially in different ways due to its multiple applications. Demand for lithium has significantly increased from approximately 2 000 tons in 2005 to over 14 000 tons in 2020. Global lithium consumption is estimated to more than double current levels by 2025.[4]

Bibliometrics is a branch of data and intelligence science whose objective is the qualitative and quantitative analysis of scientific production and its actors (authors, research groups, institutions, journals, countries, and areas of knowledge). Its use is of great value for trend analysis, identification of emerging areas of science, and decision-making and evaluation of science.[5] Several studies have analyzed LiB from different angles, whether on the dangers of LiB[6] and its toxicity.[7] However, the development of studies that analyze the scientific production on LiB from an analysis of a thematic cluster in SciVal is unknown.

The present investigation was carried out to characterize the scientific production on lithium batteries through topic analysis of SciVal.

METHOD

An observational, descriptive, longitudinal, and prospective study was carried out through a metric analysis of the information from the articles published in journals indexed in Scopus that were part of the topic "Lithium-ion Batteries; Lithium Ion; Electrodes" (T.48772) from SciVal. SciVal is an integral part of Elsevier's research intelligence ecosystem, a portfolio of solutions, enabling technologies, and corresponding data that bring clarity and focus to research planning, performance, and processes.[8]

To obtain the information, SciVal was accessed, the "Topics and Clusters" section was selected, and it was filtered by words, choosing the thematic cluster T.30 that deals with "Secondary Batteries; Electric Batteries; Lithium Alloys". Within this cluster, the topic T.48772 referring to "Lithium-ion Batteries; Lithium Ion; electrodes". The resulting data was analyzed using the different modules available within SciVal.

The following metric indicators were studied:

- Number of documents (Ndoc). Total number of documents published in the area.
- Percentage of documents (% Ndoc) concerning the total number of articles studied.
- Citations (NCit). Total citations received by the articles indexed in Scopus.
- Thematic areas: based on the area or areas assigned to the journal. Each Scopus journal is assigned to one or several thematic areas based on the topics covered in their articles.
- Quartiles (Q): Journal quartiles are defined by journal metrics CiteScore, SNIP (Source-Normalized

Impact per Paper), or SJR (SCImago Journal Rank). CiteScore, SNIP, or SJR percentiles are used to calculate each quartile: Q1 (≤ top 25 percentile), Q2 (26-50 percentile), Q3 (51-75 percentile), and Q4 (76-100 percentile).

- CiteScore: based on the number of document citations (articles, reviews, conference papers, book chapters, and data papers) from a journal over four years, divided by the number of the same types of documents indexed in Scopus and published in those same four years.
- Source-Normalized Impact per Paper (SNIP): measures the impact of a journal's citations. SNIP is a ratio between the "Gross Impact per Article", a type of calculation of Citations per publication, received by the journal compared to the "Citation Potential," or Expected Citations per publication, of that journal's field.
- SCImago Journal Rank (SJR): it is calculated using an algorithm that considers the relevance and quality of the citations received, where citations from more important journals have a greater weight in calculating the metric.
- Citations per document (Cpd). Average number of citations received by the documents.
- Types of collaboration:
  - ✓ Without collaboration or sole authorship: document with only one author.
  - ✓ Institutional collaboration: documents signed by two or more authors from the same institution.
  - ✓ National collaboration: documents signed by two or more authors where not all are from the same institution within the country.
  - ✓ International Collaboration: documents in which the affiliation of their authors includes domicile in more than one country.
- Publications: refers to the journal indexed in Scopus where the article was published
- Institutions: refers to the institutions the researchers reported being affiliated with.

The approval of any ethics committee or scientific council was not required as the data were openly available.

RESULTS

The topic “Lithium-ion Batteries; Lithium Ion; Electrodes” (T.48772) from SciVal is part of the thematic group or topic cluster T.30 “Secondary Batteries; Electric Batteries; Lithium Alloys”. In the study period, 98 articles were published on this topic, where the most productive year in documents and citations was 2017 (%Ndoc=25,51 %; %Ncit=46,53) (table 1). Regarding the typology, the originals (ndoc=89) predominated, followed by the revisions (ndoc=5) and the letters (ndoc=4).

Table 1. Distribution of articles and citations of the published articles by year

Year	Ndoc	%Ndoc	Ncit	%Ncit
2017	25	25,51	911	46,53
2018	14	14,29	260	13,28
2019	20	20,41	455	23,24
2020	18	18,36	153	7,81
2021	21	21,43	179	9,14
Total	98	100	1958	100

Figure 1 shows the thematic areas under which the articles that comprise the theme were indexed. 65,3 % of the articles were registered in the "Materials Science" area and 51 % within the "Chemistry" area.

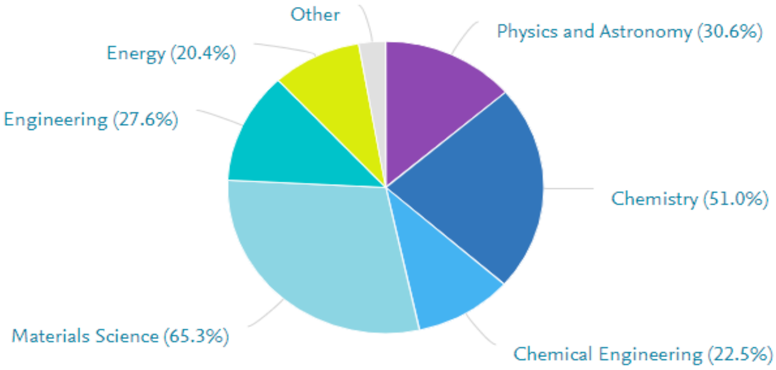

Figure 1. Distribution of articles according to the research area

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2 % of the articles were found in the 1 % most cited, and 10,2 % in the 10 % most cited. Regarding journals, 4,1 % were published in the group of 1 % most cited journals and 49,5 % in the 10 % most cited journals. The highest percentage of articles was published in first-quartile journals, exceeding 77 % and 81 %, according to CiteScore and SJR (table 2).

Table 2. Distribution of scientific production according to quartile of the journal

Quartile	CiteScore		SJR		SNIP	
	No	%	No	%	No	%
Q1	75	77,3	76	81,7	45	46,4
Q2	9	9,3	9	9,7	30	30,9
Q3	8	8,2	5	5,4	18	18,6
Q4	5	5,2	6	3,2	4	4,1

Table 3 shows the 7 most productive journals and their indicators.

Table 3. Most productive journals

Journal	Ndoc	Ncit	Cpd	SNIP	CiteScore 2021	SJR
Physical Review B	9	41	4,6	0,994	6,9	1,537
Journal of Materials Chemistry A	7	206	29,4	1,619	21	3,099
Journal of Alloys and Compounds	6	153	25,5	1,303	9,6	1,027
Electrochimica Acta	6	115	19,2	1,068	12,3	1,306
ChemElectroChem	5	52	10,4	0,635	7,6	1,038
Journal of Power Sources	3	83	27,7	1,541	15,4	1,983
Ionics	3	20	6,7	0,556	4,5	0,523

It was identified that 27,5 % of the articles presented international collaboration. These articles provided the highest citations (Ncit=975), with an average of 36,1 citations per article (table 4).

Table 4. Distribution of articles according to type of collaboration

Collaboration	Ndoc	%	Ncit	Cpd
International	27	27,5	975	36,1
National	33	33,7	483	14,6
Institutional	36	36,7	498	13,8
Single authorship	2	2	2	1

The regional distribution of scientific production was studied, which was mainly concentrated in China (Ndoc=64), Japan (Ndoc=)20, and the United States (Ndoc=8) (figure 2).

Table 5 shows the most productive institutions. It was found that the China Three Gorges University was the most productive institution (Ndoc=11), the Chinese Academy of Sciences the most cited (Ncit=542), and the University of Science and Technology of China the one with the highest FWCI (3,71) and CPD (72,1).

DISCUSSION

A bibliometric study by Dos Santos[9] identified an increasing trend in the number of articles in electrochemistry for the degradation of compounds, which differs from the present one. Lan et al.[10] found an increasing trend in scientific production in lithium battery failure diagnosis, which agrees with the present one.

Niebles-Nuñez et al.[11] conducted a study to analyze the sources of energy financing in Colombia, with a predominance of original articles. This result is to be expected since original research is the one that contributes the most to the creation and consolidation of knowledge.

Bing-Cheng[12] refers that for the study, development, and progress of LiB, research on new materials, energetic chemistry, and others are needed. Therefore, advanced technologies are required to achieve the sustainable development of LiBs, combining high electrochemical performance and sustainability. LIB sustainability implies

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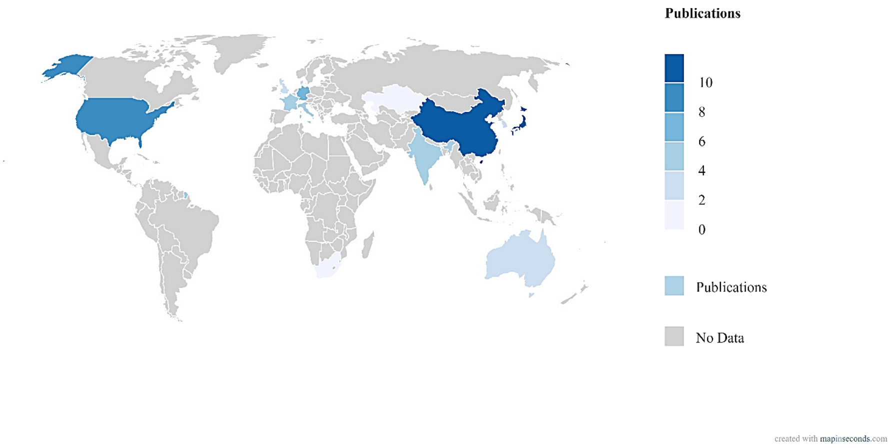

Figure 2. Geographical distribution of scientific production

Table 5. Most productive institutions

Institution	Country/Region	Ndoc	Ncit	Cpd	FWCI
China Three Gorges University	China	11	245	22,3	1,47
Waseda University	Japón	10	38	3,8	0,29
Chinese Academy of Sciences	China	9	542	60,2	3,17
Japan Synchrotron Radiation Research Institute	Japón	7	35	5	0,42
University of Science and Technology of China	China	7	505	72,1	3,71
Xiamen University	China	7	150	21,4	2,6
Wuhan University of Technology	China	5	241	48,2	1,95
CNRS	Francia	4	30	7,5	0,46
Jilin University	China	4	66	16,5	1,58
Kyoto University	Japón	4	22	5,5	0,43
Osaka Metropolitan University	Japón	4	10	2,5	0,25
Shandong University	China	4	88	22	1,53
University of Rome La Sapienza	Italia	4	31	7,8	0,6

the complete life cycle and is a set of raw materials, synthesis of battery components, assembly, use, and battery recycling. To achieve this, the coordinated action of different areas of science is required[13], such as chemistry, chemical engineering, and materials science, which is consistent with the results of the present study.

A study by Nascimento Dos Santos et al.[9] found the areas of Engineering, Chemistry, Environmental Sciences and Ecology, Electrochemistry and Materials Science as the primary research areas in their metric analysis of programs for the electrochemical degradation of organic pollutants. These results partially coincide with the present results.

Basharat et al.[14] analyzed 4112 articles published in the Chemical Engineering area between 1974 and 2018 on the Web of Science. The study found Chemical Engineering Science, followed by Computer & Chemical Engineering, to be the most cited journals in the field. These results differ from the present one regarding the most productive and cited journals.

For its part, a study conducted by Lan et al.[10] identified the Journal of Power Sources (Ndoc=303), Journal of the Electrochemical Society (Ndoc=200), and Journal of Energy Storage (n=104) as the most productive journals. Although the order differs from the present research, it coincides with several journals ranked in the top 15 of the research by Lan et al.[10]

Murugan et al. identified that 70 % of the articles it analyzed were published in Q1 journals, like the results of this one.[15]

Having the lithium resource is a relevant aspect. Still, it makes sense when there is a scientific-technological infrastructure and industries with the capacity to add value to it, even more so if it concerns contemporary strategic lines of development, as is the case of the green industry based on lithium's new energy paradigm. For this reason, cooperation in research and technological innovation in this area has a special meaning since, based on mutually beneficial agreements, countries with infrastructure can support those that lack it with technology transfer. At the same time, the parties involved can share the knowledge resulting from the scientific-investigative process.[3]

China, Japan, and the United States were identified as the top producers. This fact is determined by several factors, among them the infrastructure of its scientific systems oriented to publication. Although the world's central lithium reserves are in Latin America (Argentina, Bolivia, Chile, Brazil, Mexico, and Peru), these countries appear to be exporters since they do not have the infrastructure for exploitation. For their part, the United States and China are leaders in processing, production, and research.[16]

Nascimento Dos Santos et al.[9] found China and Spain to be the top producers, which partially coincides with the results of this study. Similarly, it partly overlaps with the results of Lan et al.[10], who identified China and the United States as the primary producers. On the other hand, around LiB connected to the network, the United States (n=15) and China (n=11) were more productive.[17]

Regarding the most productive institutions, Lan et al.[10] identified in their study the Beijing Institute of Technology (n=126), Beijing Institute of Technology (n=107), and the University of Science and Technology of China (n=107). =96) with the most productive institutions. It should be noted that although the order differs, some declared institutions coincide with the present results.

It is concluded that the scientific production of lithium batteries was mainly concentrated in first-quartile journals, with the articles responding to the areas of Materials Science and Chemistry. There was a high rate of international collaboration, however a low University-Business collaboration. China, the United States, and Japan are established as leaders in terms of scientific production in the area related to lithium batteries.

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