BIOTECNOLOGÍA
EN EL SECTOR AGROPECUARIO
Y AGROINDUSTRIAL

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Scienciometric outlook of the biotechnology in the agricultural and agroindustrial sector*

Panorama cienciométrico de la biotecnología en el sector agropecuario y agroindustrial

Panorama cienciómetrico da biotecnologia no setor agropecuário e agroindustrial

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ABSTRACT

This article presents Scientometrics as a major element in quantitatively addressing the study of a field of knowledge. This study seeks to combine complementarily and integrally the bibliometry with the technological outlook to obtain an image of the current state of biotechnology in a specific area. This contributes with a trend-setting in a socially relevant sector that currently addresses global challenges such as climate change and energy and food security. Through a bibliometric study, it determines the dynamics of the scientific production, key authors, country participation and language trends in the domain of Biotechnology in the agricultural and agro-industrial sectors. In addition, a technological outlook is presented, in which, based on the analysis of trends in patents, the innovative state of the area is established. The main result is associated with the dynamics of scientific production, which according to the Lotka law; states that the percentage of authors who produce N articles is inversely proportional to a power of N. The technological outlook is consistent with the Latin American studies, concluding that, despite of the increasing dynamics, there is a poor development of technology in the sector.

KEY WORDS:
Bibliometric Analysis; Technology Study; Patent Study.

RESUMEN

El presente artículo presenta la cienciometría como elemento principal para abordar cuantitativamente el estudio de un campo del conocimiento. Busca combinar la bibliometría con el panorama tecnológico, para obtener el estado actual de la biotecnología en un área específica. Esto contribuye al establecimiento de tendencias en un sector socialmente pertinente para abordar desafíos globales como el cambio climático y la seguridad energética y alimentaria. A través de un análisis bibliométrico, se determinó la dinámica de la producción científica, los autores clave, la participación de los países y las tendencias de idioma en el dominio de la Biotecnología en el sector agropecuario y agroindustrial. Como complemento, se presenta un panorama tecnológico, en el cual, a partir del análisis de tendencias en patentes, se logra establecer el grado de innovación en el área. El principal resultado en concordancia con la ley de bibliométrica de Lotka, establece que el porcentaje de autores que producen N artículos es inversamente proporcional a una potencia de N. El panorama tecnológico, es consistente con los estudios de Latinoamérica, concluyéndose que, a pesar de presentarse una dinámica creciente, existe un bajo desarrollo propio de tecnología en el sector.

PALABRAS CLAVE:
Análisis Bibliométrico; Estudio Tecnológico; Estudio de Patentes.

RESUMO

Este artigo apresenta a cientologia como o elemento principal para abordar quantitativamente o estudo de um campo de conhecimento. Busca combinar a bibliometria com o cenário tecnológico, para obter o estado atual da biotecnologia em uma área específica. Isto contribui para a definição de tendências num sector socialmente relevante para enfrentar desafios globais como as alterações climáticas e a energia e a segurança alimentar. Uma análise bibliométrica determina a dinâmica da produção científica, autores-chave, participação do país e tendências linguísticas no domínio da Biotecnologia no setor agrícola e agroindustrial. Além disso, apresenta-se um cenário tecnológico,

PALAVRAS-CHAVE:
Análise Bibliométrica; Estudo Tecnológico; Estudo de Patentes.

no qual, a partir da análise das tendências das patentes, o grau de inovação na área é estabelecido. O principal resultado de acordo com a lei bibliométrica de Lotka afirma que a porcentagem de autores que produzem artigos N é inversamente proporcional a um poder de N. O cenário tecnológico é consistente com os estudos latino-americanos, concluindo que, apesar da dinâmica crescente, há um baixo desenvolvimento da tecnologia no setor.

INTRODUCTION

Scientometric studies quantitatively the performance of researchers, groups, institutions and countries [1,2]. It is a discipline that is complemented by bibliometry to evaluate the dynamics of bibliographic data associated with publications, such as quantity, citations, year of publication, country of origin and authors, among others [3,4,5]. This methodological approach analyses the technical and scientific production of Biotechnology, understood as the scientific and technological application to living organisms, their parts, products and models intended to modify living organisms and/or materials applied to the production of knowledge, goods and services [6,7].

The study is carried out through the analysis of data from scientific production and patents. In this sense, its main contribution is that it complements the available literature reviews, with a bibliometric and technological outlook [8], it provides a picture of the state-of-the-art of a specific technology to discover new tends in patents [9,10], in order to accomplish a more comprehensive vision of the field. It establishes trends, gaps and fields of low bibliometric count [11, 12].

At the macro level, previous work can be referenced from the United Kingdom, the Netherlands and China, which carry out bibliometric studies on science and technology indicators, in order to address their management policies [13,14]. On the meso level, as expressed by Gaillard [15,16], the importance of such studies has been reflected in the characterization of the construction of external networks of scientific collaboration [17,18]. These meso indicators are increasingly important due to their relationship with the capacities that are translated into productivity and project execution [19,20]. Finally, at the micro level, there are works that evaluate the academic quality, productivity and potential of an institution [21], faculty [22], researcher, research group, journal or knowledge area [23]. It is possible to cite the contribution of Glänze et al [24], with a large study of Biotechnology as a domain, although, it does not focus on the agricultural and agro-industrial sectors.

It is worth noting that bibliometric and scientometric analyses have been carried out in Biotechnology to monitor the progress of a country's knowledge and research capacity [25, 26, 27], also the application of these methods to analyze patterns of collaboration in the area has been carried out [28,29]. However, to the best of the author's knowledge, to date, there is no significant work that similarly combines the two techniques focusing on the agricultural and agro-industrial sectors, thus providing a comprehensive picture of the field, which does not only identify aspects related to scientific production, but also manages to incorporate aspects related to the technological development of the area.

In terms of social relevance, a complete characterization of the field is achieved, which is relevant to Biotechnology stakeholders due its close link to global challenges such as climate change, energy security [30,31], and food security [32,33].

The objective of the study is to identify the trends of scientific and technological research in the area, measured through two techniques, which involve the analysis of data related to publications and patenting.

METHOD

An exploratory and descriptive analysis is presented, through a bibliometric analysis and a study of the technological outlook. Analysis unit: Scientific research and innovation products resulting of new knowledge activities and Patents.

Data

6412 scientific articles indexed in Scopus, classified according to the Colciencias model [34] and 16370 technological products according to international patent repositories (European Patent Office and Superintendency of Industry and Commerce of Colombia- SIC). Scopus is used as a database of scientific publications. The Orbit platform is used for the technological outlook.

Scope

For the bibliometric study, the period of time considered was 1952 to 2019. For the technological outlook the range was 1998 to 2019. For both studies the search string used was ("Biotechnology" OR "biotech") AND ("Agro-industry" OR "Agricultur?" OR "Agrarian science").

Inclusion criteria

Scientific articles indexed in Scopus in the field of Biotechnology in the agricultural and agro-industrial sector. Filters were planned in to the technology outlook to include only those items of the agricultural and agro-industrial theme in Biotechnology, as patents, accessible to 2019 on the Orbit Questel platform and at the Superintendency of Industry and Commerce in Colombia

Exclusion criteria

Grey literature, not available in Scopus and with different meanings or contexts.

Characterization of the field

The contribution of Glänze *et al*. [24] is used: (i) plant sciences, (ii) biochemical research methods, (iii) biochemistry & molecular biology (iv) biophysics, (v) biotechnology & applied microbiology, (vi) microbiology, (vii) cell biology, (viii) genetics & heredity and (ix) developmental biology. Subsequently, Boolean chains filters were used to extract only the data corresponding to the agricultural and agro-industrial sectors, using as a criterion a thematic sub-composition, of the agricultural sciences in: (i) agro-Livestock Sciences, (ii)forest sciences, (iii)forestry and (iv)aquaculture and other agricultural sciences in: (i)food agroindustry, (ii)non-food agroindustry and (iii) biotechnology. The environment was considered generic to both sectors.

Search string

It was set in english, considering for the bibliometric study: the coverage of synonyms and acronyms, capture through the title (T), abstract (A), and keywords (K). Some elements were excluded with the use of "and", "or" and truncation symbol *. The following variables were collected: iI) journal title; (ii) year; (iii) surnames and initials of the authors; (iv) country; (v) language of publication, and vi) type.

RESULTS

Bibliometric Study Results

Authors Records. Of the 14367 authors found, 86,64% registered a single biotechnology publication in the agricultural and industrial sector, the 12,56% between 2 and 5, the 0,60% between 6, the 10, 0,17% between 11 and 20, and the 0,03% more than 20 (see table 1).

Table 1. Author's productivity .

Number of papers	Authors	Articles
1	12447 (86,64%)	12447 (69,47%)
2 - 5	1804 (12,56%)	4371 (24,39%)
6 - 10	86 (0,60%)	630 (3,52%)
11 - 20	25 (0,17%)	337 (1,88%)
> 20	5 (0,03%)	133 (0,74%)
	14367	17918

Among the most representative authors, it is possible to refer to: Miller, H.I, from the Pacific Research Institute, San Francisco, United States with 38 products and an H index of 12 , followed by Fox, J.L from the University of Maryland, United States with 27 products and an H-index of 13, Zilberman, from the University of California, Berkeley, United States with 27 products and an H-index of 47, and Brookes, G. from the PG Economics Ltd, of United Kingdom with 20 items and an H index of 18.

The most cited articles, with the respective citations in the area are:

- Inhibition of anaerobic digestion process: A review [35]: 2386.
- Plant responses to drought, salinity and extreme temperatures: Towards genetic engineering for stress tolerance [36]: 1794.
- Map kinase signaling cascade in Arabidopsis innate immunity [37] :1618.
- Salt tolerance conferred by overexpression of a vacuolar Na+/H+ antiport in Arabidopsis [38]:1333.
- Biochar as a sorbent for contaminant management in soil and water: A review, [39] :1227.
- Hemicellulose bioconversion [40]: 13.
- Cloned transgenic calves produced from no quiescent fetal fibroblasts [41] :1062.
- Potential commercial applications of microbial surfactants [42] :1024.
- Bio-ethanol - the fuel of tomorrow from the residues of today [43] :971.
- Antibiotics and antibiotic resistance in water environments [44]: 941.

Figure 1 shows the percentage of authors who have published between 1 and 10 articles. The continuous line graph is obtained from the data of this study, and the dotted in-line plot is a square minimum adjustment to the Lotka Law [45], see Equation 1.

$$a = \frac{C}{p^n} \quad \text{(Ec. 1)}$$

Being the percentage of authors who produced of articles. The values obtained for the constants and were 0,8388 and 3.2616 respectively (r = -0,99, p < 0,001).

Language Participation in Scientific Production. English was found as predominant with the 94,6%, followed by French with 2,2%, and Spanish with 0,7%.

Countries Share. As shown in figure 2, the greatest influence is the United States with 25,6%, followed by India with 9,2%, the United Kingdom with 7,8% and China with 5,7%.

The overall dynamic of production in this field of knowledge is shown in Figure 3. Growth is evident after 1999 and it presents two peaks; one in 2012 with 352 articles and another in 2017 with 366. In 2006, a sharp decline was observed, but then a remarkable recovery was seen until 2012.

Figure 1. Least squares adjustment between the data obtained in the study and the Lotka Law.

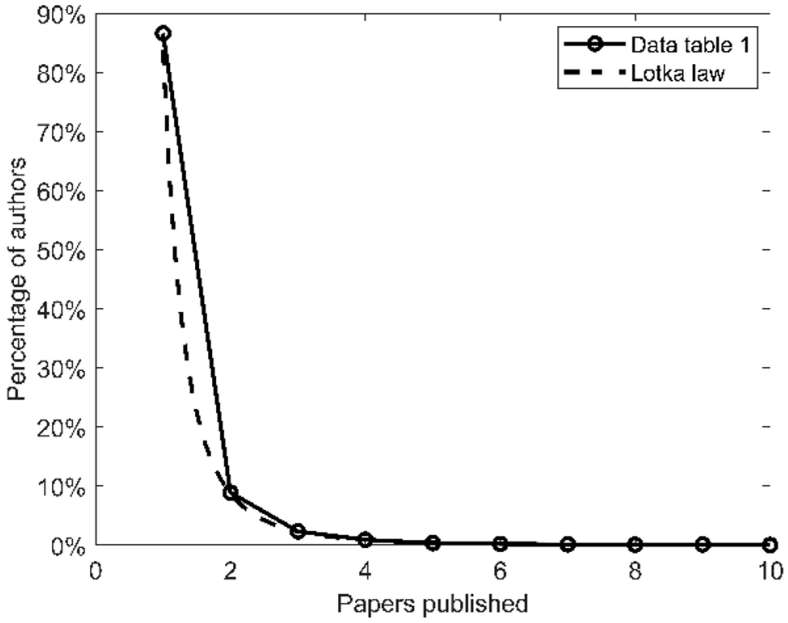


Figure 2. Country share in scientific production [46].

International Journals Participation. The 17918 Scopus articles are distributed in about 147 journals.

The 10 journals with the highest percentage of publications are: Applied Microbiology and Biotechnology (4,4%), Biofutur (3,4%), Bioresource Technology (2,4%), Biotechnology Advances (2%), Current Opinion in Biotechnology (1,7%), International Journal of Biotechnology (1,6%), Nature (1,3%), Nature Biotechnology (1,1%), Science (1%) and Trends in Biotechnology (1%).

Results of the Technologic Outlook

To obtain the results, the tool provided by Orbit Questel was used, in two scopes, international and national, described below.

Results of The International Technology Outlook

Dynamics. In conducting the study in an international field, as shown in Figure 4, it was found that the first inventions related to the area of study, evidenced through patent applications, date back to 1999. Between that year and 2007 the technological performance was in the emerging stage, from there to the present it can be said that the technology is in the stage of growth.

Figure 3. Dynamics of the scientific production. [46]

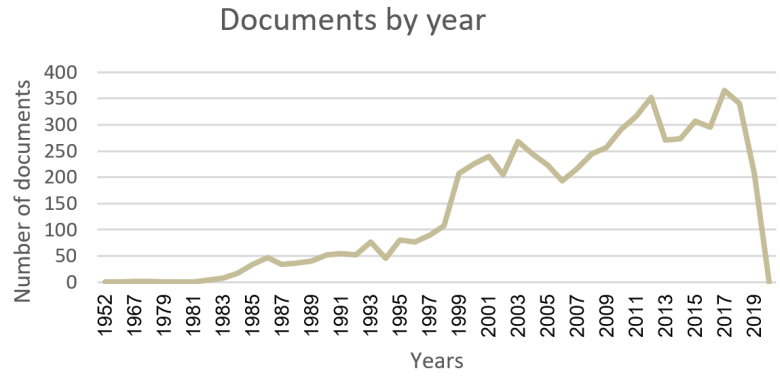
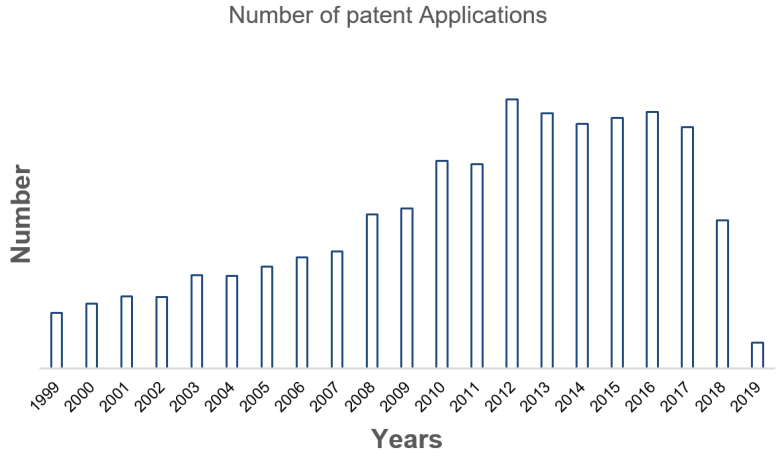


Figure 4. Evolution of the International Patent publications. Source: Orbit Questel.



Technological leadership by countries in the international context. The United States has 7595 inventions and 5729 patents on the subject, China 5687 inventions and 5413 patents, South Korea 904 inventions and 1434 patents and the European Patent Office 732 inventions and 2133 patents.

Technological leadership by organizations in the international context

The main proponents are: Monsanto with 3102 patent applications, followed by Dupont Pioneer with 1618, BASF with 1378, The Institute of the Chinese Academy of Agricultural Sciences with 1314, Syngenta with 752, The University of California with 703, Bayer with 683, Dow Agrosciences with 657 and Novozymes with 623.

International Patent Codification-IPC of the field. The main IPC codes found are:

C12N: Biocides, fertilizers, propagation, cultivation or conservation of microorganisms; A01H: New plants or processes to obtain them; plant reproduction by tissue obtaining techniques; C12Q: Measurement or testing processes with enzymes, nucleic acids or microorganisms; C07K: Genetic engineering processes to obtain peptides; C12P: Fermentation processes or processes that use enzymes for the synthesis of a chemical compound; A01N: Conservation of human or animal bodies or plants or their parts; G01N: Investigate or analyze materials by determining their chemical or physical properties; C12M: Facilities for fermenting manure, preservation of live parts of humans or animals; brewing and fermentation apparatus for wine; vinegar-making apparatus; C07H: Processes for the preparation of sugar derivatives based on the Genetic Engineer with DNA or RNA; C05F: Waste or waste fertilizers, i.e. organic fertilizers; C02F: Treatment of water, wastewater or sludge (processes to reduce harmful effects); A23K: Animal feed specially adapted for animals; Methods adapted for production.

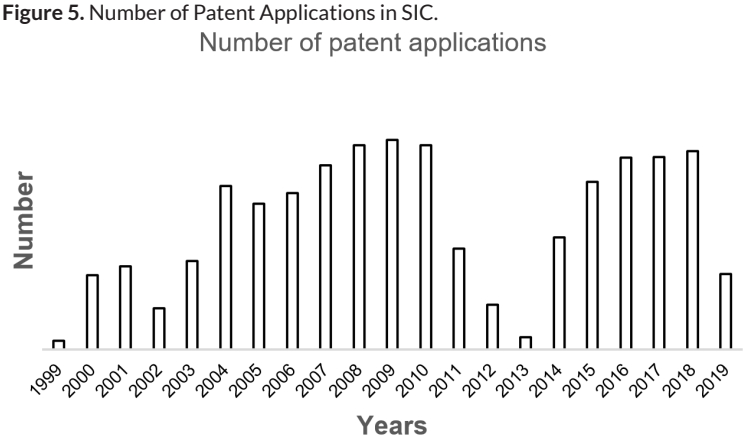
Technology outlook in the national context

National Technologic Dynamic. Figure 5 shows patent applications for Biotechnology in the agricultural and agro-industrial sectors. This dynamic began in 1999 in Colombia, and it shows greater consistency in 2004 and an increase in 2018.

National technological leadership by countries. In patent application by country in Colombia, there are: United States with 1243 applications, Germany with 748, Japan with 259, Switzerland with 228, United Kingdom with 116, France with 65, Israel with 56 and Netherlands with 42**.**

National technological leadership by organizations. The main applicants are BASF SE with 2995 applications, Bayer AG with 559, Dow Agrosciences LLC with 353, Syngenta Limited with 200, Monsanto Technology with

Figure 5. Number of Patent Applications in SIC.



64, Sumitomo Chemical with 64, Ishihara Sangyo Kaisha with 41, Fmccorporation with 39, Wyethllc with 36, Dupont Corporation with 31, Boehriger Ingelheim with 21 and Novartis Ag with 24.

It was found a technological trend for the country directed towards Biocides, herbicides, pesticides, and fertilizers regulating pests for plant growth, genetically modified varieties and technologies for obtaining plants through tissue cultivation. The inventive activity of Colombian organizations such as the Eafit University, Colombian Agricultural Research Corporation– Agrosavia, University of Antioquia and the Universidad del Norte Foundation.

This study analyzed bibliometric indicators such as authors' productivity, transitorily and growth. According to Lotka's bibliometric law, the number of authors with few articles, i.e. from 1 to 2, is greater than that of those who publish many articles. As expressed by Lotka It can be said that in this distribution 4 levels of productivity are obtained: level 1 small (1), medium level 2 (2-9), level 3 large (10-19) and maximum producers (more than 20 papers) [47,48].

The scientific production indicators on studies in the area of Biotechnology at the global level, have reported significant growths [49]. The results obtained in this study with respect to this dynamic, which would be expected to be reflected later in disciplinary development, showed a post-1999 growth trend and two peaks or hikes; one in 2012 and one in 2017. The production in this sector in Latin America has grown in recent years, however, the gap between developing and developed countries is evident, since Latin America has limited technological capabilities, in this sense, the production of patents in Latin America is lower, which leads to analyze their trend and look for strategies to promote technological innovation [50].

Regarding the results obtained with respect to the most technology-supporting countries in the field, The most representative was the United States, followed by India, the United Kingdom and China with much smaller shares. This is reflected in the fact that the economy of these developed countries depends on technology, while developing countries depend on natural resources [10]. For developing countries to strengthen their industries, they must develop plans and policies, and invest in capacity to deploy biotechnology advances across their value chain [51].

Referring to the dynamics of these patents in Colombia, initiated, most forcefully in 2004, presenting the peak of the greatest representativeness in 2018, it can be commented, that the studies undertaken by the Argentine Center for Scientific and Technological Information (CAICYTCONICET) and described by Barrere [52], demonstrate that the technological development measured through patents is very poor for the Ibero-American region when compared to the main countries of the world. According to the author, the growth of this period was precisely due to an international expansion in the field of Biotechnology that influenced the development of Ibero-America.

To comment on the weak technological leadership of organizations, where patents applications in the national territory are mostly granted to international organizations, according to Barrere [52], in the referenced development, the presence of organizations is below the individual inventors. At the Ibero-América level this trend is based on the weakness of a strong business network that enhances patenting, linked to a relative strength or tendency to train researchers and technologists. In this sense, Colombia is not representative, giving the first places to Argentina, Chile, Brazil and Mexico. In the case of the agricultural sector, this analysis at the Ibero-America level reports that patents related to genetically modified organisms predominate and correspond to the authorship of multinational companies and not to R&D-funded activities in the countries where they have been awarded. It should be noted that within patent applicant organizations, some of the academic sector were found, which supports Barrere's statements [52].

CONCLUSIONS

The focus of this study was the quantitative analysis and research and technological trends in the area of Biotechnology in agriculture and agro-industry. Despite international comparisons, the current study indicated a notable increase in the number of publications and patents at the international level in recent years, because,

in the agricultural and agricultural sector, biotechnology has played an important role in sustainability of production [53], through the development of technologies that promote conserving soil characteristics, increasing crop productivity and increasing pest resistance [54].

Colombia is considered as a potential market for countries such as the United States, Germany, Japan, Switzerland and the United Kingdom, as well as for companies such as Bayer Ag that markets sanitary and agricultural products [55], Dow Agroscience offering products such as insecticides, herbicides, fumigants and other chemicals, Syngenta AG that produces herbicides, insecticides, fungicides and seeds for field crops, vegetables and flowers Sumitomo Chemical Co Ltd that offers chemicals, petrochemicals and fine chemicals, intermediate pharmaceuticals and agrochemicals and Monsanto offering seeds, herbicides and technologies related to the field [55]

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