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PRODUCTIVITY IN THE PHARMACY SECTOR

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Abstract

The presented study uses bibliometric techniques to analyze the growth of efficiency and sustainability research in the pharmaceutical business between 2013 and 2023 with a particular focus on productivity in the field. After analyzing 319 documents from 272 sources, it was found that the amount of science produced annually increased by 22.59%. With almost 250 publications, India is the country that contributes the most, followed by Italy and Brazil. Among other things, research centers on how Industry 4.0 technologies—like artificial intelligence (AI) and the Internet of Things (IoT)—can be applied to boost productivity and flexibility in the pharmaceutical manufacturing process. The Journal of Pharmaceutical Policy and Practice and Chemical Engineering Transactions are two of the most important publications, while Jeju National University and the Institute of Chemical Technology are notable for their high levels of scientific output. Influential writers like BASIT AW and SEHRAWAT R are identified by the h-index analysis, and highly cited articles examine novelties like 3D printing in pharmacology. The research revolves around many key subjects, including "Non human," "Metabolism," and "Chemistry," which emphasize the need for multidisciplinary cooperation. The study's conclusion, which highlights the need of addressing operational challenges through cutting-edge technologies and international collaboration to improve sustainability and efficiency in the pharmaceutical sector and benefit the industry as well as society at large, is that research on pharmaceutical productivity is on the rise.

Key words: Pharmaceutical sector, Pharmaceutical industry, Pharmacy, Production, Bibliometric analysis.

1. Introduction

Like any business, the pharmaceutical industry has seen significant changes in the previous several years due to shifts in global industry dynamics, technical advancements, and market dynamics (Klimanov et al., 2021). These adjustments address the need to adjust to changing laws and consumer preferences as well as the incorporation of technology advancements that have completely changed the process of creating, manufacturing, and distributing pharmaceutical goods (Sarkis et al., 2021). Pharmaceutical companies have restructured their operational strategies and invested in emerging technologies like artificial intelligence, biotechnology, and additive manufacturing as a result of mounting pressure to increase productivity and lower production costs, as well as to adhere to strict quality and safety standards (Yunus, 2021). Globalization has also broadened the pharmaceutical market's reach and boosted cooperation and competitiveness on a worldwide scale. Companies in the industry face a variety of possibilities and problems as a result of this dynamic environment, which calls for ongoing adaptation and a never-ending quest for new and innovative ways to increase production (Di Tommaso et al., 2020).

Because the pharmaceutical industry directly affects people's health and well-being, it is extremely important on a worldwide scale. This industry is devoted to the creation, manufacture, marketing, and research and treatment of pharmaceuticals and other health goods, which are vital for illness prevention and treatment (González Peña et al., 2021). The sector's significance is demonstrated by its role in employment generation, economic growth, and scientific advancement. In the pharmaceutical sector, productivity is determined by the quality and originality of items produced in addition to their quantity. Pharmaceutical businesses work in a highly regulated industry where they have to go by stringent rules to guarantee the efficacy and safety of their goods (Rong & Zhu, 2020). Despite its difficulties, this regulatory structure guarantees that pharmaceutical items are of the greatest caliber. The pharmaceutical sector is also known for its high expenditures associated with research and development (R&D), lengthy product development timelines, and high failure rates (Rahman & Howlader, 2022). For these reasons, optimizing resources and streamlining production processes are crucial. Pharmaceutical businesses throughout the world work together and compete at the same time, advancing scientific discoveries that benefit society.

The productive status of the pharmaceutical industry worldwide is a reflection of several intricate dynamics and trends. The pharmaceutical business has witnessed a surge in demand for its goods due to several causes, including the aging population, rising rates of chronic and new illnesses, and expanding access to healthcare services in developing nations (Singh et al., 2020). But there are also serious obstacles to overcome, such as the need to lower the cost of medications and boost access to cutting-edge therapies, in order to meet this demand surge. Companies have adopted more flexible and effective tactics as a result of fluctuations in supply and demand. They have also implemented cutting-edge technology that optimize production and the supply chain (Kumar, 2023). The industry's productivity is also affected by how rapidly businesses can adjust to shifting regulations and customer demands (Halwani, 2022). The COVID-19 pandemic, for instance, highlighted the significance of having a quick and effective reaction capability and showed how production dynamics might affect the supply of necessary medications (Gereffi, 2020). The pharmaceutical sector is under continual pressure to develop and enhance its manufacturing methods while balancing sustainability, quality, and efficiency in this setting.

A significant obstacle to comprehending the correlation between the pharmaceutical industry and its productivity is the absence of a robust methodological foundation, broad acceptance, and coherence in the existing body of research. It is challenging to provide a consistent framework for assessing and measuring productivity in this industry because of its complexity, which spans from fundamental research to the manufacturing and distribution of products. This effort is further complicated by the variations in corporate practices, legal frameworks, and social and economic situations among nations. A fragmented knowledge of the influence of different production tactics on sector performance has resulted from the range of approaches utilized in prior research, leading to inconsistent conclusions. The inability to reach a consensus on methodology hinders the process of comparing outcomes and identifying best practices that may be used worldwide. It is important to establish uniform standards and more integrated methods to research since attempts to increase productivity and efficiency in the pharmaceutical sector may be disorganized and less successful in the absence of a clear and agreed methodology.

Because of the foregoing, this research aims to evaluate the evolution of productivity in pharmaceutical companies; identify the thematic axes and co-citation networks between authors, documents, and sources of literature on productivity in intersection with the pharmaceutical industry (Zhang et al., 2020). All of this is done in an effort to better understand the interrelation between productivity and the pharmaceutical sector, as described in the previous paragraph. The goal of this work is to close current knowledge gaps and lay a strong basis for further investigation. Through a historical analysis of the sector's productivity history, patterns and trends that provide light on how businesses have modified their tactics over time may be found (Kokol et al., 2021). Pharmaceutical productivity research may be categorized into primary and emergent areas of interest by identifying the topic axes, and the most significant linkages and cooperation between researchers and institutions can be found by analyzing co-citation networks (Xu et al., 2021). This multifaceted approach will enable a comprehensive understanding of the sector, making it easier to find areas of potential improvement and synergy.

The purpose of this research is to solve issues and take advantage of possibilities at the nexus of productivity and the pharmaceutical business by offering a thorough overview of the present and future directions of this field of study. Innovative and long-lasting solutions that benefit the pharmaceutical industry as well as society at large may be generated by promoting a multidisciplinary and international approach to research. Companies will be able to create more successful performance-enhancing strategies with a better knowledge of the productivity-influencing elements, and public policies drawn from this study can foster an atmosphere that is more conducive to innovation and long-term prosperity. Moreover, this study emphasizes the critical role that international cooperation plays in resolving shared problems and advancing the health and well-being of the world by stressing the significance of cross-border cooperation and the integration of cutting-edge technology. Research on productivity in the pharmaceutical industry ultimately improves people's quality of life and helps businesses succeed financially, which highlights the significance of keeping up the good work in this area.

2. Materials and methods

Bibliometric analysis is a quantitative method to evaluate the corpus of books in an area. Using bibliometric approaches, researchers can track the growth and development of their fields of study, identify changes within those fields, and identify interdisciplinary connections that are emerging within certain disciplines (Ramírez et al., 2023). Through various characteristics related to the use of various library resources, literature analysis techniques have produced a considerable number of instruments that promote excellent management to date (Serenko, 2021).

This article is framed within the seven main phases in the scientific literature evaluation process: first selecting the best software and database; then determine the most relevant keywords and how to combine them; then search for documents in the database; subsequently, filter the information collected; then export the information that has been selected; then evaluate the selected documents; and finally, create a graphical representation of the search results (Niñerola et al., 2021).

Regarding the search for information, the following search equation was reached through the Scopus search engine: (TITLE-ABS-KEY ("pharmaceutical sector") OR TITLE-ABS-KEY ("pharmacy sector") AND TITLE -ABS-KEY (production)) AND PUBYEAR > 2012 AND PUBYEAR < 2024 AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Spanish")), where it was first delimited to the pharmaceutical and pharmacy, then the search period was delimited from 2013 to 2023 and finally, the search was delimited to the languages of English and Spanish.

3. Results

Table 1 Main information

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2013:2023
Sources (Journals, Books, etc)	272
Documents	319
Annual Growth Rate %	22.59
Document Average Age	4.26
Average citations per doc	18.95
References	19534
DOCUMENT CONTENTS	
Keywords Plus (ID)	2614
Author's Keywords (DE)	1164
AUTHORS	
Authors	1231

Authors of single-authored docs	35
AUTHORS COLLABORATION	
Single-authored docs	37
Co-Authors per Doc	4.09
International co-authorships %	27.27
DOCUMENT TYPES	
article	171
book	3
book chapter	46
conference paper	26
conference review	2
note	2
review	67
short survey	2

Source: authors (2024)

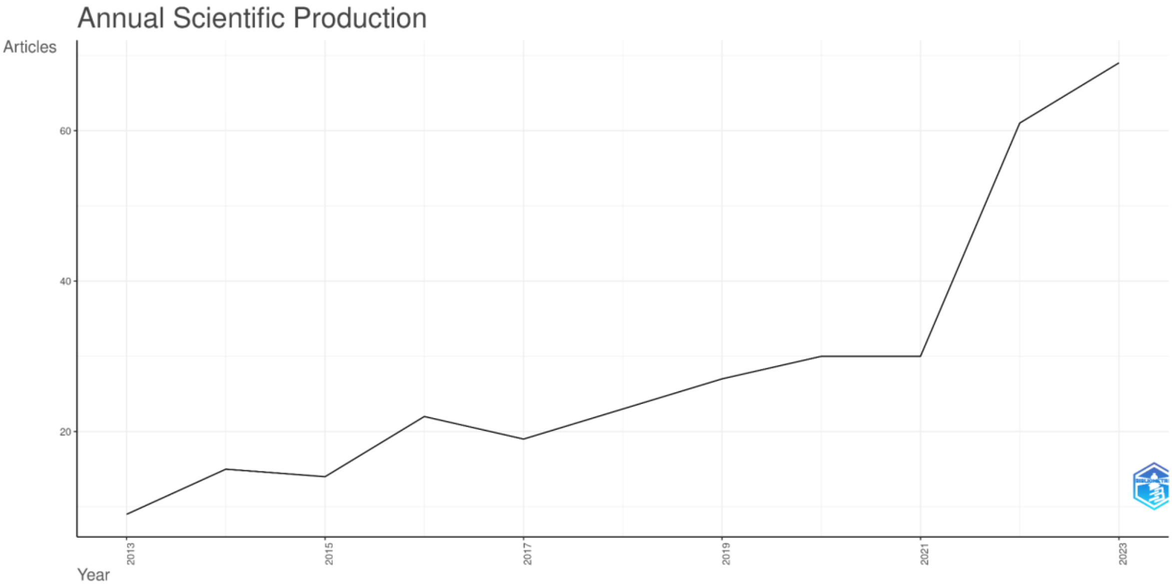

Figure 1. Annual scientific production.

From 2013 to 2023, Figure 1 illustrates a growing trend in the number of academic articles on sustainability in the pharmaceutical business. In 2013, less than ten articles were published per year, which is quite low. However, a constant and notable increase is observed as the decade progresses, with small fluctuations noticeable in the graph.

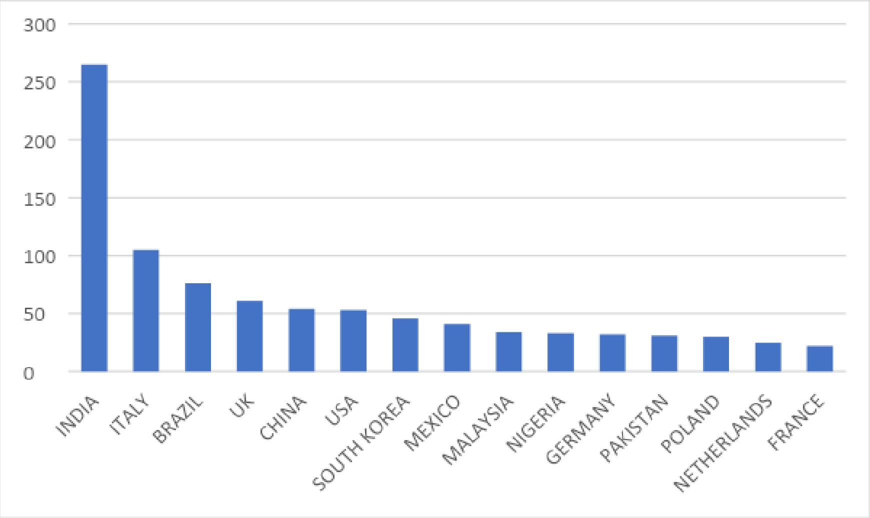

Figure 2. Scientific production by country

Figure number 2 shows the production by country, led by India, with more than 250 articles published, followed by Italy with just over 100 publications and Brazil, with just over 70. In an article extracted from the most productive country (India), authors Anthwal et al. (2024) investigate the four development phases that lead to Industry 4.0. The authors claim that Industry 4.0 is simply the fourth industrial revolution, one that will transform the production process and facilitate the production of complicated medicines in the pharmaceutical sector. According to the same authors, the emergence of Industry 4.0 and its cutting-edge technologies, including robotics, artificial intelligence (AI) and the Internet of Things (IoT), increase the flexibility of processes and are applied in various areas of the pharmaceutical industry, including manufacturing, packaging, analysis and diagnosis.

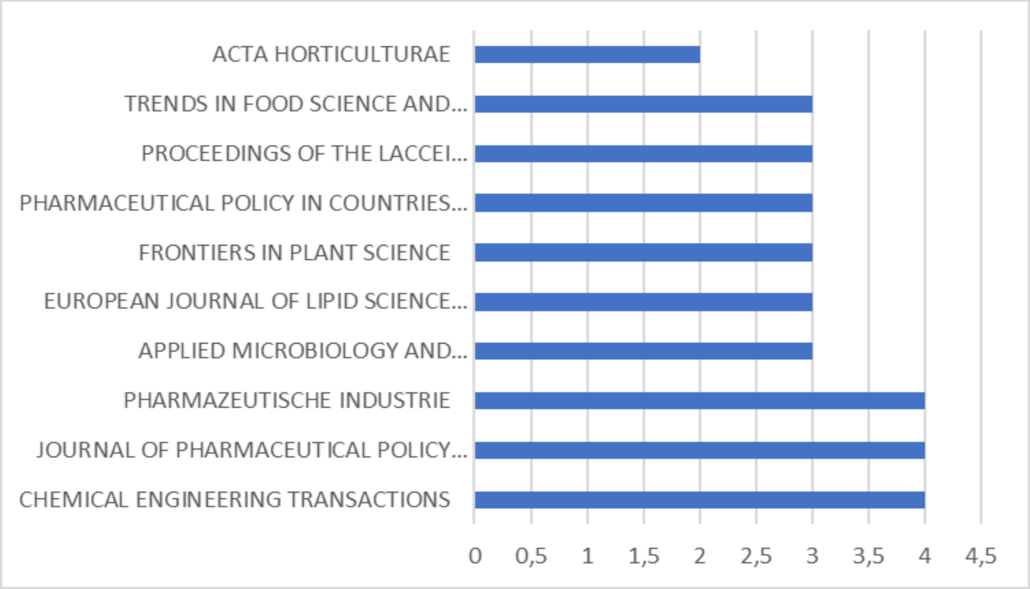

Figure 3. Most relevant sources

When it comes to talking about the most important journals (figure 3), the journals Chemical Engineering Transactions, Journal of Pharmaceutical Policy and Practice and Pharmazeutische Industrie stand out first with 4 publications each. Among these publications is that of Britton et al. (2019), who in their research comment that a polyphenol of relevance to the food, feed, nutritional supplements and pharmaceutical sectors is hydroxytyrosol (HT). According to these authors, hydroxytyrosol is among the most powerful natural antioxidants on the market. It also has anti-inflammatory and anti-cancer qualities, and may have cardioprotective and neurological effects.

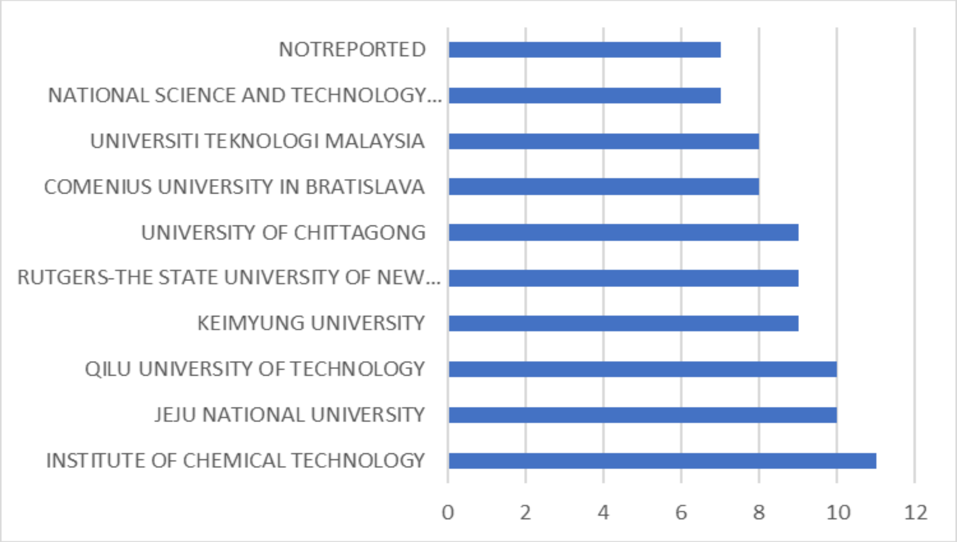

Figure 4. Most relevant affiliations

Regarding the production of the institutions, described in figure 4, this includes the number of articles or research produced by each one, where the Institute of Chemical Technology stands out, with 11 publications, followed by the Jeju National University and the Qilu University of Technology with 10 publications each.

Table 2 H-index of authors

Author	h_index	g_index	m_index	TC	NP	PY_start
BASIT AW	3	3	0.429	51	3	2018
BENEDETTI M	3	3	0.273	37	3	2014
SEHRAWAT R	3	4	0.429	63	4	2018
SHARMA M	3	4	0.333	67	4	2016
BASSANI F	2	2	0.667	31	2	2022
CAMPO M	2	2	0.286	12	2	2018
CESAROTTI V	2	2	0.182	32	2	2014
FREIRE F	2	2	0.667	31	2	2022
GAISFORD S	2	2	0.286	50	2	2018
GOYANES A	2	2	0.286	50	2	2018

Source: authors (2024)

As explained by several authors, the h-index has become one of the most popular bibliometric measures to evaluate the quality of a researcher's work and predict the future influence of their production. This is mainly because it is simple (any researcher can determine it as a single indication that includes productivity and impact) and because it eliminates biases caused by the tails of the citation distribution (Kamrani et al., 2021). For the purposes of this study, the main author of the developed H-index is involved in a work by Trendfiel et al. (2018), which is the most cited article found by bibliometric analysis, as shown below.

Table 3 Most global cite documents

Paper	DOI	Total Citations	TC per Year	Normalized TC
TRENFIELD SJ, 2018, TRENDS PHARMACOL SCI	10.1016/j.tips.2018.02.006	345	49.29	11.48
RANTANEN J, 2015, J PHARM SCI	10.1002/jps.24594	300	30.00	5.21
NATARAJ BH, 2020, MICROB CELL FACT	10.1186/s12934-020-01426-w	292	58.40	8.63
DALY R, 2015, INT J PHARM	10.1016/j.ijpharm.2015.03.017	241	24.10	4.19
VITHANI K, 2019, PHARM RES	10.1007/s11095-018-2531-1	157	26.17	4.26
CLARK EA, 2017, INT J PHARM	10.1016/j.ijpharm.2017.06.085	156	19.50	8.08
GÓRNAŚ P, 2016, IND CROPS PROD	10.1016/j.indcrop.2016.01.021	146	16.22	6.32
MEHARIYA S, 2021, CHEMOSPHERE	10.1016/j.chemosphere.2021.130553	145	36.25	10.38
AYATI N, 2020, DARU J PHARM SCI	10.1007/s40199-020-00358-5	139	27.80	4.11
ANBARASI M, 2019, INDIAN J PUBLIC HEALTH RES DEV	10.5958/0976-5506.2019.00053.6	138	23.00	3.75
KUMAR A, 2019, INT J PROD RES	10.1080/00207543.2018.1543969	114	19.00	3.10
FISHER AC, 2019, TRENDS BIOTECHNOL	10.1016/j.tibtech.2018.08.008	108	18.00	2.93
PAPPENBERGER G, 2013, ADV BIOCHEM ENG BIOTECHNOL	10.1007/10_2013_243	105	8.75	3.29
FISCHER R, 2020, BIOTECHNOL ADV	10.1016/j.biotechadv.2020.107519	104	20.80	3.07
TAPIA F, 2016, APPL MICROBIOL BIOTECHNOL	10.1007/s00253-015-7267-9	103	11.44	4.46
CHANDEL V, 2022, FOODS	10.3390/foods11172683	88	29.33	9.02
LUCARINI M, 2018, MOLECULES	10.3390/molecules23081888	87	12.43	2.90
NAZIR A, 2019, TRENDS FOOD SCI TECHNOL	10.1016/j.tifs.2019.02.049	80	13.33	2.17
FODI T, 2017, CHEMSUSCHEM	10.1002/cssc.201701120	77	9.63	3.99
PRABAKAR D, 2018, J ENVIRON MANAGE	10.1016/j.jenvman.2018.03.136	75	10.71	2.50

Source: authors (2024)

Table 3 is a list of the documents that have been cited the most by other research in this or related fields since they were published. In this item, the article with the most citations, developed by Trendfield et al. (2018), sets out how three-dimensional (3D) printing is bringing about a paradigm shift in clinical pharmacy and pharmacology, from mass-produced prescriptions to personalized medicines. The idea, according to the authors, allows the creation and on-demand manufacturing of adaptable formulations with customized dosage, size, shape and drug release, as well as multi-drug combinations, benefiting patients, pharmacists and the pharmaceutical sector. This article highlights the critical role that healthcare professionals will play in the future integration of 3D printing into the pharmaceutical industry. It also provides an overview of the most recent generation of 3D printing processes, as well as the main advantages and reasons for using 3D printing in medicine.

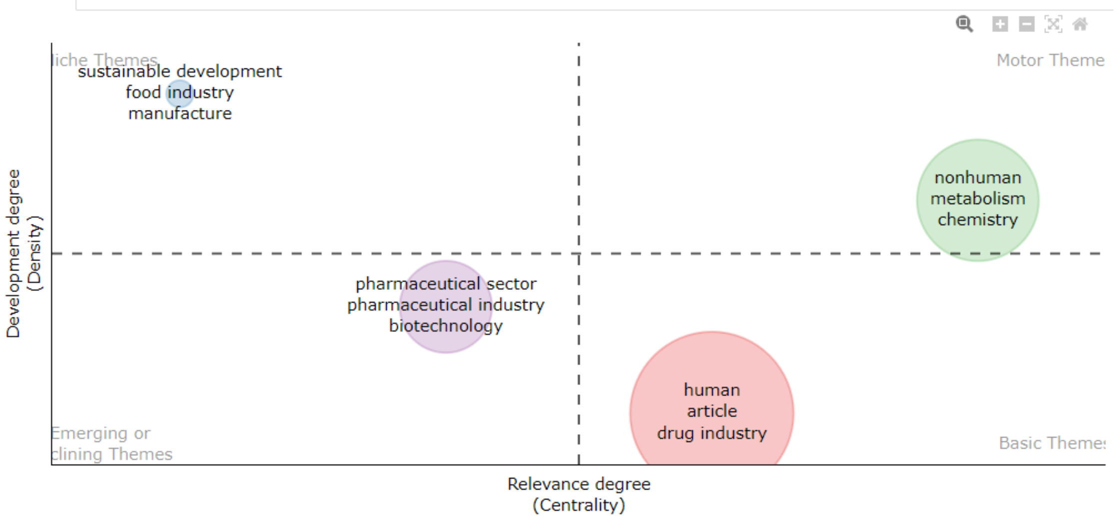

Figure 5. Thematic map

The thematic map in Figure 5 is analyzed, which clearly indicates that, as the main or driving theme (top right side) there are the key terms “Non human”, “Metabolism” and “Chemistry”; From this, the interpretation that can be made is that there is a theme focused on productivity in the pharmaceutical sector. As basic themes (bottom right) there are 3 key terms, these being “Drug industry”, followed by “Article”, and finally, “Human”; These themes are considered to be transversal with the other terms that appear on the map. Finally, it can be stated that the terms that appear on the left side, both at the top and at the bottom, are emerging or declining topics.

In co-citation networks, a CR (Cited Reference) record is represented as a node, and if two CRs are co-cited by the same source record (Ramírez-Durán et al., 2023), a connection is formed. The number of times two CRs are referenced together determines the weight of the tie. Since it is believed that the more times two CRs are cooked, the more similar their content will be, the weight can be interpreted as a measure of node similarity (Bu et al., 2020). Other metrics included in the exam are detailed below (Polanco, 2006):

Degree centrality: the number of direct connections to other nodes; Weighted grades are used to indicate relationships with strength attributes.

Intermediate centrality: The degree to which a node is on the shortest path between two other nodes, mediating or falling between them.

Cluster: A set of nodes within a network that have a greater degree of connectivity with each other than with other nodes.

Bridge: a node in a network that joins two different clusters.

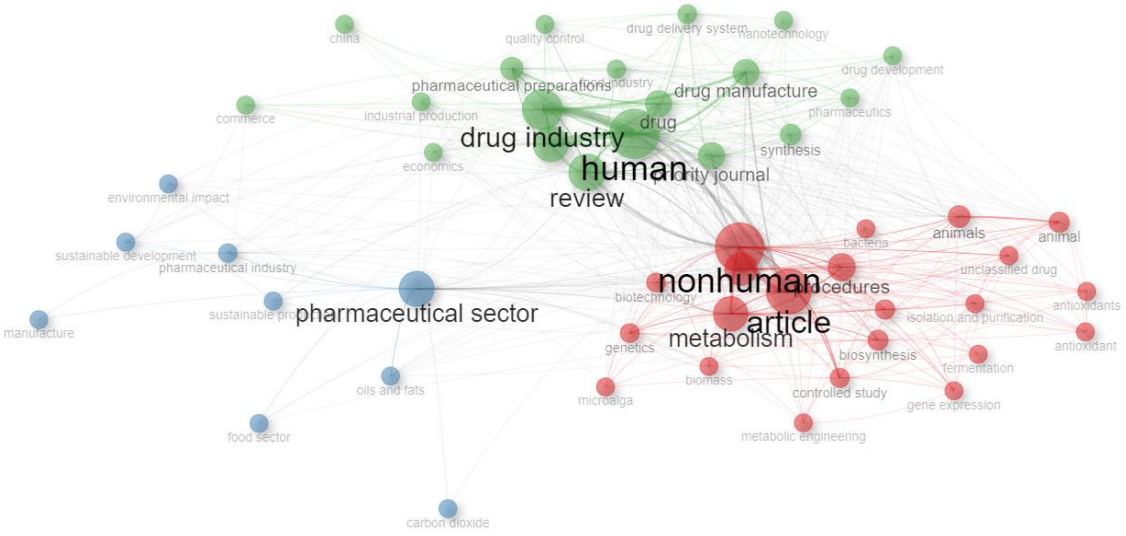

Figure 6. Co-occurrence network

In Figure 6, 3 clusters are identified, red and green being the most prominent with words such as: “Drug industry”, “Human”, “Review” and “Drug manufacturing” among others, while in red the clusters stand out. words “Non human”, “Article”, “Metabolism”, etc. Finally, the blue cluster indicates words such as “Pharmaceutical sector”, “Sustainable development”, “Environmental impact”, among others.

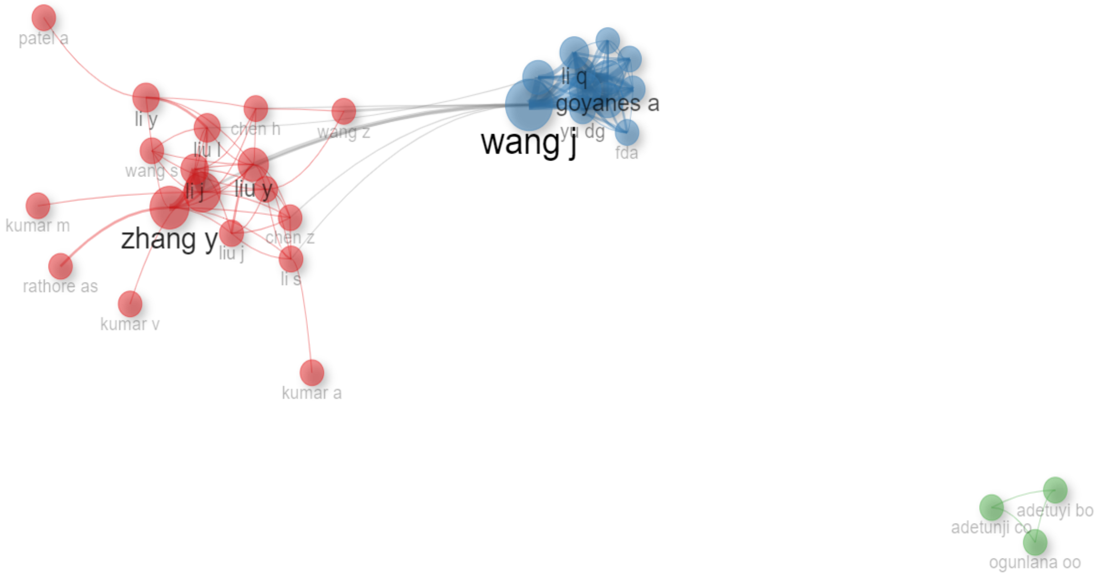

Figure 7. Authors cocitation

Taking into account the previous paragraph and figure 7, which shows the co-citation of authors, it can be said that there are 3 groups related, each one with a line of research, distributed as follows: Red color: It is made up of 18 authors, which include Zhang Y, Kumar M, Patel A, Kumar Y, among others.

Blue cluster: Made up of 12 researchers, of which Wang J, Genina N, Zhang J and Li Q stand out. Green cluster: They have the same line of work that includes authors such as Adetunji CO, Ogunlana OO and Adetuyi BO.

4. Conclusions

The number of studies and scientific publications devoted to the issue of pharmaceutical productivity is on the rise, according to this bibliometric analysis conducted in the area. A notable rise in research on process optimization and efficiency improvement in the pharmaceutical industry has been detected through data collecting and analysis on publications, citations, and author cooperation. This trend encourages more effective and efficient operations by highlighting the increased awareness of the need to solve operational difficulties in pharmacies. This bibliometric analysis provides a strong basis for future research and improvement plans by mapping the present research environment and identifying areas of highest effect and persistent gaps that need attention.

The pharmaceutical industry is becoming more and more concerned with sustainability, as seen by the steady rise in research output. It is clear that the academic community is giving this important issue greater resources and attention, as seen by the rise in publications from less than ten per year in 2013 to an increasing trend with slight variations. This increase in published work is a sign of a vibrant scientific community dedicated to finding novel approaches to enhancing the pharmaceutical industry's efficiency and sustainability. With over 250 publications, India leads the world in scientific production geographically, followed by Italy and Brazil. This shows that pharmaceutical research and sustainability are given significant funding and attention in these nations.

Leading with four articles each, Chemical Engineering Transactions, Journal of Pharmaceutical Policy and Practice, and Pharmazeutische Industrie have been the most pertinent journals in this sector. These publications serve as important venues for the exchange of cutting-edge and pertinent research, advancing our understanding of the field where sustainability and medicines meet. The studies that are published in these publications show how novel substances and technological advancements may raise the sector's sustainability and efficiency. With eleven and 10 publications apiece, the Institute of Chemical Technology, Jeju National University, and Qilu University of Technology lead the list of most prolific universities. This suggests that these universities have a strong focus on pharmaceutical research and are establishing themselves as pioneers in the hunt for novel approaches to improving the sustainability and productivity of pharmaceutical manufacturing.

An indicator of the caliber and significance of a researcher's work may be obtained by analyzing the authors' h-index. With a h index of 3, authors like BASIT AW, BENEDETTI M, and SEHRAWAT R stand out for their noteworthy contributions to the subject. This index, together with the g_index and m_index, provides a clear picture of these authors' impact on pharmaceutical productivity research and aids in identifying key research fields and thought leaders. With 345 citations, the paper by TRENFIELD SJ, 2018, TRENDS PHARMACOL SCI, is the most referenced document. The significance of technological innovation in promoting sustainability and efficiency in the pharmaceutical sector is underscored by this study on three-dimensional (3D) printing and its potential to revolutionize clinical pharmacy and pharmacology.

Key phrases like "Non-human," "Metabolism," and "Chemistry" are identified as important topics in the produced thematic map, indicating a strong bias towards pharmaceutical productivity research. Cross-cutting core topics like "Drug industry," "Article," and "Human" highlight the words' extensive applicability in the field of current study. Future study might be guided by the rising or decreasing phrases found, which highlight areas that may be growing or losing significance in the subject. However, co-citation networks—which are described in depth in—showcase three notable research clusters, each of which is centered on a distinct facet of the pharmaceutical sector. These clusters demonstrate the connections between several fields of study and the value of multidisciplinary cooperation in tackling the intricate problems associated with sustainability in the pharmaceutical industry.

In conclusion, this study's bibliometric analysis offers a thorough and quantitative picture of the state of pharmaceutical productivity research. The results highlight the significance of efficiency and sustainability in the sector, pointing out new trends, areas of influence, and areas in need of improvement. Innovation and sustainability in the pharmaceutical industry depend on global cooperation and the uptake of cutting-edge technologies like Industry 4.0 and 3D printing.

Subsequent studies have to concentrate on delving further into cutting-edge technologies and their uses in the pharmaceutical sector, in addition to creating more reliable measurements and techniques for evaluating efficiency and sustainability. To successfully address the global difficulties facing the industry, it is also imperative to promote multidisciplinary collaboration and information transfer across researchers, institutions, and nations. Promoting sustainable practices and raising productivity in the pharmaceutical sector will also heavily depend on putting supporting regulations into place and funding research and development.

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