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The value chain approach in red biotechnology companies from a bibliometric perspective

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Abstract:

This paper analyzes the value chain approach in the red biotechnology sector from the point of view of bibliometrics, using Scopus and Web of Science databases from 2011 to 2021. The 82 papers covering this topic were analyzed with VOSviewer and R studio. The primary results show increased scientific interest with a positive trend in publication for the period considered. However, there is no author network in both database. Furthermore, the main reason for using the value chain approach in the red biotechnology sector is that it highlights government involvement in the industry due to its social impact. As a research gap, it is advisable to study the impacts of Industry 4.0 on the red biotechnology value chain approach.

Key words:

Value chain approach, red biotechnology, bibliometric analysis.

1. Introduction

The academic community has discussed value theory in several scientific conferences, journals (Benington & Moore, 2011), and research fields. From an economic point of view, value is considered as the willingness of customers to pay for a good provided by a company. This value is entered into the company's income statement by multiplying the quantity sold and the price of a particular product. However, Porter (1991) recognizes value theory as a tool for strategic competitive analysis.

Porter (1991) provides the seminal definition of a Value Chain (hereafter, VC). This author defines a VC as a tool for configuring and linking a company's activities to create a product or service. To source and supply products to customers, a company is not alone but must develop relationships with other companies and their value chains. This network is called Value System.

Kaplinsky & Morris (2000) points out that there is considerable overlap between Porter's definition and similar definitions used in other contexts, which becomes a problem of terminology confusion.

The *filière* concept, for instance, was developed in the 1960s in France to describe the flow of inputs and services involved in producing a final product and is entirely in line with Porter´s Value System definition. On the other hand, Gereffi (1994) talks about *global commodity chains* focusing on the power relations embedded in VC in a globalized ecosystem. A similar idea is provided by Womack & Jones (1996), who use the phrase *value stream* to refer to VC.

The modern VC analysis shows it as a tool that includes both, internal and external activities, to obtain and realize a product, from producers to consumers, including post-sale actions.

Ricciotti (2020) confirms that over the years, the definition of VC has been expanded, improved, and innovated with concepts such as Virtual VC, Added

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VC, Reverse VC, Sustainable VC, etc. However, in this study, the authors will only work with the concept of VC because from their point of view, other related concepts are attributes or characteristics of VC and not a different approach to VC.

A VC consists of a set of value-creating activities that are planned, coordinated, controlled, and continuously improved. All these activities occur to obtain a product or provide a service, along the flow channel, from the initial source to the final destination.

In addition to tasks directly related to the production of goods, its distribution and sale, a VC includes those activities of research, development, patenting, search for and obtaining financing, waste treatment, recycling, and disposing of the final product after it is no longer in use.

VC performance is characterized by flexibility and cooperation between the different actors or decision makers. On this path, the main goal is to maximize the chain´s margins, profitability and value, in order to gain or maintain a competitive advantage.

The VC approach aligns with the new industrial policy's goal (Kaplinsky & Morris, 2000) to create global competitiveness, value-adding, and innovative industries to generate more productive jobs and reduce poverty towards shared prosperity (Terzi et al., 2022).

Nowadays, one of the five most innovative sectors is the biotechnology (hereafter, biotech) industry (Ideascale, 2017), which is considered one of the critical technologies of the XXI century for the production of knowledge, goods, and services (Uecke, 2012). Biotech applications are classified using a color index as shown in Table 1.

Companies that develop medical applications are also referred to as red biotechnology companies, as shown in Table 1. Uecke (2012) shows that the number of biotech companies active in health (51%, followed by 19% for companies in agriculture and food), as well as the R&D spending on red biotech internationally (87% of total expenditures in this sector) and the share of healthcare-related biotech products (80% of the industry's total sales), demonstrate that the red sector is the largest of all biotech sectors. Ten years later, Martin et al. (2021) reveals a global growth rate of 1.3% from 2015 to 2020, and claims that there will be more investment in R&D worldwide within the next five years.

Table 1. Biotech activities by colors.

Biotech Activity	Color sector
Health, Medical, Diagnostics	Red
Food Biotechnology, Nutrition Science	Yellow
Aquaculture, Coastal, and Marine Biotech	Blue
Agricultural, Environmental Biotechnology-Biofuels, Biofertilizers, Bioremediation, Geomicrobiology, Food Production	Green
Arid Zone and Desert Biotechnology	Brown
Bioterrorism, Biowarfare, Biocrimes, and Anticrop warfare	Dark
Patents, Publications, Inventions, IPRs	Purple
Gene-based Bioindustries	White
Bioinformatics, Nanobiotechnology	Gold
Classical Fermentation and Bioprocess Technology	Grey

Source. Adapted from De la Vega et al. (2015).

From a VC perspective, this study selects red biotech for several reasons. First, products or therapies are derived from research aimed at improving a patient's quality of life and are evaluated for added value. Researchers are constantly creating new knowledge in this field, and their contributions to science are measured by the value of this knowledge or its social impact. Third, this is a science-intensive field where innovation and cutting-edge technology are essential to their success.

Published works addressing the value chain in the red biotechnology sector seem to focus more on medical and technological issues. This does not appear to be an area that is sufficiently studied from a management standpoint.

Given this defined gap, the research questions posed in this study are: (1) What are the trends and citation networks of VC publications in red biotechnology? (2) Who are the most influential and productive authors, affiliates, countries and years? (3) What are the most relevant reasons to use the VC approach in red biotech? (4) What are the research gaps in this field?

To answer the research questions, this study aims to analyze the VC approach in the field of red biotechnology from the bibliometric point of view.

To fill it, its authors use Scopus and Web of Science (WoS) databases as well as VOSviewer and R studio software to display the results and highlight findings and conclusions. This is the first bibliometric study to address this topic to the best of the authors' knowledge.

2. Methodology

Bibliometric analysis is increasingly popular in the scientific community (Choudhri et al., 2015; Dhiaf et al., 2021; Holgado de Frutos et al., 2020; Movahedipour et al., 2016). It is employed to analyze bibliographic literature from a quantitative perspective and to evaluate the activity of the scientific community in a particular area of knowledge (Dhiaf et al., 2021; Merigó et al., 2015).

The methodology pursued in this manuscript is shown in Figure 1 and developed following Carrizo & Moller (2018) and Choudhri et al. (2015) propositions.

To complete step 1, it is necessary first to demonstrate the relevance of the study. The next step is to define a specific and measurable research goal. To achieve meaningful research, specific keywords and inclusion and exclusion criteria must be identified, and these are the follow-up actions. Search execution consists of consulting the Scopus and the WoS databases to collect the published papers on red biotech VC approach, following the criteria defined in step 1. The final step is intended to display, analyze and discuss the results provided by the database and processed by the authors using Microsoft Excel, VOSviewer, and R studio software.

According to the research field, the keywords identified and selected are: "value chain"; "biotechnology"; "health biotechnology"; "disease biotechnology"; "medical biotechnology"; "red biotechnology"; "biopharmaceutical"; and "biopharmacy".

Selected inclusion and exclusion criteria were keyword combination, period analysis, document type and communication language. In this sense, the first decision focused on determining the keyword combination to be researched, resulting in articles containing in their titles, abstracts, and keywords combinations of the following keywords: "value chain" AND "biotechnology" AND "health".

The time period of the research is from 2011 to 2021 which is justified according to Carrizo & Moller (2018), Gómez-Cedeño et al. (2014), and Codina (2019) recommendations. Additionally, the publications before 2011 are not significant either in number or citations. The final date of data collection is February 15, 2022.

Selection criteria for the document type included the choice of journals and articles, excluding conference papers, books, and book chapters. The journal editorial board has the knowledge and experience to identify relevant articles (often previously presented at conferences), to be used as the first filter. Another

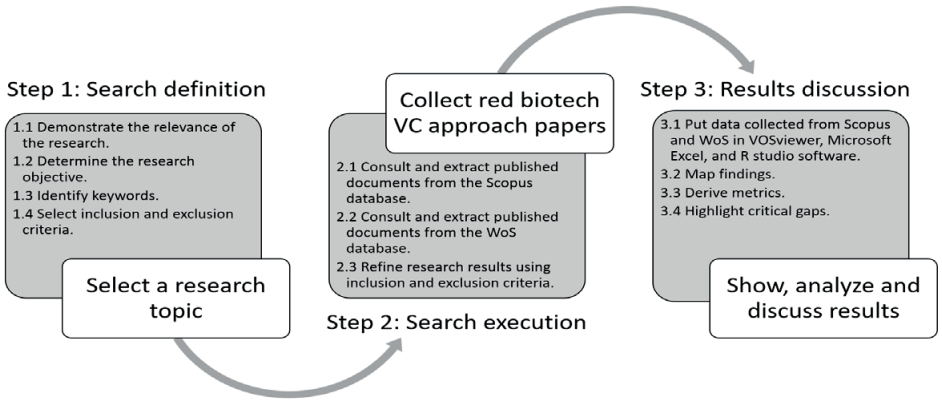

Figure 1. The methodological research process of this study. Source. Self-made.

reason is that usually most book chapters used to be an article published by an academic journal.

After eliminating duplicate papers, the results from the first step are 30 and 52 papers from Scopus and WoS, respectively.

3. Results and Discussion

This section specifically: (1) identifies the most influential authors, their affiliations, and also the most productive publication´s year and countries; (2) reveals current research trends; (3) highlights the main reason to adopt the biotech VC approach, and (4) maps and summarizes results.

3.1. Value chain approach on the selected databases

Amador & Di Mauro (2015) argues that the VC approach has become at the heart of the competitiveness debate and that by studying publications in different databases, researchers can compare this. Since 1928, the Scopus and WoS databases have collected 22,285 and 14,327 VC publications, respectively. The first documents related to the VC approach to appear in the Scopus and WoS databases were "CXLVIII. - On the oxidation of n-hexane", and "The role of global procurement in the value chain of Japanese steel".

Regarding the VC approach, the most cited paper, with 398 citations between 2011 and 2021, is "The governance of global value chains", published by Gereffi et al. (2005) in the Review of International Political Economy. Likewise, in more than 70 authors, all publications following the VC approach are concentrated. Table 2 summarizes the most productive authors in the two databases.

Even if Table 2 shows that only Ponte, S. and Rich, K.M. have a publication in both databases, during the period 2011-2021, Gereffi, G.; Lee, J.; Bush, S.R.; Rushton, J.; Donovan, J.; Samsatli, S.; Alarcon, P.; Minten, B.; Mudambi, R.; Reardon, T.; Bijman, J.; Morris, M.; and Sieber, S. are frequent repeat authors in Scopus and WoS, but they are not listed in Table 2 because they are not in the top 20.

Related to the most influential affiliations, Wageningen University & Research highlights a more prolific membership in the Scopus database, and the Consultative Group on International Agricultural Research (CGIAR) prevails in the WoS database. On the other hand, in both databases, USA, Germany, England, China, and Italy emerged as the most productive countries in VC research.

Table 2. Top 20 more productive authors in Scopus and WoS databases relative to the VC approach over the years.

Scopus		WoS	
Author	Number of publications	Author	Number of publications
Gereffi, G.	42	Ammann, M.J.	42
Ponte, S.	31	Wang, L.	38
Rich, K.M.	26	Cooke, D.R.	37
Minten, B.	23	Labaste, P.	32
Samsatli, S.	23	Webber, C.M.	32
Bijman, J.	22	Liu, Y.	30
Bush, S.R.	22	Li, Y.	28
Donovan, J.	22	Rich, K.M.	25
Morris, M.	22	Skreiberg, O.	25
Swinnen, J.	22	Dunshea, F.R.	24
Pietrobelli, C.	21	Wang, Y.	24
Reardon, T.	21	Ponte, S.	23
Rushton, J.	21	Fuentes, S.	22
Demont, M.	20	Grace, D.	22
Ingram, V.	20	Chen, Y.	21
Barrientos, S.	19	Farrell, R.	21
Dannenberg, P.	19	Viejo, C.G.	21
Häsler, B.	19	Zhang, J.	21
Nadvi, K.	19	Li, J.	20
Di Maria, E.	18	Torrico, D.D.	20

Source. Self-made.

3.2. Biotechnology on the selected databases

Biotechnology "is considered to be one of the key technologies of the 21st century […], is the application of science and technology to living organisms, as well as parts, […] for the production of knowledge, goods, and services" (Uecke, 2012, p. 84). The first publication related to this topic in Scopus and WoS databases was dated 1933 and was provided by Nature Journal. From this year until 2021, the Scopus database shows 179,054 papers, while the WoS database collected 469,057 in the same period.

Especially health studies in biotech publications represent 7.9% in the Scopus database from 1961 to 2021 and 11.1% in the period 1982-2021 for the WoS database (1961 and 1982 represents the first publication year in red biotech registered in Scopus and WoS databases, respectively). The first publication in Scopus and WoS databases related to red biotech using the VC approach is "Disruptive technologies, stakeholders and the innovation value-

added chain: a framework for evaluating radical technology development". Until today, it is the most cited paper in Scopus and WoS databases, with more than 100 total citations in each.

3.3. Temporal activity in red biotech VC approach: volume and impact of authors and publications

Figure 2 summarizes the number of publications in Scopus and WoS, where a positive trend can be appreciated clearly. However, it is not an intensive research topic studied by authors in Scopus, who commonly have published only one publication over the period analyzed. Authors in WoS evidence a more stable behavior about year publications.

Table 3 summarizes the authors´ publications related to the research topic in both databases and all their published and registered papers in these databases. Using all records (column of All Publications) in Scopus and WoS, H-index and M-index have been calculated separately. H-index measures quantity (number of papers) with quality (number of citations) of published research, is a metric to assess the entire body of scholarly output by an author and means how many papers H has at least H citations. M-index is like an average of the H-index while it is calculated by dividing the h-index by the number of years since the first published paper, represented in the PY_Start column in Table 3.

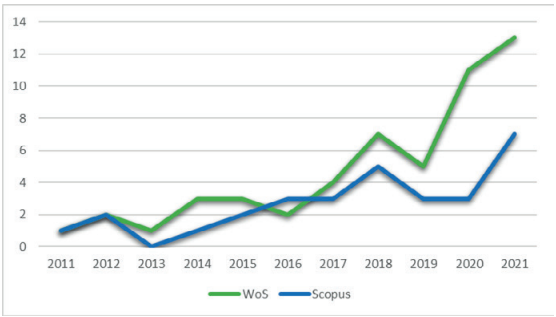

Figure 2. Red biotech VC approach's publications between 2011 and 2021. Source. Self-made.

According to Scopus records, Van Montagu, M. ranks first in productivity with the highest h-index, followed by Giacca, M. and Singer, P.A. Fevre, E.M. ranks first in WoS with eleven published papers about red biotech VC, seconded by Alarcon, P., and Rushton, J. Analyzing M-index, Van Montagu, M. and Antun, R. rank first as more productive researchers as average per year in Scopus and WoS respectively.

These metrics present the inconvenience that authors in different databases are incomparable because the indexes depend on where you get the publication and citation data. In addition, even if the M-index is a time correction of the H-index, it depends on the H-index, which favors authors with more experience as far publishing years are concerned.

Table 4 presents five major publications on the topic of the study. G-index is calculated by ranking articles by the number of citations received in Scopus and WoS, in descending order. The next step is to number the positions. Finally, the G-index represents the number of documents that have accumulated at least g^2 citations (Hirsch, 2005), resulting in 5 papers for the two databases.

3.3.1. Network and content analysis

For network analysis (co-authorship, co-citation analysis, and bibliographic coupling), the VOSviewer software was used. Scopus authors are not connected, but Figure 3 shows the author's network in WoS.

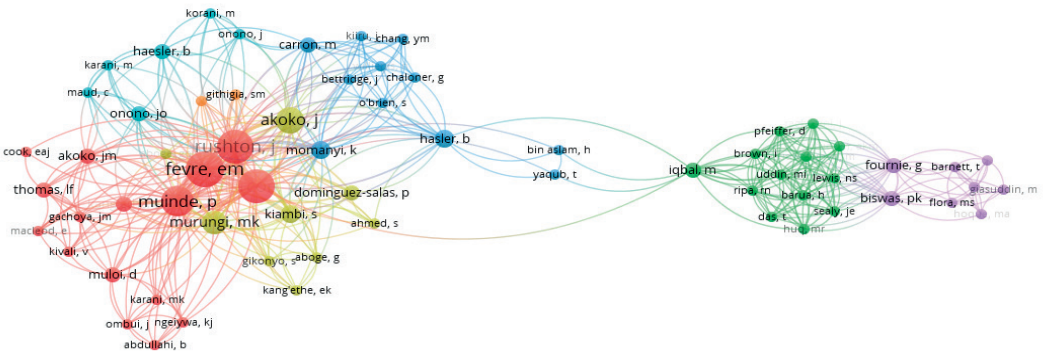

Figure 3. Co-authorship network visualization in WoS. Source. VOSviewer report.

Table 3. Top 15 authors in publications and citations.

Scopus					
Authors	Topic´s Publications	All Publications	H-Index	PY_Start	M-Index
Van Montagu, M.	1	709	129	1993	4.61
Giacca, M.	1	512	70	1993	2.50
Singer, P.A.	1	408	76	1993	2.71
Wittmann, C.	1	312	46	1993	1.64
Wieland, T.	1	240	58	1994	2.15
Daar, A.S.	1	219	64	1994	2.37
Becker, J.	1	87	31	1991	1.03
McGahan, A.M.	1	87	21	1992	0.72
Philp, J.	1	68	26	1991	0.87
Kannt, A.	1	63	24	1996	0.96
Pietrobelli, C.	1	59	33	2005	2.06
Rao, N.H.	1	44	18	1993	0.64
Heijde, M.	1	40	9	1989	0.28
McCarthy, B.	1	24	10	2000	0.48
Katz, J.	1	22	10	1997	0.42

WoS					
Authors	Topic´s Publications	All Publications	H-Index	PY_Start	M-Index
Fevre, E.M.	11	161	38	1977	0.86
Alarcon, P.	10	20	11	2011	1.10
Rushton, J.	10	135	22	1990	0.71
Muinde, P.	8	14	7	2016	1.40
Akoko, J.	6	18	6	2016	1.20
Atun, R.	5	394	58	2000	2.76
Fitchett, J.R.	5	79	23	1994	0.85
Hasler, B.	5	88	16	1997	0.67
Head, M.G.	5	42	12	2007	0.86
Murungi, M.K.	5	9	5	2017	1.25
Cooke, M.K.	3	21	11	1967	0.20
Hayward, A.C.	3	121	37	1990	1.19
Kiambi, S.	3	14	8	2017	2.00
Momanyi, K.	3	7	4	2018	1.33
Wurie, F.B.	3	24	10	2013	1.25

Source. Self-made.

Authors in the WoS conform 65 links in 7 clusters. Therefore, a weak network of authors investigating VC in the red biotech sector exists. Fevre, E.M. is a vital author that connects other researchers, mainly due to his productivity.

The authors of the sample of papers in both databases come from a few countries: USA, UK, France, and Netherlands. In the same way, the authors´ affiliations are also not extensive.

A co-citation source map for papers in both databases is inexistent. According to the co-citation reference map, the situation with Scopus is the same, and only two articles in the WoS form a network: Alarcon et al. (2017) and Gereffi et al. (2005). This result is in line with the dispersion of authors and the few quantities of clusters.

The content analysis provides an overview of the nature of the topic studied in this research. R studio software was used to plot the word cloud based on the author' keywords in Figure 4.

Table 4. Top five cited papers.

Scopus			
	Paper´s Title	Time Cited	G-index
1	Becker & Wittmann (2019). A field of dreams: Lignin valorization into chemicals, materials, fuels, and health-care products. *Microbial Engineering Biotechnologies, 37*(6), 107360	113	1
2	Lokko et al. (2018). Biotechnology and the bioeconomy—Towards inclusive and sustainable industrial development. *Bioeconomy, 40*, 5-10	52	4
3	Philp (2018). The bioeconomy, the challenge of the century for policymakers. *Bioeconomy, 40*, 11-19	52	9
4	Kalpana Sastry et al. (2011). Nanotechnology for enhancing food security in India. *Food Policy, 36*(3), 391-400	53	16
5	McCarthy et al. (2016). Innovations in the agro-food system. *British Food Journal, 118*(6), 1334-1349	33	25

WoS			
	Paper´s Title	Time Cited	G-index
1	Becker & Wittmann (2019). A field of dreams: Lignin valorization into chemicals, materials, fuels, and health-care products. *Microbial Engineering Biotechnologies, 37*(6), 107360	113	1
2	Head et al. (2013). UK investments in global infectious disease research 1997–2010: A case study. *The Lancet Infectious Diseases, 13*(1), 55-64	55	4
3	Kalpana Sastry et al. (2011). Nanotechnology for enhancing food security in India. *Food Policy, 36*(3), 391-400	44	9
4	McCarthy et al. (2016). Innovations in the agro-food system. *British Food Journal, 118*(6), 1334-1349	32	16
5	Alarcon et al. (2017). Mapping of beef, sheep and goat food systems in Nairobi—A framework for policy making and the identification of structural vulnerabilities and deficiencies. *Agricultural Systems, 152*, 1-17	31	25

Source. Self-made.

Figure 4 shows that in papers from the WoS (Fig. 4a) and the Scopus (Fig. 4b) databases, the most common keywords and therefore the most researched topics are: (1) value chain as a strategic tool, (2) innovation in the value chain, (3) impact and application of the VC approach in the bioeconomy and biotech industry, (4) sustainability of VC, (5) risks in the pharmaceutical sector, (6) VC governance, (7) VC mapping, and (8) social health impacts.

4. Conclusions and Highlights

This study provides the first bibliometric analysis of the value chain approach in the field of the red biotechnology. It was developed to answer the four

Figure 4. Authors´ keywords word cloud in Scopus and WoS. Source. R studio report.

original research questions, presented in Section 1, and follows a three-step methodology with data collected from the Scopus and the WoS databases. The five most relevant findings are summarized as follows:

(1) After examining the performance of the VC publications on red biotechnology and its current trends, it can be said that this is not a broad area of research (only 82 papers have been reviewed, published in the last ten years). Publications have increased over the years, but the low number of publications per author proves that publications on red biotechnology focus on health topics rather than industry. Network does not connect much research. Co-citation analysis of articles is not possible because the articles do not make up the network.

(2) According to Scopus productivity, Van Montagu, M. is the most productive author, while Fevre, E.M. featured in WoS. Prominent institutions are Wageningen University and the University of Liverpool. The most productive years and countries are 2021 and the USA respectively. H-index and G-index were calculated, but these metrics were inconclusive because the authors in different databases could not be compared. After all, the indexes depend on where researches gets the publication and citation data.

(3) The most relevant reasons to use the VC approach in this industry are the effects of government, due to its social impact, and the ability to link activities in the technology and global environment.

(4) This study demonstrates the existence of certain gaps that shape the future agenda. First, the modern concept of VC, which analyzes a company's complex network, including international relations, is not widely studied and applied in the field of red biotechnology. Second, and regarding red biotechnology and its business model, there are no published works that analyze the early stages of a biotechnology product, i.e. when the product is a project. The value created in this process is just as important as the impact of the product in the future, if not more, because if the project cannot make it past this stage, it will never become a product. Third, research indicates that current topics such as the impact of Industry 4.0 on red biotech VC have yet to be thoroughly studied. Industry 4.0 applications such as Blockchain technology and the Internet of Things (Dhiaf et al., 2021; Khan et al., 2021; Meseguer-Sánchez et al., 2021; Wang et al., 2020; Wiedmer & Griffis, 2021; Zhang & Chen, 2020) can boost business performance and deliver better economic, social and environmental outcomes.

(5) Finally, future research can be directed toward mapping VCs for products in less developed countries, applying techniques to reduce the uncertainty and risks these regions. All actors must be taken into account, including governments, funding organisations, universities and regulatory agencies.

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