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Scientific Research Trend in Biorefineries in India: Analysis and Systematic Review

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ABSTRACT

The aim of this article is to provide a comparative analysis regarding the production of the scientific research of biorefineries in India using Web of Science and Scopus databases. The rate of growth of publications, production, citation, correlation and overlap between databases, authors, journals and universities has been analyzed. The results of both databases show exponential growth of publications in India from 2015-2020 on the topic of biorefineries. The index of citations per document is similar in WoS and Scopus. The correlation of citations was found to be high between databases used. Most Indian authors publish in quartile 1 (Q1) journals. Most of the published documents are review and the highest number of citations were found in the journal "*Renewable and Sustainable Energy Reviews*". Both databases present a series of publications on the topic of biorefinery by authors from India, the difference between the databases lies in the indexing criteria and the updating of the journals.

1. INTRODUCTION

With the growth of the population and the need for energy, various countries have focused at the possibility of using renewable energy to satisfy their needs, as well as promoting the use of clean energy to reduce health risks and environmental effects during CO_2 emissions. There are different sources of renewable energy such as wind, solar, thermal, hydro and derivates from plants or biological materials that can be used to produce clean fuels; the biofuels are considered the main substitute of fossil fuels, however there are factors such as policy or legal guidelines and competitive cost that impede the large-scale production and marketing [1].

In this sense, biorefineries play a critical role in the development of technology to promote the use of biofuels in mixtures of gasoline or diesel, as well as to improve their efforts through energy policies.

Hence, the government has created policies and initiatives such as the National Policy on Biofuels, which was released in August 2018, as well as a more liberal environment to encourage foreign investment in order to rapidly expand the country's renewable energy industry. Over the next few years, it is anticipated that the clean energy market will generate a significant number of domestic jobs [2].

The biorefinery is a promising solution for converting raw materials into biofuels, amino acids, enzymes, antibiotics, and energy [3, 4]. The aim of the biorefinery concept is to maximize the economic potential of raw materials by generating high-value products through the application of manufacturing technologies and processes, as well as the separation and purification of byproducts. Also, biorefineries have categorized generations considering the feedstock, technology and the number of products obtained; the first generation employed a single feedstock and technology to generate limited products; in the second generation it is possible generate diverse products; the third and fourth generation different products could be produced from diverse feedstocks (microalgae) and technologies [5].

Also, biorefineries have categorized generations [5]. Crops such as rapeseeds and corn are used for the first generation, however, its use raises ethical concerns around human nutrition [6]. The second generation uses lignocellulosic biomass as the main source, as well as industrial byproducts such as glycerol and whey [7]. The third generation of biorefineries uses microbiological cellulose to use CO_2, giving them an advantage over products associated with food [8].

Additionally, various investigations have focused on the development of biorefineries in recent years, as a result of the work of postgraduate students, research groups, universities, and research centers, producing publications in various fields of energy. However, it is necessary to understand the effect of these publications over time in India. A clear answer on a country, journal or field can be estimated development a rigorous bibliometric analysis [9]. In research assessment, bibliometric studies play an important role, and they have been used to assess individual and organizational performance [10]. Furthermore, a significant number of bibliometrics papers have been published in India in various fields [10], but an initial search (in the topic of bibliometric analysis and biorefinery) of the Scopus and Web of Science (WoS) databases showed no results for India. In this aspect, it is necessary to address the need for research on the topic of biorefineries in India as well as to identify the major trends in the field.

The aim of this work is to analyze the production of scientific research of biorefineries in India using the Web of Science (WoS) and Scopus databases during the period from 2008 to 2020.

This study was developed in five sections: the introduction shows the description of the biorefineries in the global context, the materials and methods show a systematic process of generation of information using the databases and its described the analysis of data, the results and discussions contain the main data and criterial for different bibliometric indicators, also a discussions was stipulated based in the main results and finally, the references was added.

2. MATERIALS AND METHODS

In this regard, bibliometric analysis is deemed acceptable because it allows for the quantitative analysis of bibliographic material while also providing valuable tools and procedures for describing and understanding the scientific process [11, 12]. Bibliometrics is an interdisciplinary science that focuses on the analysis and description of bibliographic data from a specific field of knowledge using statistical and mathematical tools, with the findings revealing a broad view of the topic.

The authors obtained the relevant data of publications from both the SCOPUS and WoS databases. Scopus and WoS are valuable resources for researchers who need documentation to support their claims [13], and they are considered the most important scientific information databases.

The literature was retrieved using the following search terms (biorefiner*) AND (biofuel*), refined by: countries/regions (India") AND excluding publications years (2021). The literature was retrieved on May 25, 2021. The sign (*) in the search box was used to obtain both singular and plural versions of a keyword, and the marks (" ") were used for exact phrases search.

In a bibliometric analysis, the material can be classified in a variety of ways. The total number of articles or the total number of citations are the most popular ways; whereas the number of articles demonstrates productivity, the number of citations measures the impact of articles [14]. Bibliometric indicators were extracted and analyzed both quantitatively and qualitatively. The data was analyzed using Microsoft Excel.

The evolution of the publications was analyzed by fitting mathematical models with the solver-function of Microsoft Excel. The Gompertz growth model (1) and normalization Eq. (2) were used to adjust of number of documents [1] obtained in both databases.

$$P(y) = ae^{-be^{-\mu t}} \quad (1)$$

$$\left(P_{(y)database} - P_{(y)model}\right)^2 \quad (2)$$

where, P(y) represents the volume of documents by year, μ the specific growth rate of publications, *a* the asymptotic publications, *b* an integration constant related to initial publications, *t* is time, P(y) database publications reported on the databases and P(y) model estimated publications by model.

The data of the databases was fitted to determine the value of specific growth rate (μ) with the solver function of Microsoft excel. The results generated by the model were analyzed using regression curve fitting with statistical significance set at $p=0.05$ with data analysis of Microsoft Excel and the determination coefficient (R^2) was estimated.

3. RESULTS AND DISCUSSIONS

This section presents the main bibliometric results found in WoS and Scopus database for the publications on the topic biorefineries in India country.

3.1 Rate growth and trends of publications

During 2008-2020, a total of 158 and 218 publications were published in Web of Science (WoS) and Scopus databases, respectively. In both databases there are two stages of publications, the first from 2008 to 2014 and the second from 2015 to 2020.

Figure 1 illustrates the trends in the number of scientific publications in WoS database, in the first stage the production was of 10.76% and the second stage with 89.24 %. As can be observed, the experimental data was fitted using the logistic model, the rate of growth was of 0.020 h^{-1} with fit of R^2=0.93 ($p>0.05$). Similar results were obtained with Scopus database, the rate of growth was 0.021 h^{-1}, R^2=0.87 for the same period, Figure 2. With the results of modelling the field of biorefinery in India is in exponential growth.

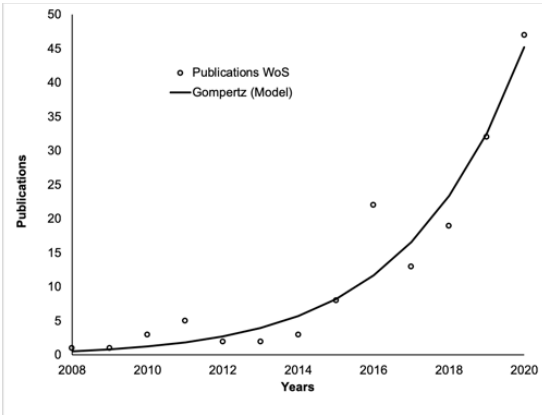

Figure 1. Total number of publications (WoS) for biorefinery research

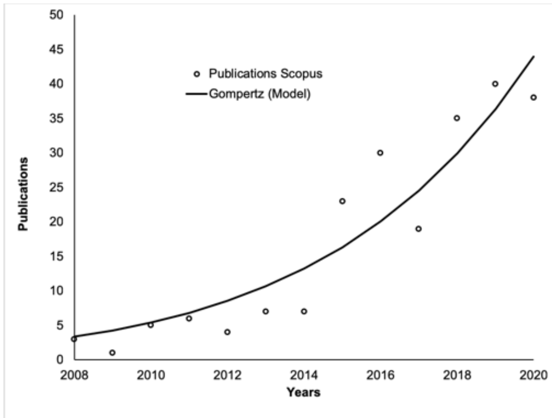

Figure 2. Total number of publications (Scopus) for biorefinery research

3.2 Publications between WoS and Scopus databases

Table 1 displays the comparative of databases, also for both databases there were more than 2000 citations in 2010 and the highest H index was obtained in 2016 with a value of 16 for the WoS publications and 19 for the Scopus publications.

Regarding the number of published documents, in WoS the highest number was reached in 2020, with 47 publications, while in Scopus, the highest number was in 2019 with 40 publications.

Interest in the biorefinery topic has generated an increase in publications from 2016 to 2020, in addition to the fact that the number of citations increased in 2016 to 1,350 in WoS and 1,675 in Scopus. The total number of publications and total number of citations are the two basic metrics used to assess the amount and quality of scientific publications in general, on the other hand, the H index characterizes the scientific production of a researcher based on the number of articles published and the number of citations that these works have reached [15], Regardless of the number of publications, there is a similar relationship of citations per publication in both databases.

Finally, we can observe that in the Scopus database there is a greater number of citations with respect to WoS, also a greater mean and a greater H index, in general.

3.3 Correlation of publications in WoS and Scopus

WoS and Scopus are the main citation databases in the world [16]. Figure 3 shows the correlation between the number of articles indexed in WoS and Scopus, and Figure 4 shows the correlation between the number of citations that the publications have.

Figure 3 shows a moderate correlation of publications data and their fit to a line between WoS and Scopus databases (R^2=0.81). A strong positive relationship exists between WoS and Scopus with the citations of the publications. The level of fit for citation of databases was R^2=0.95, see Figure 4.

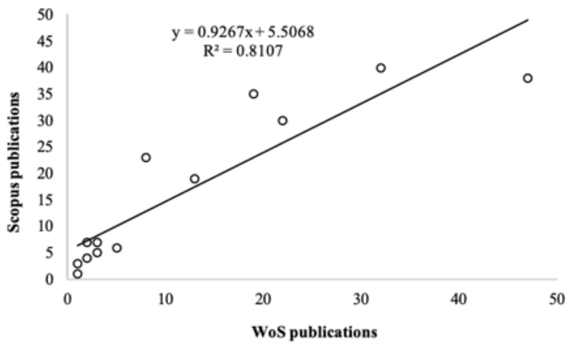

Figure 3. Correlation of publications between WoS and Scopus

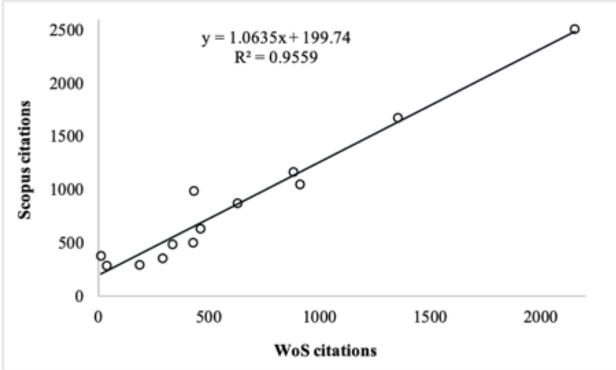

Figure 4. Correlation of citations between WoS and Scopus

3.4 Publications between WoS and Scopus databases

The details of publications most cited are shown in Table 2. The most cited document belonged to Naik et al. [17] of the Indian Institute of Technology Delhi. This document is a review titled "Production of first and second generation biofuels: A comprehensive review" published in the journal Renewable and Sustainable Energy Review. The number of citations of the review were between 1584 and 1759 for WoS and Scopus, respectively.

Of the 12 documents most cited on the topic of biorefinery in India, 11 of them belong to reviews and 1 is an article. On other hand, the average citation by years (C/Age) is greater in all Scopus documents. Generally, the peer reviewed and longer review times results in an increase in paper quality of the document [18].

3.5 Overlap between WoS and Scopus databases

Because the data for the analysis was gathered from two distinct databases, it was important to examine the overlap between the databases. As show in the Figure 5, there was significant overlap (115 documents) between WoS and Scopus databases, similar overlap occurs when the journals of both databases were analyzed, in this case exist 58 journals with overlap. From the documents, 72.77% (WoS) and 52.75% (Scopus) they are present in both databases. The difference in the overlap can be explained by the indexing policies of the databases [19], the dynamics of citations that affect the quality of the journals and the coverage of topics in each region.

Table 1. Publications of documents of the topic biorefinery in India, comparison between WoS and Scopus

Year	WOS								Scopus							
	TP	hi	Fi	Hi	C	Fc	Mean	H-index	TP	hi	FI	HI	C	Fc	Mean	H-index
2008	1	0.63%	1	0.63%	12	12	12.0	1	3	1.38%	3	1.38%	378	378	126.00	3
2009	1	0.63%	2	1.27%	291	303	291.0	1	1	0.46%	4	1.83%	359	737	359.00	1
2010	3	1.90%	5	3.16%	**2152**	2455	717.3	3	5	2.29%	9	4.13%	**2512**	3249	502.40	5
2011	5	3.16%	10	6.33%	429	2884	85.8	5	6	2.75%	15	6.88%	502	3751	83.67	6
2012	2	1.27%	12	7.59%	913	3797	456.5	2	4	1.83%	19	8.72%	1053	4804	263.25	4
2013	2	1.27%	14	8.86%	39	3836	19.5	1	7	3.21%	26	11.93%	286	5090	40.86	6
2014	3	1.90%	17	10.76%	187	4023	62.3	3	7	3.21%	33	15.14%	297	5387	42.43	6
2015	8	5.06%	25	15.82%	432	4455	54.0	7	23	10.55%	56	25.69%	990	6377	43.04	14
2016	22	13.92%	47	29.75%	**1352**	5807	61.5	**16**	30	13.76%	86	39.45%	**1675**	8052	55.83	**19**
2017	13	8.23%	60	37.97%	336	6143	25.8	8	19	8.72%	105	48.17%	486	8538	25.58	10
2018	19	12.03%	79	50.00%	881	7024	46.4	13	35	16.06%	140	64.22%	1170	9708	33.43	16
2019	32	20.25%	111	70.25%	627	7651	19.6	14	40	18.35%	180	82.57%	877	10585	21.93	16
2020	47	29.75%	158	100.00%	460	8111	9.8	12	38	17.43%	218	100.00%	638	11223	16.79	14
	158	100%			8111				218	100%			11223			

TP=number of documents; hi=relative frequency; Fi=accumulated absolute frequency; Hi=accumulated relative frequency; C=citations, Fc = accumulated absolute frequency for citation; h=Hirsch´s index

Table 2. Publications most cited in WoS and Scopus

Author/s	Year	Age	Title	WoS			Scopus		
				R	C	C/Age	R	C	C/Age
Naik et al. [17]	2010	11	Production of first and second generation biofuels: A comprehensive review	1	1584	144	1	1759	160
Menon and Rao [20]	2012	9	Trends in bioconversion of lignocellulose: Biofuels, platform chemicals & biorefinery concept	2	838	93	2	911	101
Singh and Gu [21]	2010	11	Commercialization potential of microalgae for biofuels production	3	500	45	3	602	55
Venkata Mohan et al. [22]	2016	5	Waste biorefinery models towards sustainable circular bioeconomy: Critical review and future perspectives	4	299	60	6	317	63
Khan et al. [23]	2009	12	Prospects of biodiesel production from microalgae in India	5	291	24	4	359	30
Suganya et al. [24]	2016	5	Macroalgae and microalgae as a potential source for commercial applications along with biofuels production: A biorefinery approach	6	256	51	7	290	58
Dahiya et al. [25]	2018	3	Food waste biorefinery: Sustainable strategy for circular bioeconomy	7	173	58	10	178	59
Minhas et al. [26]	2016	5	A Review on the Assessment of Stress Conditions for Simultaneous Production of Microalgal Lipids and Carotenoids	8	172	34	9	184	37
De Bhowmick et al. [27]	2018	3	Lignocellulosic biorefinery as a model for sustainable development of biofuels and value added products	9	147	49	13	151	50
Trivedi et al. [28]	2015	6	Algae based biorefinery-How to make sense?	10	134	22	12	153	26
Ingram et al. [29]	2008	13	Pyrolysis of wood and bark in an auger reactor: Physical properties and chemical analysis of the produced bio-oils	-	-	-	5	357	27
De et al. [30]	2015	6	Hydrodeoxygenation processes: Advances on catalytic transformations of biomass-derived platform chemicals into hydrocarbon fuels	-	-	-	8	202	34

Abbreviations: R=ranking; C=citations; C/Age=average citations by year

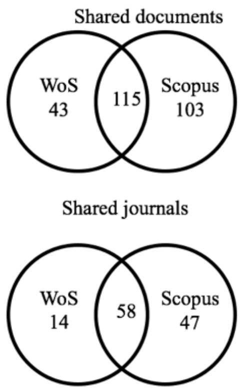

Figure 5. Overlap of documents and journals in both WoS and Scopus databases

3.6 The main publishing journals

In terms of Quart (quartile), the top 5 journals in which biorefinery topics are published belong to Q1 or Q2, indicating the quality and relevance of the topic among Indian researchers, that represent a greater number of citations [31] see Tables 3 and 4. In addition, the journal "Bioresource Technology" has the highest number of publications (18.35% and 23.39% for Wos and Scopus, respectively) and the highest H-index (19 for WoS and 25 for Scopus), followed by the journal "Renewable and Sustainable Energy Reviews" which has the highest number of citations for both databases. The Relative Quality Indexes (SJR and JCR) show that articles have been published in high impact journals [32].

3.7 Most productive authors on the topic of biorefinery in India

Table 5 shows the most productive authors about the topic of biorefinery in India. The author with the most documents was Sen Ramkrishna in both databases, however, her publications have 360 and 411 citations in WoS and Scopus respectively. The author most cited reported in WoS was Mohan, S. V. with 788 citations; on the other hand, the most cited author in Scopus was Pandey A. with 543 cites. It is worth mentioning that Pandey A. also has 14 publications in Scopus, as does Sen Ramkrishna.

The author with the greatest impact derived from the average number of citations between publications is Mohan, S. V. with an average of 88 in WoS, and Chandel A. K. with an average of 84 in Scopus.

3.8 The most productive institutions

There is an overloap in the top 5 institutions in India that published and are cited in both databases. WoS and Scopus do not have the same criteria for the indexing of academic work [33], there are 66.6% matches of institutions in both databases, but not in the same top position. In the WoS database, the institution with the most citations number is the Indian Institute of Technology Guwahati (1681), followed by CSIR-Indian Institute of Chemical Technology (788). In the Scopus database, the institution with the highest number of citations is the Indian Institute of Technology Delhi (2127), followed by the Indian Institute of Technology Guwahati (1876). Table 6 and 7 shows the institutions and some of them present the same number of publications.

Biorefineries have brought great advantages to humanity, since they are capable of mitigating problems that we have been dragging years after year, such as climate change and the high consumption of fossil fuels. The establishment of biorefineries has the potential to enrich rural areas by providing a diverse range of bioproducts and low-cost energy in an economically, socially, and environmentally sustainable manner. It may be argued that India has enormous potential for converting available biomass into electricity [34]. However, the development of biorefineries needs a collaborative effort by the government, research institutions, and researchers.

The integral use of raw materials of biomass origin favors the development of second and third generation biofuels, for the generation of bioproducts in the biorefinery, the use of organisms such as micro and macroalgae must be used, which increase the profitability of the biorefinery.

Table 3. Main journals that publishing the topic of biorefinery in WoS database

R	WoS Journals	TP	hi%	C	h	Q
1	Bioresource Technology	29	18.35%	1478	19	Q1
2	Renewable and Sustainable Energy Reviews	9	5.70%	3040	9	Q1
3	Biofuels Bioproducts and Biorefining	7	4.43%	175	5	Q2
4	Biomass and Bioenergy	6	3.80%	122	6	Q1
4	Science of the Total Environment	6	3.80%	131	6	Q1
5	Energy Conversion and Management	5	3.16%	139	5	Q1
-	Fuel	5	3.16%	79	5	Q1

TP=number of documents; hi=relative frequency, C=citations, h=Hirsch´s index, Q=quartile

Table 4. Main journals that publishing the topic of biorefinery in Scopus

R	Scopus Journals	fi	hi%	C	h	Q
1	Bioresource Technology	51	23.39%	2537	25	Q1
2	Renewable and Sustainable Energy Reviews	9	4.13%	3556	10	Q1
3	Science of the Total Environment	8	3.67%	201	8	Q1
4	Bioresource Technology Reports	6	2.75%	73	5	Q1
5	Renewable Energy	5	2.29%	216	5	Q1
-	Biofuels, Bioproducts and Biorefining	5	2.29%	187	3	Q2
-	Biomass and Bioenergy	5	2.29%	152	5	Q1
-	Waste Biorefinery: Potential and Perspectives	5	2.29%	22	3	ND

TP=number of documents; hi=relative frequency, C=citations, h=Hirsch´s index, Q=quartile

Table 5. Authors most influential in biorefinery topic for India

R	Author/WoS	TP	C	Mean	R	Author/Scopus	TP	C	Mean
1	Sen, R	11	360	33	1	Sen R.	14	411	29
2	Mohan, S. V.	9	788	88	-	Pandey A.	14	543	39
3	Shastri, Y.	8	103	13	2	Venkata Mohan S.	10	210	21
4	Kumar, G.	6	161	27	3	Kumar S.	8	223	28
5	Pandey, A.	5	184	37	4	Kumar G.	7	350	50
					-	Binod P.	7	427	61
					5	Chandel A. K.	5	419	84
					-	Gnansounou E.	5	276	55
					-	Pugazhendhi A.	5	87	17
					-	Bhaskar T.	5	43	9
					-	Sukumaran R. K.	5	48	10

R= ranking, TP=number of documents, C=citations

Table 6. Top 5 most productive institutions in WoS database

R WoS	Affiliations	TP	C
1	Indian Institute of Technology Bombay	14	288
2	Indian Institute of Technology	13	431
3	University of Illinois at Urbana-Champaign	12	535
4	Indian Institute of Technology Guwahati	10	1681
5	CSIR-Indian Institute of Chemical Technology (CSIR-IICT)	9	788
5	Indian Institute of Technology Kharagpur	9	202

R= ranking, TP=number of documents, C=citations

Table 7. Top 5 most productive institutions in Scopus database

R Scopus	Affiliations	TP	C
1	Indian Institute of Technology	23	552
2	Indian Institute of Technology Guwahati	10	1876
2	Indian Institute of Technology Bombay	10	265
2	Indian Institute of Technology Kharagpur	10	227
3	CSIR-Indian Institute of Chemical Technology (CSIR-IICT)	9	613
4	Indian Institute of Technology Delhi	8	2127
5	Indian Institute of Technology Kharagpur	7	241
5	University of Illinois at Urbana-Champaign	7	339
5	CSIR-Indian Institute of Petroleum	7	148

R= ranking, TP=number of documents, C=citations

Biorefinery implementation needs either the use of technologies that allow for the scaling up of laboratory processes to pilot an industrial scale. The implementation of public energy policies and the development of research projects focused on biorefineries are an option that countries should explore to guarantee energy sufficiency from renewable biofuels. The need for energy continues to grow and biorefineries are a solution to take advantage of the biomass resources of each country. With the economically viable sequence of generating high-value products and with improvements in biofuel production research, a technically and environmentally sustainable biorefinery will be achieved.

4. CONCLUSIONS

This study provides an analysis of the topic of biorefinery in India. The databases used were WoS and Scopus. The Gompertz model was used to estimate the rate of publications, in this work was showed that the rate growth of publications for both databases have a similar behavior. The main growth of the publications was determined from 2015 to 2020 with an exponential growth. The author of India prefers the publication of the topic of biorefinery in journals with quartile 1 (Q1) because they seek the dissemination of their work in a global context where they can have a greater number of citations. There is a trend of publications of review in comparison with others document type. The highest citations were received by "Renewable and Sustainable Energy Reviews", followed by "Bioresource Technology". This work gives a trend of publications of authors and institutions of India, the correlation in each database was determined and the results show that the institutions are important in the field of biorefinery. The work can be helps people (scientifics, academics and students) to learn more about the development of the biorefinery field.

There are some limitations to this study, the first is to focus the search efforts on two databases, which might not be sufficient to represent all of biorefinery studies in the India. The second is related to the use of software such as VOSViewer in the analysis of interactions. The future research is sought by adding other comparatives with database of India, and it is necessary development a study using a comparative between India and other countries of the same continent. Also, can be used the VOSViewer in next comparative to determine the interactions of authors and universities.

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NOMENCLATURE

(R^2)	Determination coefficient
TP	Number of documents
hi	Relative frequency
C	Citations
h	Hirsch´s index
R	Ranking
WoS	Web of Science
Fi	Accumulated absolute frequency
Hi	Accumulated relative frequency
Fc	Accumulated absolute frequency for citation

Greek symbols

μ	Specific growth rate, h^{-1}

Subscripts

CO_2	Carbon dioxide