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The Most Influential Countries in Publications of Seaweed to Biofuels

Donaji Jiménez-Islas[1*], Miriam Edith Pérez-Romero[2,3] and Martha Beatríz Florez-Romero[2]

[1]*Higher Technological Institute of Huichapan, Division of Renewable Energy, Biofuels, El Saucillo, Huichapan, Mexico, 42411.*

[2]*Michoacan University of San Nicolas of Hidalgo, Faculty of Economic and Administrative Sciences, Ciudad Universitaria, Morelia, Mexico, 58030.*

[3] *Higher Technological Institute of Huichapan, Business Management Division, El Saucillo, Huichapan, Mexico, 42411.*

Abstract

Seaweed or macroalgal fuel is an important solution as a substitute for fossil fuel. Several studies being conducted on macroalgal search the industrialization to the development of the sector. The purpose of this work is to analyze the most productive and influential countries in biofuels of macroalgal, using the comparative between Web of Science and Scopus data base. The results indicate that the 6 leading countries produce more than 50% of total publications. South Korea, China, USA, India, England and Ireland are the most productive and influential ones, because they account for the most publications with a high number of citations and high h-index. The size of literature of seaweed to biofuels showed a noticeable increase in the past decade, the growth was a result of collaborative works between countries and policies government than searched for the energetic transition. Latin American countries which are best placed in the ranking of 30 publications of macroalgae for biofuels are: Brazil and Chile. The collaborative research is predominant in macroalgae global research. The USA headed the article ranking of countries with the highest h-index. Both databases differ in data volume due to a scope and indexing policies that each database follows.

Keywords: Web of Science, Scopus, bibliometric, renewable energy, macroalgal

INTRODUCTION

The depletion of fossil resources and the environment proliferation of the exploitation of petroleum and coal, create a necessity for a gradual transition towards a bio-based economy [1]. The development and utilization of biomass energy can help to change the ways of energy production and consumption and establish a sustainable energy system that can promote the development of the national economy and the protection of the environment [2].

The concept of sustainability is strongly linked to the development of renewable markets; the development of renewable energy sources is important for the economy because they are responsible for energy security [3]. All countries are looking for new types of energy that are sustainable and clean and that can replace conventional fossil fuels, and the development of new energy and renewable energy has been regarded as the focus of a new trend of industry promotion and development [2].

Renewable energy sources (electricity) such as hydropower, solar power, wind power, geothermal, tidal and biomass can replace fossil fuel regarding power generation [4,5], the biomass is the only source that can be used for the production of solid, liquid and gaseous biofuel, the biofuel liquids have more advantages than solid and gaseous fuel in terms of transport, storage, and high energy density [6].

In the practical arena, biofuels and bioenergy are already a commercial reality towards the 2050 climate goals [7]. Internationally, biofuels energy, as a renewable energy source, has been increasingly appreciated by various industries [8]. The production of biofuels is determined by many factors; the European Union is obliged to reduce the greenhouse emissions under the Kyoto Protocol and global climate warming is a world-wide problem [3].

The production of biofuels of third generation from macroalgae has emerged as an alternative feedstock to food crop-based starch and lignocellulosic biomass; this is mainly due to its fast growth rate of macroalgae, which does not compete with agricultural land, high carbohydrate content and to its relatively simple processing steps compared to lignocellulosic biomass [9].

The marine algal biofuels are considered a promising solution for energy and environment challenges, because of the potential for bypassing the shortcoming of first and second generation of biomass form food crop and lignocellulosic sources, also the by-products utilization for biorefinery [10]. Algal biofuels are sought, in part, from the desire for fuels with fewer greenhouse gas (GHG) emissions than those which would be produced by conventional petroleum fuels and from the desire to reduce petroleum and fossil fuel use [11].

Seaweed (marine macroalgae) farming represents an important component of aquaculture production, the innovation technologies are necessary for sustaining the emerging global market demands [12].With the increasing popularity on macroalgae, several countries implemented programs to development research to contribute in the area; South Korea with the project "Greenhouse gas emission reduction using seaweeds", the project was funded first by the Ministry of Marine Affairs and Fishery and later by the Ministry of Land, Transport and Maritime Affairs of Korea, the main components were seaweed research and seaweed Clean Development Mechanism [13]. Seaweed aquaculture is a relatively young industry in the USA compared to Asian countries, the US Marine Biomass Program (1980) was a research and development program to develop an integrated process for producing and harvesting seaweeds of interest in the ocean and converting their biomass to methane [14], the Marine Biomass Program was discontinued in 1986, however the Connecticut Sea Grant Program continued to support kelp research until 1991[15]. The US Department of Energy supported 18 innovative projects with a total of US$22 million to develop offshore seaweed aquaculture technologies with the program called MARINER [14].

Seaweed in Ireland was historically regarded as a food source, one of the goals of the National Marine Research & Innovation Strategy 2017-2121, is the continued contribution of seaweed for Ireland food production and processing sector [16]. In the UK and Ireland, efforts are underway to harness the stock of natural available “laminar” for fermentation, The Supergene II consortium brings together a significant body of expertise to investigate macroalgal as a bioenergy source, and the Supergene project is an initiative of the Engineering and Physical Science Research Council in the UK [17].

The energy planning of the countries has taken relevance for the governments, the development of public policies that allow investment in clean energy has become a topic of discussion among the scientific community, therefore, to contribute to the analysis of this issue is necessary to know the documents indexed to the data base [18]. The study of scientific production is a good indicator of the progress in research and knowledge generation, bibliometrics is a discipline that uses a set of indicators to quantitatively express the bibliographic characteristics of science publications [19]. The results of a bibliometric analysis may depend on the database used, few previous bibliometric analysis studies were related to macroalgal and none with comparative between WoS (Web of Science) and Scopus for biofuels using macroalgae. The aim of this study is to identify the most influential countries in publications of macroalgae to biofuels using the Web of Science and Scopus databases.

MATERIALS AND METHODS

This study uses bibliometric analysis on data obtained from the WoS and Scopus from the years 1986-2020; both databases are commonly regarded as the most influential databases for classifying academic research and indexing journals, recognized to be of the highest quality. Therefore, analyzing the bibliographic information using this database is fairly representative.

The search for information was performed by topic, which includes title, abstract, author keywords and keywords plus; through the following words and connectors: “seaweed OR macroalgae OR macroalgal” AND biofuels. Documents classified as article or review were selected. Data was extracted on March 2020.

Once the corresponding information per country was obtained, the next step was to classify countries according to number of publication (TP) which serves as a proxy of the country productivity, number of citation (TC) which serves as an input that highlights the influence of the article or document, TC/TP that represents the average of citations per study and general citation structure which is used to evaluate the citations rate of papers in this field, as suggest [20]. Additionally, we used h-index to show the relationship of scientific production of a country based on the number of articles and the number of citations; h-Index represents the point where both numbers are intersected [21].

In this study, we address the two basic categories of bibliometric analysis according to [22]: activity indicators and relationship indicators. Activity indicators provide data on the volume and impact of research activities, while relationship indicators do so on the ties and interactions between researchers and fields of knowledge, do not forget that in this case we are talking about countries.

Finally, an analysis of bibliographic data was carried out using the VOS viewer software from Leiden University, the reason why we decided to use this software is because it allows us to create, visualize and explore maps that represent bibliometric networks, further items in these networks can be connected by co-authorship, co-occurrence, citation, bibliographic coupling, or co-citations links [23]. We created maps of co-authorship, citation, and bibliographic coupling; only for countries. These maps are based on bibliographic data. We used full counting, the maximum number of countries per document were 25 and the minimum number of countries per document were 5.

The methodology proposed in this work follows the guidelines set by other relevant bibliometric articles such as those developed by [24-27]. The research design is of a documentary type because we analyze the written information on the subject under study, is descriptive since it outlines qualities and attributes of information and is longitudinal due to the fact that it is obtaining data from the same object in various years [28].

RESULTS AND DISCUSSION

Type of publication

A total of 505 documents were recovered in WoS and 521 in Scopus. The type of publication shows that most publications are articles (420 in WoS and 436 in Scopus) and reviews (85 for both database), Figure 1.

Our results showed that most documents are articles (WoS 83.17 %, Scopus 83.68%), there is a lower number of reviews (WoS 16.83% and 16.33 Scopus). [29] using a scientometric study of macroalgal biomass as a source of biofuel feedstock it was found that the number of publications were 81.25 % articles followed by reviews with 6.87 %. In 2015, articles were the dominant document type with 85.36 %, followed by reviews with 4.38 % using the advanced search of “seaweed” in WoS for the period 2015-2014 [30].

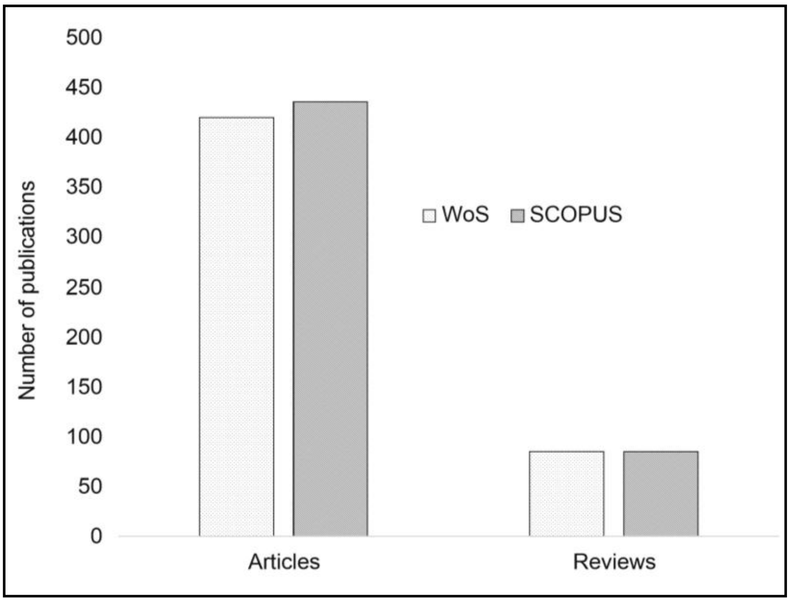


Figure 1: Document type in WoS and Scopus with the topic search seaweed and biofuels.

Publications outputs

Figure 2 shows the annual production of the research in the period between the years of 1994 to 2019 (WoS) and 1985 to 2019 (Scopus). A lag-phase of publications was observed during a long period from 1985-2009. Indeed, the publications on seaweed to biofuels grows exponentially for the last decade for both databases. The development of this research can be classified into two stages of evolution, a lag-phase or first stage and exponential-phase or exponential stage. There are similar data between both databases of articles and reviews.

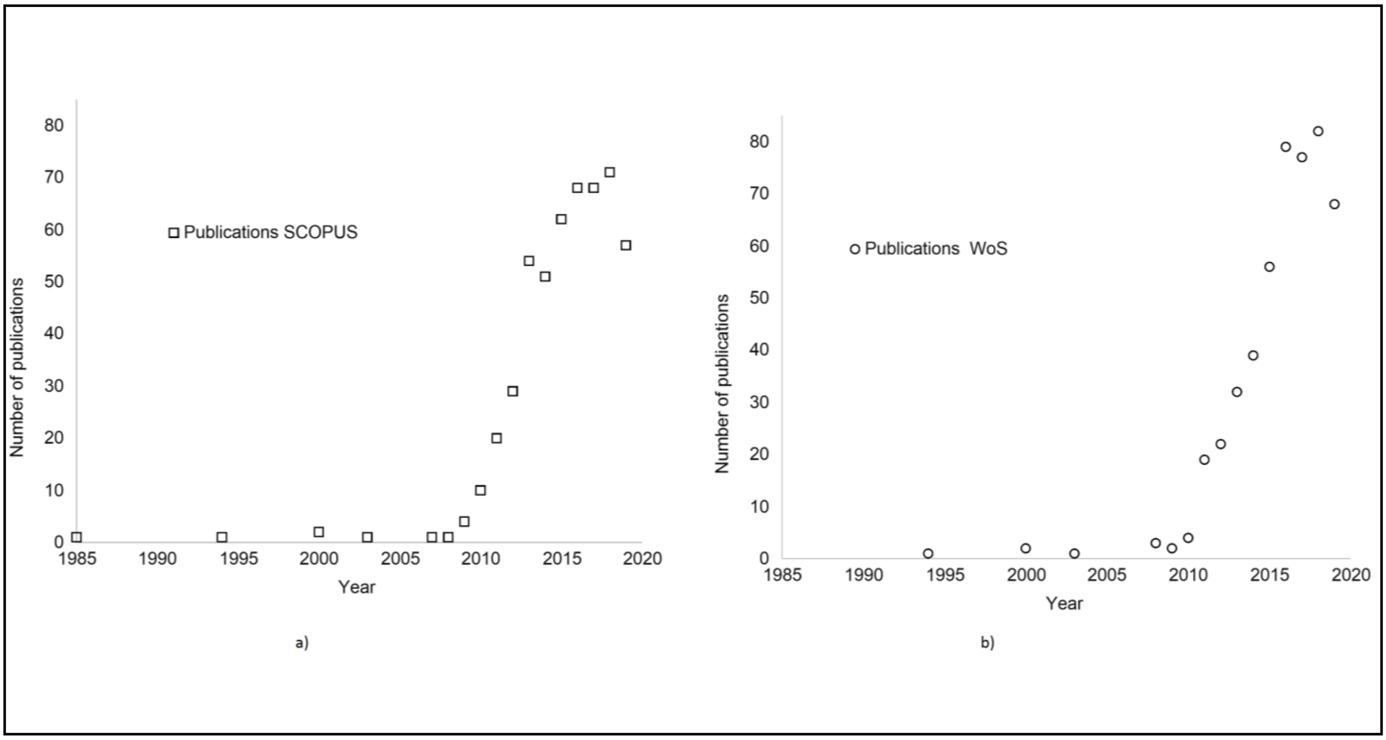


Figure 2: Annual development of publications of the top thirty most productive countries. • Scopus, ◯WoS

Influential of countries in publications of seaweed to biofuels

In Table 1, the total number of publications, the number of citations per publication, H index and ratio total citation/total publications can be seen for each of the countries organized according to number of publications searched in WoS. It is important to note that the TP of the first 6 ranked countries hold more than 50% of the total publications of seaweed to biofuels with China (10.19%), South Korea (10.03%), USA (8.64%), India (7.87%), England (7.56%) and Ireland (6.64%).

Table 1: Ranking of top 10 most productive countries in publications of macroalgal to biofuel from WoS

Ranking	Country	H	TP	TC	TC/TP
1	China	20	66	1305	19.77
2	South Korea	21	65	1311	20.17
3	USA	24	56	2782	49.68
4	India	15	51	1360	26.67
5	England	17	49	1179	24.06
6	Ireland	20	43	1184	27.53
7	Australia	17	24	813	33.88
8	Scotland	14	21	720	34.29
9	Denmark	12	20	386	19.30
10	Japan	9	20	192	9.60
11	Germany	13	19	401	21.11
12	Malaysia	12	19	709	37.32
13	Israel	11	17	334	19.65
14	Brazil	7	16	177	11.06
15	Canadá	7	15	662	44.13
16	Portugal	8	14	427	30.50
17	Norway	9	13	816	62.77
18	Spain	4	13	48	3.69
19	Egypt	6	12	97	8.08
20	France	7	11	192	17.45
21	Iran	6	10	246	24.60
22	Italy	10	10	268	26.80
23	Netherlands	6	10	275	27.50
24	Chile	8	9	691	76.78
25	Poland	4	9	46	5.11
26	Pakistan	4	8	31	3.88
27	Sweden	4	8	76	9.50
28	Taiwan	6	7	168	24.00
29	Wales	4	7	269	38.43
30	Indonesia	4	6	161	26.83

Elaborated from the Web of Science database. Abbreviations: R, Ranking; TP, Total number of publication; TC, Total number of citation; H, H-index; TC/TP, Total number of citation/total number of publication.

China and Korea lead the ranking of countries with the highest number of publications, followed by the USA; however, the latter has a better positioning in the H index of 24, in both databases, Table 1, 2. In a bibliometric report from 2004 to 2014, the USA ranked first in total publications with 11.1%, followed by China (9.4%) and Korea (9.2%) using the word "seaweed" in the search criteria [30]. In 2006, the top ten countries of cultivation of marine macroalgae belonged to Asia, South America, and Central America; however, aquaculture-based production of marine microalgae was concentrated in Asian countries, mainly China with 72% of the total [31-32].

Major producing countries are located in east and Southeast Asia, the most dominant producers are China, Indonesia, Philippines, the Republic of Korea, Japan and the Democratic People´s Republic of Korea [33,34].

Table 2: Ranking of top 10 most productive countries in publications of macroalgal to biofuel from Scopus

Ranking	Country	H	TP	TC	TC/TP
1	South Korea	26	72	2125	29.51
2	China	21	71	1599	22.52
3	India	22	64	2329	36.39
4	England	24	55	2359	42.89
5	USA	24	49	2867	58.51
6	Ireland	19	35	1151	32.89
7	Malaysia	14	27	863	31.96
8	Japan	10	24	324	13.5
9	Denmark	15	22	846	38.45
10	Australia	17	20	870	43.5
11	Germany	12	17	400	23.53
12	Egypt	8	16	151	9.438
13	Israel	11	15	784	52.27
14	Brazil	7	13	219	16.85
15	Italy	11	13	410	31.54
16	France	9	12	764	63.67
17	Iran	8	12	389	32.42
18	Norway	8	12	671	55.92
19	Portugal	9	12	534	44.5
20	Spain	4	12	140	11.67
21	Sweden	7	10	275	27.5
22	Canada	4	9	140	15.56
23	Chile	7	9	734	81.56
24	Netherlands	7	9	375	41.67
25	Taiwan	5	8	93	11.63
26	Philippines	5	7	234	33.43
27	Indonesia	3	5	118	23.6
28	Nigeria	3	5	20	4
29	Pakistan	4	5	43	8.6
30	Saudi Arabia	3	5	90	18

Elaborated from the Scopus database. Abbreviations: R, Ranking; TP, Total number of publication; TC, Total number of citation; H, H-index; TC/TP, Total number of citation/total number of publication.

Latin American countries that are best placed in the ranking of 30 publications of macroalgae for biofuels are Brazil and Chile, which together represent 3.85% of the publications in WoS and 3.41% in Scopus, a low percentage compared to Asian countries.

Usually, citations are assumed to reflect the impact of the research or its quality, although the search quality is a multidisciplinary concept where plausibility, originality, scientific value and social value commonly are perceived as a key characteristic [35]. In this work, the countries with the greatest Total Citation in WoS are the USA (2782 TC), India (1360 TC), South Korea (1311), China (1305) and the total citation in Scopus are the USA, England, India and South Korea (all with >2000 TC Scopus), Table 1, 2.

When examining the top 30 countries with the largest scientific publication output in Scopus data base, only the top 6 of countries exceed more than 53.6 %; It is noteworthy that, although Korea has the largest productivity in this field, the percentage of citation and H index is lower that the USA, Table 2. In both databases, Ireland is on the Top 6 of most productive countries in publications of macroalgae to biofuels; followed by Denmark, Germany, Israel and Brazil (ranking 9, 11, 13 and 14, respectively).

Many developed countries in South Asia, the Middle East and Africa are geographically situated in climatic zones favorable for large-scale cultivation of algae for biofuels production [36]. A scientometric study on macroalgae, [29] showed that South Korea, China, England, USA and India were the countries that most contributed with publications of macroalgal biomass as a source of biofuels feedstock during the period of 1945-2013.

The publications by researches from Asia, Europe and America can result of the high farming technology and experience in the cultivation of algae, China, Indonesia, Japan, Philippines and South Korea are some countries with this characteristic [29]. Cultivations of seaweed was developed, promoted and industrialized in the 1970´s in Korea [37]. South Korea, since 2009, the Marine Bioenergy Development Project concentrates on the selection of algal strains for biofuel production from marine micro and macroalgal. The National Energy Ministry has started a 10-year project with the aim of producing nearly 400 million gallons a year of ethanol by 2020 [38]. In 2011, the Korean government released "Green Energy Strategic Roadmap 2011" emphasizing key strategic items and technologies in 15 green energy sectors. The final aim of project was established an automated mass-cultivation system for high-density brown algae, extraction of value substances from the seaweed, and use of remaining biomass for the production of biomass [39].

Seaweed aquaculture history in the USA is relatively recent compared to Asian countries such China, Korea and Japan [37], the program began in the early 1970s in California, however this initial attempt at seaweed farming failed, the Marine Biomass Program in New York was initiated in 1980 with support from the Gas Research Institute to selection of seaweed species suitable for methane production. Different programs continued to explore seaweed research until a dramatic advance in aquaculture occurred in the USA in 2010, the first commercial kelp farer cultivated the native a kelp specie, in 2011 the commercial seaweed farm in southern New England with the assistance of the University of Connecticut started cultivation of *S. latissimi*. Success of the United States is attributed to the development of suitable aquaculture technologies for operation in US waters, strong domestic markets and strong support from coastal manager, stakeholders and the public [14]

In India, the national policy on biofuels has framed in 2009 with the intent of implementing the usage of bioenergy as a motor fuel with the blending ratio of 20% by 2017, the implementation of biofuel policy requires research and development effort to attain an economic biofuel production [40]. Seaweed harvest is dominated by Asia when China, Philippines, Japan, Korea and Indonesia, while in Europe Ireland, Norway and Scotland [41].

Research into bioethanol in China began around 1930, whereas biodiesel was not investigated as a biofuel until 1980, the Renewable Energy Law (2006) was perhaps the most important decree aimed to promoting the development and utilization of renewable energy, the government has implemented a subsidy program for ethanol production, also in 2010 the Chinese government granted 22 national energy research centers to promote renovation in the energy sector and integrated efforts between research and industry [42].

In 2011, China was conducted R&D for bioethanol production form algae in collaboration with private USA companies and government [43], the results of R&D to biofuels using seaweed permitted to increase the number of publications in each country. The biofuels industry and governments are constantly exploring new biofuels feedstocks, processing technologies and policy mechanism in order to ensure that future expansion is achievable and sustainable, the policy and legal issues related to the potential development of macroalgae biofuels are not widely discussed in the academic or not-academic literature, the expansion in the last 50 years has been driven primary by energy policy in the form of subsidies, mandates, blending targets and tax relief or exception for the fuel [44,45].

Citation structure for macroalgae to biofuels

Table 3 shows an analysis about the citation structure for microalgae to biofuels. The first country is the USA with 4 publications: "An Engineered Microbial Platform for Direct Biofuel Production from Brown Macroalgae", "Hydrothermal liquefaction of biomass: Developments from batch to continuous process", "Marine macroalgae: an untapped resource for producing fuels and chemicals" and "Use of macroalgae for marine biomass production and CO_2 remediation - a review" with TC>200 in WoS.

Table 3: Number of publications through from your total citations

TC	Number of publications based on their TC values WoS	Number of publications based on their TC values Scopus
>200	10	19
>100	21	25
>50	48	71
>25	100	116
<=25	469	354

Source: Elaborated from the WoS database and Scopus database.
Abbreviations: TC, Total number of citation.

In Scopus database 1 publication increase with respect to WoS in TC>200, the title was "Recent advances in liquid biofuel production from algal feedstocks". With the same number of citations, the publication "Micro and macroalgal biomass: A renewable source for bioethanol" by India and Canada; England with "Hydrothermal liquefaction of biomass: Developments from batch to continuous process", Portugal with "Hydrothermal processing, as an alternative for upgrading agriculture residues and marine biomass according to the biorefinery", Norway with "Towards sustainable production of biofuels from microalgae" and Chile with "An Engineered Microbial Platform for Direct Biofuel Production from Brown Macroalgae". Publications with TC> 100 were 21 and 25 to WoS and Scopus respectively.

Quinquennial analysis of publications

Table 4 shows that 98.7 % of the publications (WoS) corresponding to quinquennial 4 (2010-2015) and 5 (2015-2019) of the total, in the case of Scopus 98.25 corresponding to quinquennial 5 (2010-2015) and 6 (2015-2019), in both data bases the growth of publications corresponding to exponential phase showed in Figure 2. With the growth of publications, the citations for each articles is less due to the fact that the scientific community precedes information and citations in the feed of the advances of their own research, it is logical to think that if the number of articles grows, the time for its appointment will take a few years to modify its effect in the macroalgae area.

During the fourth five-year period, publications grew and the need for information led to the growth of citations on topics related to macroalgae, with Korea remaining in the top 3 of the most influential countries in the 4^{th} and 5^{th} five-year periods.

Finally, we make a science mapping analysis of publications by countries in the topic of seaweeds. We use VOS viewer software, to realize three analyses: co-authorship, citation, and bibliographic coupling. We set the minimum number of documents by country as 5. As a result, there are 33 of 64 countries which meet the threshold in the case of WoS; and there are 30 of 60 in the case of Scopus.

Co-authorship analysis

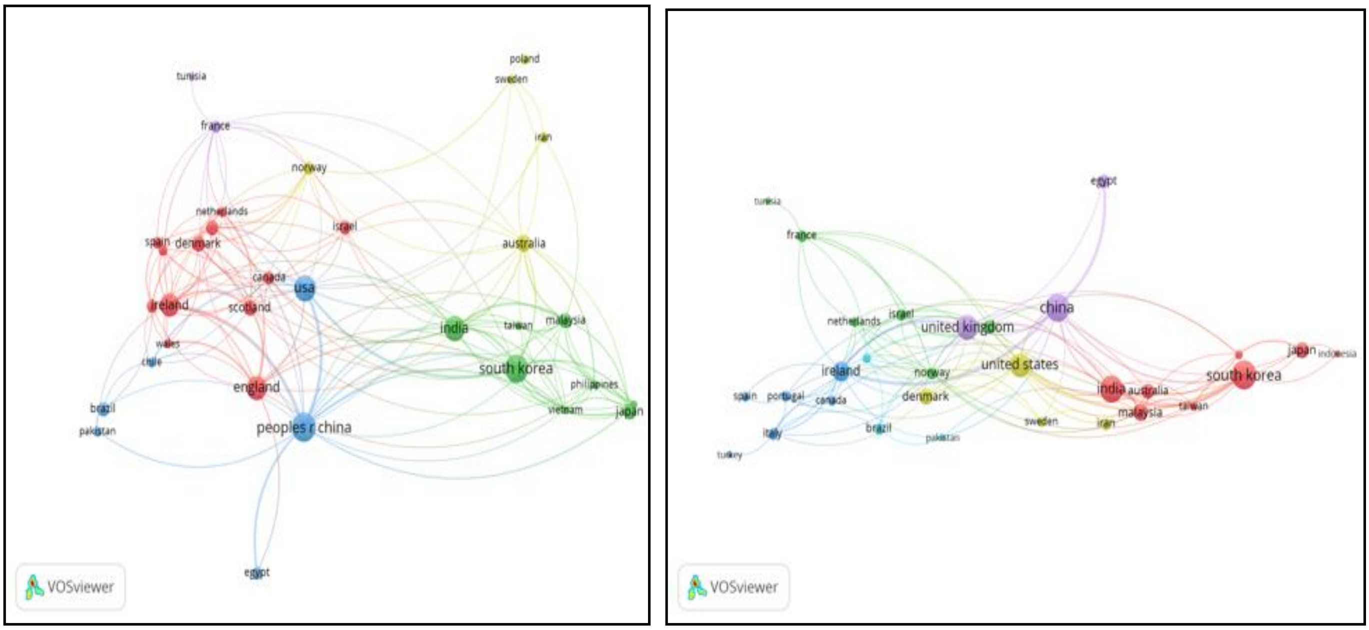
To describe the collaboration relationship of publications in seaweed research, we make co-authorship analysis at the level of country. The co-authorship network of countries through WoS information is shown in Figure 3a, and from Scopus information is shown in Figure 3b. Each node represents a country, and the bigger the node, the greater the co-authorship in study topic.

For WoS, the People´s Republic of China had the highest link strength (50), followed by the USA (36), Ireland (32), South Korea (32), and India (28). According to various colours, a total of 5 clusters were involved in publishing articles and reviews related to seaweed.

Table 4: Quinquennial analysis, 1985-2019 period

	Quinquennial	TP WoS	TC WoS	TP Scopus	TC Scopus
1	1985-1989	-	-	1	0
2	1990-1994	1	201	1	225
3	2000-2004	3	272	3	220
4	2005-2009	4	501	6	343
5	2010-2014	147	8657	200	13233
6	2015-2019	482	7982	418	8116

Elaborated from the WoS database and Scopus database
Abbreviations: TP, Total number of publication; TC, Total number of citation.



(a) **(b)**

Figure 3: Co-autorship network of countries in the field of seaweed to biofuels. (a) WoS; (b) Scopus.

Cluster 1 is formed by 12 countries: Canada, Denmark, England, Germany, Ireland, Israel, Italy, Netherlands, Portugal, Scotland, Spain, and Wales; this cluster is identified by red color. Cluster 2 is formed by 8 countries: India, Indonesia, Japan, Malaysia, Philippines, South Korea, Taiwan, and Vietnam; this cluster is identified by green color. Cluster 3 is formed by 6 countries: Brazil, Chile, Egypt, Pakistan, Peoples R China, and USA; this cluster is identified by blue color. Cluster 4 is formed by 5 countries: Australia, Iran, Norway, Poland, and Sweden; this cluster is identified by yellow color. Cluster 5 is formed by 2 countries: France, and Tunisia; this cluster is identified by purple color. You can see the clusters previously mentioned in Figure 3a.

For Scopus, China had the highest link strength (37), followed by the United States (29), Ireland (26), South Korea (20), and India (18). In this case, a total of 6 clusters were involved in publishing articles and reviews related to seaweed. Cluster 1 is formed by 8 countries: Australia, India, Indonesia, Japan, Malaysia, Philippines, South Korea, and Taiwan; this cluster is identified by red color. Cluster 2 is formed by 6 countries: France, Germany, Israel, Netherlands, Norway, and Tunisia; this cluster is identified by green color. Cluster 3 is formed by 6 countries: Canada, Ireland, Italy, Portugal, Spain, and Turkey; this cluster is identified by blue color. Cluster 4 is formed by 4 countries: Denmark, Iran, Sweden, and United States; this is identified by yellow color. Cluster 5 is formed by 3 countries: China, Egypt, and United Kingdom; this cluster is identified by purple color. Cluster 6 is formed by 3 countries: Brazil, Chile, and Pakistan; this cluster is identified by cyan color. You can see the clusters previously mentioned in Figure 3b.

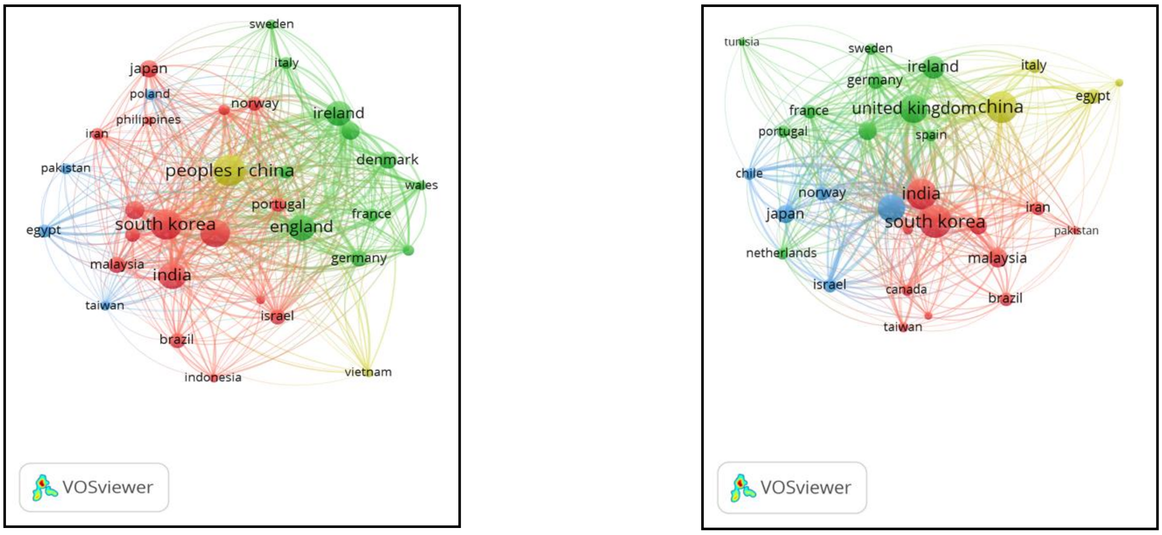
Citation analysis

According to the visualization tool VOS viewer, Figure 4a and 4b show the citation analysis between the most productive and influential countries in seaweed research; from WoS, and Scopus information, respectively.

For WoS, England had the highest link strength (877), followed by Ireland (764), the USA (695), China (658), and South Korea (558). According to various colours, a total of 4 clusters were involved in the topic. Cluster 1 is formed by 16 countries: Australia, Brazil, Canada, Chile, India, Indonesia, Iran, Israel, Japan, Malaysia, Norway, Philippines, Portugal, South Korea, Tunisia, and USA; this cluster is identified by red color.

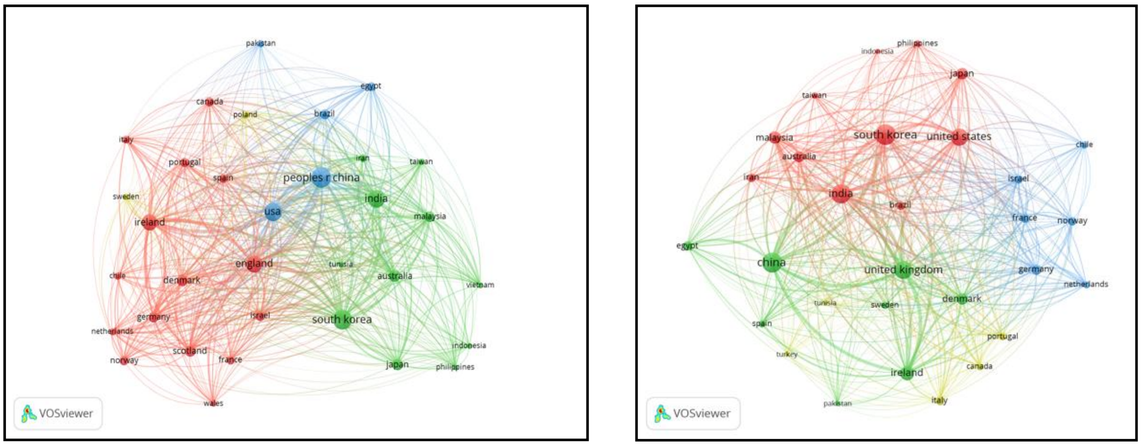
Cluster 2 is formed by 11 countries: Denmark, England, France, Germany, Ireland, Italy, Netherlands, Scotland, Spain, Sweden, and Wales; this cluster is identified by green color Cluster 3 is formed by 4 countries: Egypt, Pakistan, Poland, and Taiwan; this cluster is identified by blue color. Cluster 4 is formed by 2 countries: Peoples R China, and Vietnam; this cluster is identified by yellow color. You can see the clusters previously mentioned in Figure 4a.

For Scopus, the United Kingdom (791) had the highest link strength, followed by China (661), South Korea (655), Ireland (622), and the United States (603). In this case, a total of 4 clusters were involved in the topic. Cluster 1 is formed by 11 countries: Australia, Brazil, Canada, India, Indonesia, Iran, Malaysia, Pakistan, Philippines, South Korea, and Taiwan; this cluster is identified by red color. Cluster 2 is formed by 10 countries: Denmark, France, Germany, Ireland, Netherlands, Portugal, Spain, Sweden, Tunisia, and United Kingdom; this cluster is identified by green color. Cluster 3 is formed by 5 countries: Chile, Israel, Japan, Norway, and United States; this cluster is identified by blue color. Cluster 4 is formed by 4 countries: China, Egypt, Italy, and Turkey; this cluster is identified by yellow color. You can see the clusters previously mentioned in Figure 4b.



(a) (b)

Figure 4: Citation network of countries in publications of seaweed to biofuels, (a) WoS; (b) Scopus.



(a) (b)

Figure 5: Bibliographic coupling network of countries, (a) WoS; (b) Scopus.

Bibliographic coupling analysis

The bibliographic coupling is related to citation of two papers to a third article; again, the countries were used as a variable. Figure 5a and 5b show the bibliographic coupling between the most productive and influential countries in seaweed research; from WoS, and Scopus information, respectively. It's possible to observe the existence of several groups or clusters of countries bibliographically coupled, presenting a bibliographic network.

For WoS, England (33780) had the highest link strength, followed by, China (28066), Ireland (25928), India (24623) and South Korea (24599). According to various colours, a total of 4 clusters were involved in the topic. Cluster 1 is formed by 15 countries: Canada, Chile, Denmark, England, France, Germany, Ireland, Israel, Italy, Netherlands, Norway, Portugal, Scotland, Spain, and Wales; this cluster is identified by red color. Cluster 2 is formed by 11 countries: Australia, India, Indonesia, Iran, Japan, Malaysia, Philippines, South Korea, Taiwan, Tunisia, and Vietnam; this cluster is identified by green color. Cluster 3 is formed by 5 countries: Brazil, Egypt, Pakistan, Peoples R China, and USA; this cluster is identified by blue color. Cluster 4 is formed by 2 countries: Poland, and Sweden; this cluster is identified by yellow color. You can see the clusters previously mentioned in Figure 5a.

For Scopus, the countries with the largest number of coupling are United Kingdom (24955), India (20894), South Korea (20747), China (20007) and Ireland (16708). In this case, a total of 4 clusters were involved in the topic. Cluster 1 is formed by 11 countries: Australia, Brazil, India, Indonesia, Iran, Japan Malaysia, Philippines, South Korea, Taiwan, and United States; this cluster is identified by red color. Cluster 2 is formed by 8 countries: China, Denmark, Egypt, Ireland, Pakistan, Spain, Sweden, and United Kingdom; this cluster is identified by green color. Cluster 3 is formed by 6 countries: Chile, France, Germany, Israel, Netherlands, and Norway; this cluster is identified by blue color. Cluster 4 is formed by 5 countries: Canada, Italy, Portugal, Tunisia, and Turkey; this cluster is identified by yellow color. You can see the clusters previously mentioned in Figure 5b.

With the results on co-authorship, citation and bibliographic coupling for both database (WoS and Scopus) differ in their data volume and node integration. The differences between both databases can be explained by the policies of indexation and the year of register, in the case of Scopus database, it was the first database with a document registered of seaweed in 1985. According to [46], there is a strong correlation between databases WoS and Scopus in relation to the number of articles that both bases incorporated annually despite the greater number of magazines that include Scopus, in general both database differ in terms of their scope, data volume and coverage policies with high degree of sources and unique articles.

It is clearly that the most prolific countries in the field of publications and collaborations of macroalgae to biofuel are Korea, China, India, the USA and England, these countries had developed government policies to generate an energetic transition to biofuels and byproducts of high value.

CONCLUSIONS

In this article, we present an overview of the most influential countries in the area of seaweed to biofuels following a comparative bibliometric evaluation of publications for countries. WoS and Scopus databases were used to develop a comparative analysis of publications (articles and reviews) for the 30 most influential countries in the research area of seaweed. China and Korea lead the ranking of countries with the highest number of publications, followed by the USA. The development and implementation of government policies for the research of seaweed determined the growth of publications of the most influential countries in the commercialization of byproducts, additional to that a program to develop different sources of renewable energy to substitute fossil fuels was stablished. China, Korea, the USA, India, England and Ireland hold more than 50 % of the publications of seaweed to biofuels, the top 6 ranked countries are the most influential in the field of seaweed to biofuels. The paper also showed an increasing amount of publications in the field of seaweed, with an exponential growth since 2010 year. The profile of growth of publications can be used to predict the evolution in the next years in countries than need independence energetic with the seaweed for bioenergy and consolidate a policy energetic.

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