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PROSPECTIVE ANALYSIS OF ALGAL BIODIESEL PRODUCTION

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Abstract. This article aims to carry out an initial patent mapping of algal biodiesel, which means a first study on what has been filed under patents on biodiesel produced by algae. The production of algal biodiesel is one of the forms of third generation biodiesel; it is an environmentally friendly alternative energy whose main advantage is that it does not compete with food, as the algal biodiesel is produced from synthesized lipids by algae in growth using sunlight. The methodology used was the patent mapping by activity having as search criteria: the Espacenet database ("worldwide"); and, the keyword: biodiesel and algae and algal biodiesel. It was observed that about 80% of the family of patent documents referring to this technology were applied between 2007 and 2016 and that these documents were published mainly in China (34% of patent documents), followed by the United States (25% of patent documents) and thirdly, the World Intellectual Property Organization (WO), that is, the PCT's international patent application, which indicates an interest in protection in several countries (15% of patent documents). Concluding that China and the United States are the countries that invest the most in the development and protection of technologies related to the production of algal biodiesel, however, the interest in protection goes beyond these countries, since the interest in alternative energies is worldwide.

Keywords: Biodiesel; Seaweed; Patent Document; Patent; Patent Mapping.

1 Introduction

One of the biggest challenges of the world economy is the search for clean fuels and energy, which will allow us to guarantee energy demand, economic balance and environmental sustainability in the future, noting that the rising price of fuels has led the market to seek cheaper solutions and above all possible.

In the search for alternatives to make clean energy available, there is great potential offered by the production of fuels - in particular, biodiesel - using algae as an energy source, as these have the ability to double their biomass several times a day, promoting an oil production much more relevant than other cultures used for this productive factor (LEE, 2011; MIZIK; GYARMATI, 2021).

The great current challenge is the use and optimization of productive factors in the production and extraction process of oils, in the selection, handling and management of biological resources with greater exploration potential, which makes the study of patents and the technologies that surround them, a great differential for analyzes and investments in the energy and fuel sector, using algae (AMANOR-BOADU; PFROMM; NELSON, 2014; BOŠNJAKOVIĆ; SINAGA, 2020).

2 Algal Biodiesel

Algae are chlorophyll organisms, that is, they transform light energy into chemical energy, generating several molecules that are used in the most diverse processes, and in addition, the algae itself is a product. One of its abilities is to synthesize a high amount of lipids with high productivity and growth rate throughout the year,

a characteristic used in the production of biodiesel from algae, in English "algal biodiesel" (SERO et al., 2020; REIS et al., 2021).

Biodiesel production has three generations: (a) in the first generation the raw material is food, especially conventional sources of oil such as rapeseed, rapeseed, soy, castor beans, coconut, palm, sunflower and corn; (b) in the second generation, the raw material is inedible plants, for example: cotton seed, linseed, rubber seed and tobacco; and, (c) in the third generation, the raw material is used cooking oil, residual animal fats and from lipids produced by microalgae - the focus of this research (TAYLOR et al., 2013; PIKULA et al., 2020; MIZIK; GYARMATI, 2021).

The production of algae consists of the following steps:

a) algae production (source of lipids from which biodiesel is extracted);

b) extraction of lipids (oil), some more stable and effective methods are exemplified below;

   i. accelerated solvent extraction,
   ii. microwave assisted extraction,
   iii. ultrasound assisted extraction,
   iv. supercritical fluid extraction, and
   v. enzymatic extraction;

c) biodiesel production itself, normally by trans esterification (which can be catalytic or non-catalytic); and,

d) separation of algal biodiesel (PIKULA et al., 2020).

Biodiesel production from algae has some advantages, such as: (a) it is simply cultivated with a high growth rate of biomass (algae) with a high lipid content; it does not compete with food, as it does not grow on soils, it does not alienate fertile soil, and it is also not influenced by the cost of food resources.

3 Patent Documents as a Source of Information

Given the above, patent documents are a rich source of technological information, as they disclose, mainly in their descriptive report, technical information on inventions worldwide, being accessible to the general public and being able to be used in various activities in addition to research and development, as for example, in risk analysis studies (REIS et al., 2021). Furthermore, according to WIPO (World Industrial Property Organization) approximately 70% of all information is in the form of a patent document, of which more than 80% will be published only in this form (INPI, 2015a).

Patent documents in relation to their legal validity can be classified as: (a) patent application documents; and, (b) patents or patent documents granted. The first refers to the patent document since it was filed at the patent office; the second refers only to those who obtained the title granted by the State to their holders of rights during its term (INPI, 2015c).

In relation to the deposit, they can be classified as: (a) priority document; and, (b) document from the "same" family. The first refers to the first filing of the invention before protection is claimed in another country(ies); and, (b) the second refers to subsequent requests made within the period protected by priority, that is, to the deposit made in other country(ies) guaranteed by the Paris Convention - CUP (INPI, 2015c). The Patent Cooperation Treaty (PCT) also allows filing in several countries, generating a family, but not by the principle of priority, but by an international patent application (INPI, 2015b).

Given the importance of patent documents, this article aims to carry out an initial mapping of algal biodiesel, enabling the public to verify in practice some expertise that can be acquired from patent documents, in this specific case only from the cover sheet.

4 Methodology

The methodology adopted in this article was the patent mapping by activity as defined by Porter et al. (1991) with the following search criteria:

- Scope of search - no restriction
- Database - Espacenet (available at: worldwide.espacenet.com), one of the most complete and free databases;
- Definition of Technology - the following keywords were used in the title, summary and claims: biodiesel AND (algal OR algae OR alga), classification was not used because it is a recent technology; and,
- Period – no restriction.

The search was carried out in April 2021 and 864 families were recovered with 1754 patent documents.

The following data from the cover sheet of published patent documents were tabulated and processed: year of oldest priority; “country of publication”, in English country code; depositor and his country; and, inventor and his country.

5 Results and Discussion

Performing the search according to the methodology above, 864 families were retrieved with 1754 patent documents referring to algal biodiesel.

As seen in Figure 1, there is a concentration of patent documents with the oldest priority year between 2007 and 2016 (701 families equivalent to 80% of families), with a peak in 2009 (with 98 families equivalent to 11% of families); it should be noted that before the peak, that is, families with the oldest priority year between 2002 and 2006 (with 49 families, equivalent to 6% of the families) there are about half of the families after the peak, that is, families with year of oldest priority between 2017 and 2019 (with 101 families equivalent to 12% of families), indicating that interest in biodiesel production from algae is recent (first inventions in 2002) and that despite having already passed the peak there is interest in this topic. The years 2020 and 2021 were not considered due to the period of secrecy, time between filing and publication; as the patent document is only available after publication with its filing date and oldest priority year that are prior to the publication date, so there is a gap between the document existing and it appearing in the databases, this gap varies from up to 24 months in the CUP or up to 30 months in the PCT.

The oldest priority year is related to when the invention was created and from Figure 1 it can be seen that the interest in inventions related to the term algal biodiesel started in 2002, being concentrated between 2007 and 2016 (with a peak in 2009) and following in a second level from 2017.

One of the reasons for the peak was the search for alternative energies arising from the commitment signed by 192 countries, the Kyoto Protocol, which entered into force in 2005 and expires in 2012, it should be noted that a successor agreement is still under discussion. It should be noted that several countries have implemented policies and incentives in order to encourage the production of alternative energy, including biofuel, especially biodiesel, for example, the one produced by algae. China is one example, it has specific policies for biodiesel productions since 2005, when the State encourage the production and use of biological liquid fuels (CHUNG et al., 2020). The drop from 2016 may be related to the search for other renewable energy sources, such as from biomass.

Figure 2 refers to the "country of publication", in English "country code", and is directly related to the place where you want to obtain protection for the deposited invention, where patent documents are considered separately (not grouped by family), A highly concentrated behavior can be observed in it, with emphasis on China (with 594 patent documents equivalent to 34% of patent documents), followed by the United States (with 442 patent documents equivalent to 25% of patent documents) and in third place is the World Intellectual Property Organization (WO), that is, the PCT’s international patent application, which indicates an interest in protection in several countries (with 268 patent documents, equivalent to 15% of patent documents).

The highlight for China and the United States in the number of patent documents related to the production of algal biodiesel was to be expected, since they are the two largest countries in technological development and in patent filing; in addition to having a large coastline rich in algae and aquatic microorganisms. The highlight of the World Intellectual Property Organization (WO), that is, of protecting itself in several countries was also expected since the search for alternative energies is a global objective and not of a single country or region.

The Figure 3 refers to the country of the holders of the invention, that is, the country of the applicant, showing that they hold or will hold the economic right of the patents granted or that will be granted, it considers the patent documents grouped by family, observing a behavior highly concentrated in the United States (with 656 patent documents equivalent to 55% of patent documents), followed by China (with 86 patent documents equivalent to 7% of patent documents), and Korea (with 76 patent documents equivalent to 6% of patent documents). This behavior is due to the fact that US patent documents usually have more co-holders than Chinese patent documents; of this were; to prepare the figure, each applicant is considered individually, being he/she the owner or co-holder of the patent document with the same weight, that is, an application is counted more than once, and applications with more co-holders are counted more times, inflating the number of American documents that have more co-holders.

The Table 1 shows the ten main applicants for patent documents referring to algal biodiesel, of which 8 are Chinese and only 2 are North American, indicating that although the United States holds the majority of

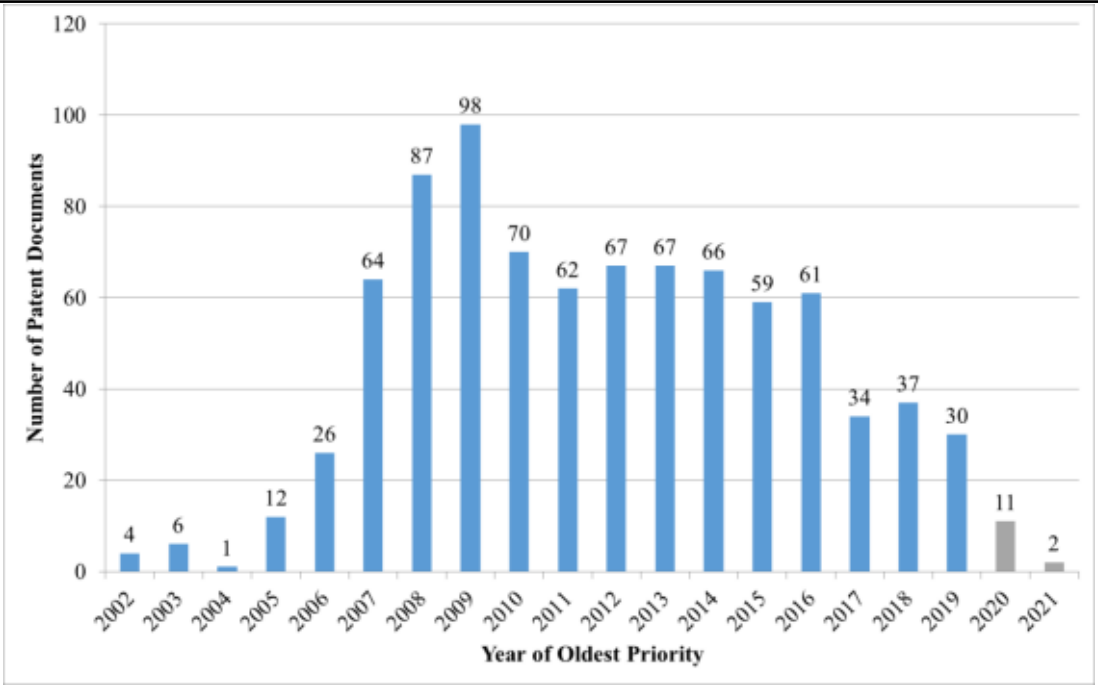

Figure 1: Distribution of patent documents referring to algal biodiesel by year of oldest priority.
Source: Prepared by the authors based on data obtained from ESPACENET (2021).

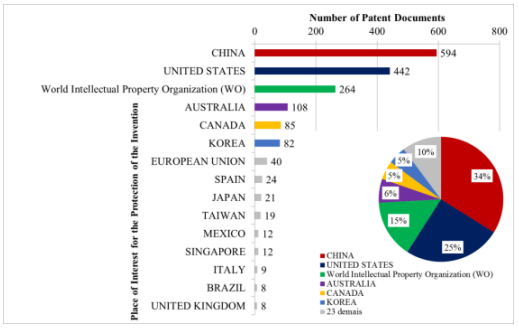

Figure 2: Distribution of patent documents referring to algal biodiesel in relation to the place of interest for the protection of the invention ("country code").

Source: Prepared by the authors based on data obtained from ESPACENET (2021)

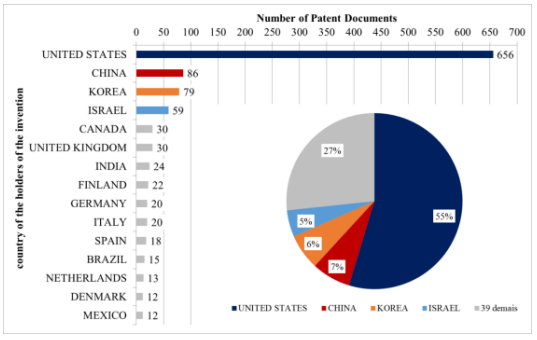

Figure 3: Distribution of patent documents referring to algal biodiesel in relation to the country of the holders of the invention ("country of the applicant").

Source: Prepared by the authors based on data obtained from ESPACENET (2021)

patent documents referring to algal biodiesel, the main depositors are Chinese.

Figure 4 refers to the location of the inventors of the invention, that is, the country of the inventors, and is usually related to the location where the invention was developed, it also considers the patent documents grouped by family, with a similar behavior being observed to that of depositors, a highly concentrated behavior in the United States (with 618 patent documents equivalent to 54% of patent documents), followed by China (with 93 patent documents equivalent to 8% of patent documents), and Korea (with 76 patent documents equivalent to 7% of patent documents). This behavior is due to the fact that US patent documents typically have more inventors than Chinese patent documents; of this were; in the elaboration of the figure, each inventor is considered individually, with the same weight, that is, an order is counted more than once, and orders with more inventors are counted more times, inflating the number of American documents that have more inventors per document.

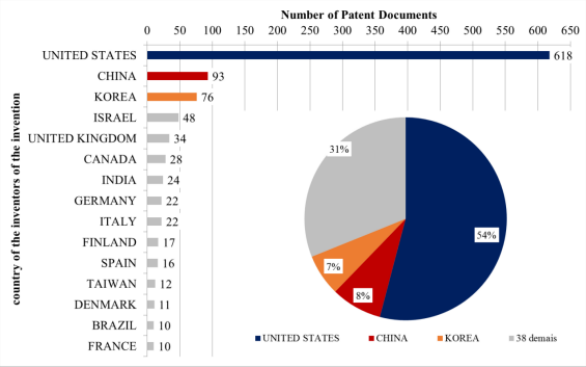

Figure 4: Distribution of patent documents referring to algal biodiesel in relation to the country of the inventors of the invention ("inventor's country").

Source: Prepared by the authors based on data obtained from ESPACENET (2021)

Table 2 shows the ten main inventors of patent documents referring to algal biodiesel, of which 7 are Chinese and only 3 are North American, indicating that despite the majority of inventors being North American, the inventors who hold the largest number of documents patents referring to algal biodiesel the main applicants are Chinese. As the behavior of depositors is very similar, including in number, to the behavior of inventors, there is a strong indication that the right of invention (depositor) is in the same country in which it was developed (inventors).

6 Conclusion

The preparation of this patent mapping proved to be opportune for a process of technological management and monitoring through patent documents for technologies related to biodiesel produced by algae because of the information in these documents used strategically.

From the above, it can be concluded that patent documents for technologies related to biodiesel are concentrated in two levels: the first between 2007 and 2016 (with a peak in 2009) and a second level from 2017. The focus of protection of these patent documents it is mainly China, the United States and several countries (applications filed via PCT). Regarding technology holders (depositor) and technology developers (inventors), the United States stands out, which may be inflated, as US patent documents usually have more than one author (depositor or inventor), in relation to the ten first authors (depositor or inventor), the highlight is China with 8 depositors and 7 inventors among the top ten.

This research contributed to the improvement of knowledge about the production produced by algae in the patent perspective, reaching the objective of this research. Furthermore, the authors were encouraged to study new innovative correlations on the production of algal biodiesel, especially its viability in Brazil.

Table 1: The 10 main depositors of patent documents referring to algal biodiesel.

Name of Applicant	Number of Patent Documents	Country of Applicant
Tsinghua University	27	China
Kunming University of Science and Technology	17	China
ENN Reserch and Development CO., LTD.	15	China
University of Texas	15	US
China Petroleum & Chemical Corporation	13	China
ENN Science and Technology Development Co., Ltd.	10	China
Tianjin University	10	China
Zhejiang University	10	China
ENN Technology and Development Co., Ltd.	9	China
ExxonMobil Chemical Patents Inc	9	US

Source: Prepared by the authors based on data obtained from ESPACENET (2021)

Table 2: The 10 inventors of patent documents referring to algal biodiesel.

Name of Inventor	Number of Patent Documents	Country of Inventor
JIANJUN HUANG	15	China
WENJING SHI	13	China
SHA LIAO	12	China
XUYA YU	12	China
XIAOSHU LI	11	China
QIMEI SUN	11	China
MATTHEW S BEDOYA	9	U.S
JOHN R HAGADORN	9	U.S
MATTHEW W HOLTCAMP	9	U.S
HONG WU	9	China

Source: Prepared by the authors based on data obtained from ESPACENET (2021)

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