



Brazil's leading role in second-generation ethanol production

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ABSTRACT

Second-generation ethanol (E2G) is a biofuel made from lignocellulosic biomass, such as sugarcane bagasse and straw. This research uses scientometric analysis to examine the growth of publications and the role of Brazil in E2G production. Data were collected from Web of Science, and a total of 25 articles from 2018 to 2023 were analyzed. The results show Brazil's leadership in this field, with 9 publications, 8 of them from Brazil, and the presence of two commercial E2G plants.

Keywords: Biofuel; Bioethanol; E2G; Lignocellulosic biomass.

INTRODUCTION

The carbon footprint is a measure that evaluates how much a production process emits carbon (CO₂) or another equivalent gas into the atmosphere. Second generation ethanol has a 30% lower carbon footprint compared to first generation, and up to 80% lower than fossil fuels such as gasoline [1]. Therefore, in addition to being renewable, E2G is considered a clean fuel, because it emits less CO₂ into the atmosphere. Due to recent policies that encourage sustainable energy solutions, products with a low carbon footprint are valued and gain a different market value, a monetary premium [2].

As second-generation ethanol (E2G) has the same chemical composition and uses as ethanol (E1G), it is possible to increase its productivity by up to 50%, without increasing the size of the planted area, as no extra sugarcane is needed to produce it [3]. Furthermore, E2G resolves a dispute in the agroenergy sector over the use of agricultural land. There is a duality between the production of food or energy, but cellulosic ethanol does not create competition between raw materials and food, since humans do not consume cellulose. Thus, the planting area used brings economically and socially favorable results [4].

MATERIALS AND METHODS

The research was carried out in the Web of Science Database from the insertion of filters, considering original articles and review articles. Publications on second generation ethanol were extracted from the Web of Science (WoS) -



Clarivate database. Therefore, the keywords “Second-generation ethanol”, “sugarcane” and “E2G” were inserted in the platform’s search field without filtering the publications by period of time. The following scientometric indicators were used to collect data: (i) year of publication (2016-2018), (ii) research area and periodicals, (iii) contributions from countries and institutions, (iv) author citations, (v) most cited articles and network analysis. The scientometric evaluation was carried out through the VOSviewer software. The software, developed at the University of Leiden, in the Netherlands, is an open access tool that allows researchers analyze a wide range of bibliometric networks based on co-citation data, bibliographic coupling or co-authorship relationships journals, authors, publications, research funding organizations and countries. Furthermore, the literature can be organized into clusters, where it is possible to visualize the status of the research, points with high density and perspectives of trends in research fields. The range of publication years was from 2018 to 2023, with a total of 25 selected articles.

RESULTS AND DISCUSSION

The keyword map demonstrates a clear increase in publications related to bioethanol research between 2016 and 2023, with the color gradient representing publication density—purple indicating lower density and yellow representing higher density. The prominence of yellow around terms such as bioethanol, sugarcane, and second-generation ethanol (E2G) underscores the growing focus on E2G technologies during this period.

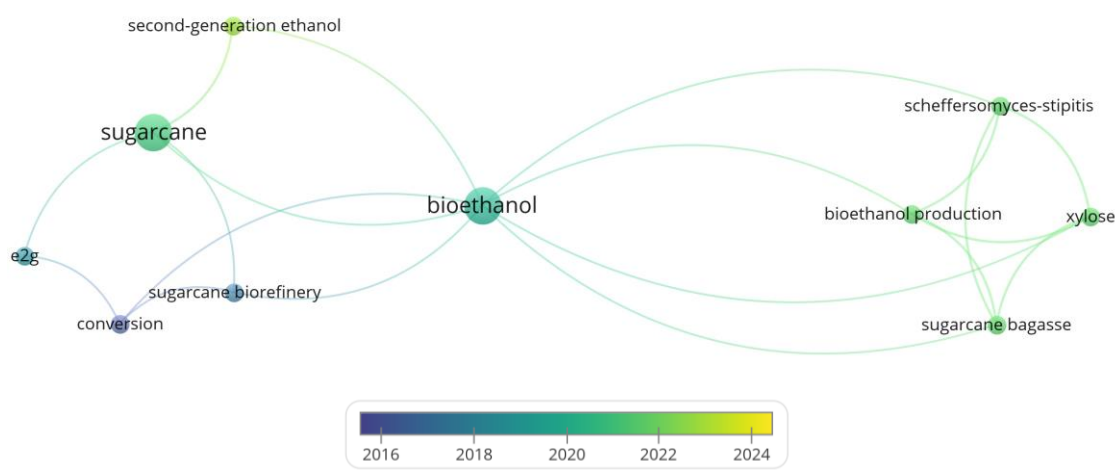


Figure 1. Keyword map highlights.

Of the 9 articles analyzed, 8 originated from Brazil, highlighting the country's leadership in research and development in this field. The prominence of keywords such as sugarcane bagasse, bioethanol production, and sugarcane biorefinery further reinforces Brazil's pivotal role in advancing bioenergy, particularly in second-generation ethanol, through the utilization of agricultural residues as renewable resources.



The shift from purple to yellow on the map reflects the expanding literature on E2G technologies, with Brazil emerging as a major contributor. This demonstrates the country's commitment to innovation in sustainable energy and biofuels, solidifying its position as a global leader in second-generation ethanol research. Additionally, Brazil is home to two commercial-scale plants producing second-generation ethanol [5].

In addition to its prominence in research, Brazil also holds a leading position in global ethanol production, being the second largest producer with 28% of the world's output, while the United States leads with 53%, as shown in Figure 2, according to the Renewable Fuels Association - RFA (2023) [6].

Region ● United States ● Brazil ● European Union ● India ● China ● Rest of World ● Canada ● Argentina ● Thailand

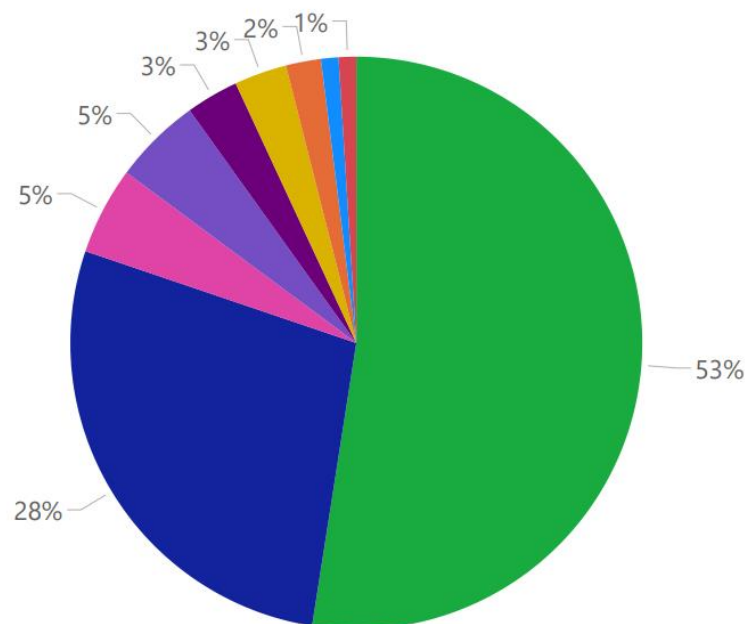


Figure 2. World Fuel Ethanol Production by Region. Adapted the Renewable Fuels Association - RFA (2023) [6].

Table 1 shows the annual ethanol production values for the leading producing countries from 2019 to 2023, according to the RFA (2023). The percentage of ethanol production over the analyzed period remained relatively stable. Despite the production decline observed in 2021 and 2022, attributed to the impact of the pandemic, Brazil continued to hold the position of the second largest ethanol producer.

The production methods of these two countries differ significantly: in Brazil, almost all ethanol is produced from sugarcane, while in the US, the primary feedstock is corn. This distinction gives Brazil a prominent role in the sustainable and efficient production of ethanol, as sugarcane is considered the most efficient feedstock for producing this biofuel, according to NovaCana (2023) [7].



Table 1. Annual World Fuel Ethanol Production (Mil. Gal.)

Region	2019	2020	2021	2022	2023	% of World Production
United States	15,778	13,941	15,016	15,361	15,62	53%
Brazil	8,86	8,1	7,32	7,4	8,26	28%
European Union	1,38	1,33	1,41	1,46	1,44	5%
India	500	520	870	1,23	1,43	5%
China	1,02	940	900	920	950	3%
Canada	497	429	434	447	460	2%
Thailand	430	390	350	370	370	1%
Argentina	290	210	270	310	300	1%
Rest of World	645	620	680	722	760	3%
Total	29,4	26,48	27,25	28,22	29,59	

Source: Adapted the Renewable Fuels Association - RFA (2023) [6].

Brazil is the world's largest producer of sugarcane, accounting for 25% of global production, as illustrated in Figure 3, according to the USDA (2023) [8]. This explains the increase in publications by Brazilian researchers in the field of second-generation ethanol production.

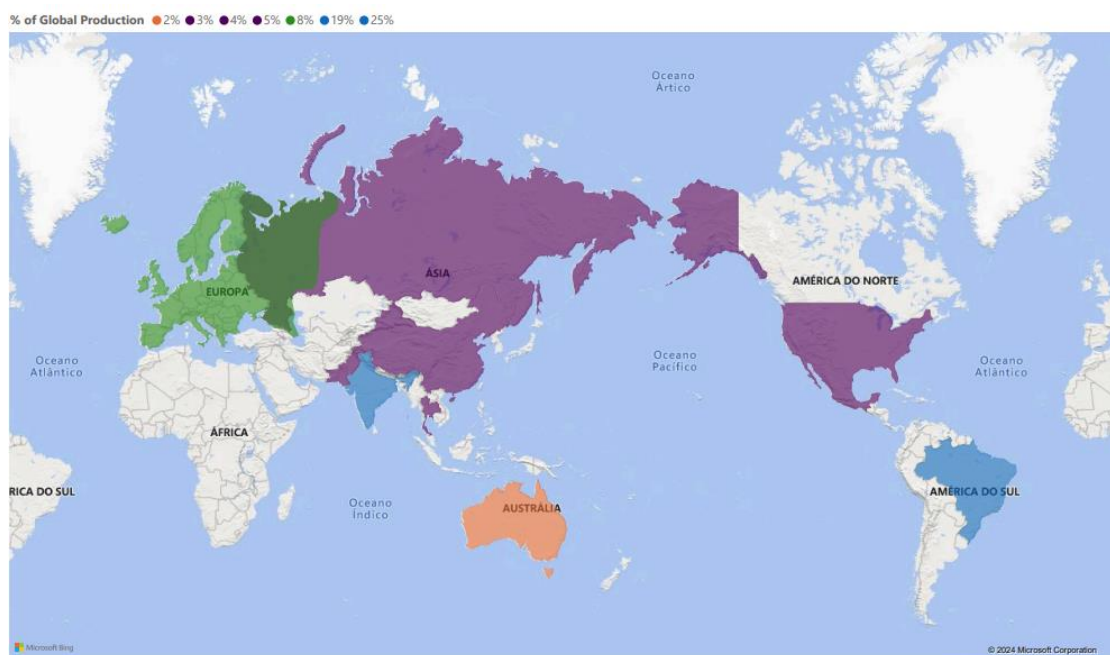


Figure 3. World sugarcane production. Developed in Power BI.

CONCLUSION

Given the results presented, it is concluded that Brazil is the country with the greatest potential for second-generation ethanol production. Although Brazil is the second largest ethanol producer in the world, losing to the USA which uses the



route of obtaining ethanol by ethylene hydration and corn fermentation, Brazil is the largest producer of sugarcane in the world, whose residue known as bagasse is intended to produce E2G.

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