Exploring *Prosopis juliflora* as a Sustainable Biomass Source for Bioethanol: A Review of Processing Methods and Production Potential

Geise Camila de Araujo Ribeiro[1]*, Yuri Uriel Cerqueira Gil Braz Moreira[2], Lilian Lefol Nani Guarieiro[3]
[1]SENAI CIMATEC University, Stricto Sensu/CNPq; [2]SENAI CIMATEC University, GETEC/PRH 27.1 ANP; [3]SENAI CIMATEC University, MPDS/PRH 27.1 ANP/Sustainable Development; Salvador, Bahia, Brazil

As the 20th century progressed, the accelerated growth of industry and the consistent increase in population size in major urban areas contributed to an escalating release of greenhouse gases, including carbon dioxide (CO_2). Fuels derived from renewable materials, such as plant biomass, offer an alternative to traditional fuels, providing a more environmentally friendly energy source. A highly relevant alternative would be to align the development of sustainable technologies with the bioprocessing of biomass waste from non-food sources. The tree *Prosopis juliflora* (*P. juliflora*) is a promising candidate due to its accessibility and energetic properties. The success of *P. juliflora* biofuel hinges on pretreatment techniques that maximize enzymatic accessibility to cellulose. This study systematically reviews the extant research on *P. juliflora* as bioethanol feedstock, with a focus on identifying which plant parts are used, the treatments applied to these parts, and the methods employed for biomass breakdown. The research methodology entailed a bibliometric analysis, which was conducted using the Web of Science database between July 25, 2025, and August 5, 2025. The Vosviewer® software was utilized for the analysis of keyword co-occurrence and author co-citation. The search yielded 29 publications and 32 keywords, with a minimum of three occurrences in the analyzed articles. Of these, 20 publications met the study's scope. The findings of the study demonstrate that chemical pretreatment provides the optimal balance between delignification and cellulose preservation. Acid degradation is still preferred over enzymatic hydrolysis, as it is the approach used in most of the studies that were analyzed. While there are studies that have applied *P. juliflora* in the production of bioethanol using these strategies, the development of more sustainable research and methodologies is still necessary to obtain biofuel in an effective and ecological way.
Keywords: Bioethanol. Delignification. Enzymes. Fermentation. *Prosopis juliflora*.
Abbreviations: IEA, International Energy Agency. EPE, Brazilian Energy Research Corporation. CO_2, carbon dioxide. Nox, nitrogen oxides. WoS, Web of Science.

The increase in population and industrialization has resulted in higher consumption of non-renewable fossil fuels and accelerated global warming and climate change [1-3]. Globally, CO_2 is the most prevalent greenhouse gas, mainly from energy production. In 2023, energy-related CO_2 emissions rose by 1.1% to approximately 37.4 Gt, with over 40% from electricity and heat, followed by transport and manufacturing [4-6]. NOx emissions from vehicles, power plants and industry are a significant contributor to air pollution, with road transport accounting for nearly half of total emissions. Agriculture, via synthetic fertilisers, is a significant source of N_2O, another potent greenhouse gas [7-8]. Ethanol's advantages make it an increasingly viable alternative or complementary transport fuel, boosting global research on renewable biofuels [9]. In this context, *Prosopis juliflora* (commonly known as algaroba or mesquite) is a promising biomass resource to ethanol producing [10].

P. juliflora trees are native to North and South America [11-13]. The fruits of *P. juliflora* (pods) are historically known for their palatability due to their high sucrose content, similar to corn and barley [11]. *P. juliflora* lignocellulosic biomass is notable for its capacity to release high levels of sugars as a result of cellulose and hemicellulose. These polymers consist of residual units of glucose and xylose [14]. These sugars can be fermented to produce ethanol. However, the presence of lignin in lignocellulosic biomass makes it need an effective

Received on 27 March 2026; revised 15 May 2026.
Address for correspondence: Geise Camila de Araujo Ribeiro. Av. Orlando Gomes, 1845 - Piatã, Salvador – BA – Brazil, Zipcode: 41650-010. E-mail: ribeirocamila0207@gmail.com.

J Bioeng. Tech. Health 2026;9(6):604-608

pretreatment process to facilitate cellulose and hemicellulose conversion into fermentable sugars for bioethanol production [14]. The aim of the present study is to provide a comprehensive review of existing research on the use of *Prosopis juliflora* as a feedstock for bioethanol production.

Materials and Methods

The research methodology was bibliometric analysis. The study had three steps: (1) data collection, (2) data visualization, and (3) data analysis.

Data Source and Collection

The search for keywords representative of the topic under study was carried out using the Web of Science database. Data collection in the databases was carried out between July 25, 2025, and August 5, 2025. The keywords were refined based on relevance and coverage to closely align with the research objectives and the gaps in this study.

The keywords were divided into three main groups: (a) Feedstock: ("*prosopis juliflora*" OR "algarob*" OR "algarrob*" OR "mesquite"); (b) Process: ("pretreatment" OR "delignification" OR "biomass pretreatment" OR "biomass delignification" OR "pretreatment of lignocellulose" OR "ethanol production" OR "fermentative microorganisms" OR "fermentation conditions" OR "ethanol fermentation" OR "distillation process" OR "fermentation optimization"); and (c) Product: (“biofuel” OR “renewable fuels” OR “bioethanol” OR "ethanol" OR “second-generation ethanol” OR “cellulosic ethanol” OR “lignocellulosic ethanol”). Quotation marks (“”) were used to delimit the search term. The asterisk (*) was used to find words written with the same prefix and different endings, such as “algarob*” for “algaroba” and “algarobo”, for example.

The keywords were indexed in the database following three distinct phases: (I) search for keywords groups; (II) search for keywords groups combinations; (III) search for keywords groups combinations using inclusion criteria. using the Boolean operator “OR”, separating the combinations of terms within the same group to combine equivalent terms, and the operator “AND”, to combine the different groups to form the research descriptors.

The results were filtered by selecting only English-language articles published in the last two decades (from 2005 to 2025) and impact factor above 0.5 (2023/2024). The search parameters were "All fields" to result in more publications.

Data Visualization and Analysis

Vosviewer® software was used for the analysis of keyword co-occurrence and author co-citation. The co-occurrence of keywords was used to map the intensity of the association between terms used in the keywords of the publications extracted, filtering the keywords for a minimum of 3 occurrences. Co-citation was used to measure the degree of collaboration between authors, countries and institutions, and the citation of a given author. These associations were represented by cluster networks generated by Vosviewer software.

The data obtained were analyzed evaluating the number of publications by author, country, year, publisher, and research area.

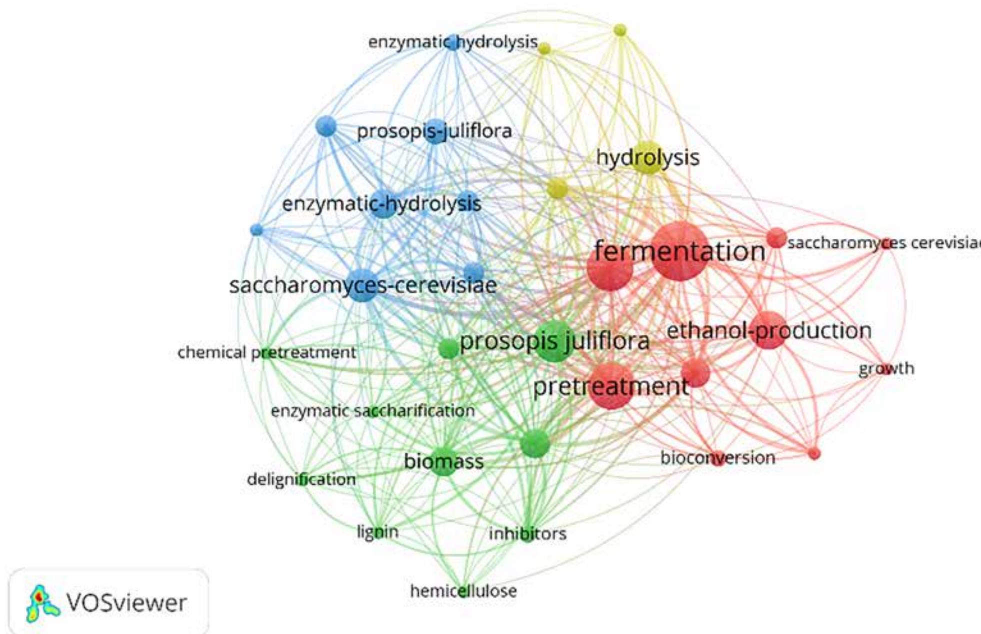
Results and Discussion

Bibliometric Analysis

The search on Web of science resulted in 3.084 publications *P. juliflora* using specific descriptors for feedstock. When searching for articles in English using descriptors related to feedstock, process and product, the database provided 29 publications.

The visualization of the research data in Vosviewer showed 32 keywords with a minimum of 3 occurrences in the analyzed articles, forming the network shown in Figure 1. The following keywords were of particular significance:

Figure 1. Representation of the co-occurrence of keywords on *P. juliflora* and bioethanol production.



"fermentation", exhibiting 14 occurrences; "bioethanol" and "pretreatment" with 11 occurrences; and "*prosopis juliflora*" with 10 occurrences each.

55% of the 29 studies analyzed in this research are in the Biotechnology Applied Microbiology area and 37% published by Elsevier between 2007 and 2022. During this period, there was a fluctuation from 0 to 4 publications/year, with a maximum of publications in 2016.

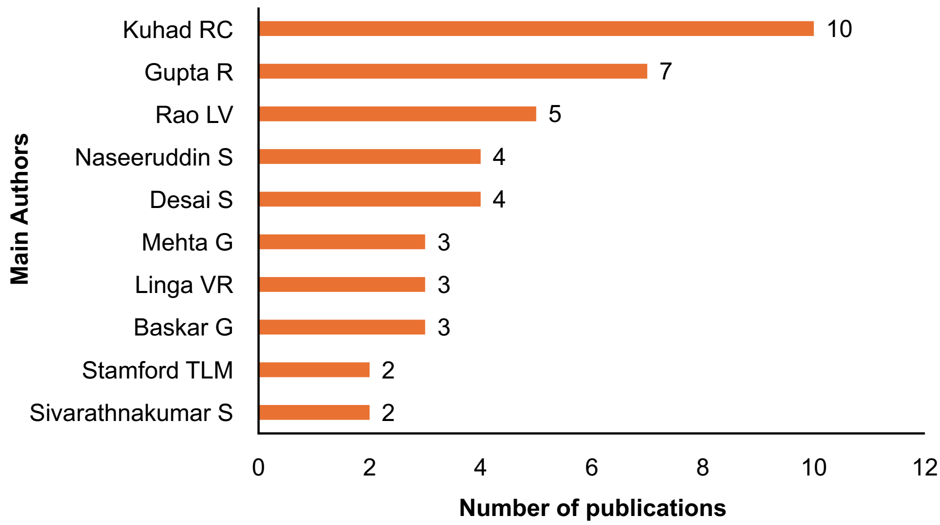
In the co-authorship analysis (Figure 2), of the 69 authors, two stood out with the highest number of publications: Ramesh C. Kuhad, with 10 publications, of which 7 have Rishi Gupta from the University of Delhi (India) as the main author. These authors had 547 and 455 citations, respectively.

79% of the studies published in this period originate from research groups linked to educational institutions in India that has intensified research into the use of new biomass for bioethanol production due to the implementation of the Ethanol Blended with Petrol Programme, which has the target of 20% blending of ethanol with petrol by 2025 to reduce the price of fuel and CO_2 emissions in the country [1]. The educational institutions that had more published on the topic were the University of Delhi and Osmania University, both in India, with 10 and 9 publications, respectively. Six Brazilian institutions appeared in three of the articles shown in the research. Researchers from the Federal University of Paraíba, Federal University of Pernambuco and Federal Rural University of Pernambuco collaborated on two studies that examined the use of *P. juliflora* pods as biomass for the growth of *Saccharomyces cerevisiae* and *Zymomonas mobilis* and producing ethanol. The Federal Institute of Bahia, the Federal University of Bahia and the Federal University of Reconcavo of Bahia have produced paper the use of *P. juliflora* wood for charcoal production.

Prosopis juliflora Bioprocessing to Produce Biofuel Review Analysis

Following a thorough review of the 29 articles extracted from Web of Science (WoS), 9 were excluded at this stage of the analysis. These were either on other types of biomass (e.g. banana, coconut, cotton, etc.) or were published in journals with an impact factor lower than 0.5 in 2023/2024.

Figure 2. Representation of number of publications by author on *P. juliflora* and bioethanol production.



Among the studies analyzed, the plant part most used was wood from the woody stem, used in 80% of studies on *P. juliflora* pretreatment. The wood sample is an excellent choice when one wants to study the efficiency of pretreatment. The wood from the stem will be more resistant to hydrolysis due to its high lignin content. During the pretreatment process, the lignin and hemicellulose contents are reduced, and the lignocellulosic materials are ready for cellulose digestion into fermentable sugars. In addition, the use of wood is chosen as a measure to eradicate *P. juliflora* in countries where it is considered a weed, such as India and Brazil [11,15]. Analyzing the 20 articles that were in accordance with the study criteria, 15 were about *P. juliflora* biomass pretreatment. 86% of studies on pretreatment of *P. juliflora* used chemical pretreatments with acid, alkaline solutions, and oxidizing or reducing agents. The remaining two studies used biological pretreatment using white rot fungus. The main chemical pretreatments described in the literature use sulfuric acid (acid pretreatment) and sodium hydroxide (alkaline pretreatment), isolated or combined. The highest delignification rate was obtained by Gupta and colleagues [16] carried out pretreatment in three steps: impregnating *P. juliflora* wood with sulfuric acid, followed by reduction with sodium sulfite and oxidation with sodium chlorite, obtaining 93% lignin removal. Regarding the biomass saccharification process, seven studies performed enzymatic degradation using commercial cellulase enzymes from Trichoderma reesei supplemented with exogenous β-glucosidases from *Aspergillus niger*. The other authors performed acid hydrolysis using sulfuric acid or nitric acid.

Twelve studies analyzed biofuel production using *P. juliflora* biomass as a substrate. Ten of these focused on bioethanol, one on biomethane and one on charcoal production. This fact shows that the use of *P. juliflora* in the bioenergy area is still minimal compared to its potential.

Conclusion

The *P. juliflora* tree has been the aim of study for decades due to its wide applicability. However, studies on the *P. juliflora* biomass pretreatment and its use in biofuel production are still scarce. Among 3,084 articles about *P. juliflora*, only 1.2% are about biomass pretreatment, and less than 1% are about the use of *P. juliflora* biomass to produce biofuels. Among the *P. juliflora* biomass pretreatments described in the literature analyzed, chemical pretreatment was the most used and with the highest yield, especially when performed at high temperatures.

Acknowledgement

The authors express their gratitude to the SENAI CIMATEC University for providing all the necessary support for completing the work. This research was supported by the National Council for Scientific and Technological Development (CNPq), which provided funding for Project No. 406154/2023-6, as well as for the award of the DTI-A scholarship, through case No. 381109/2024-0. We also gratefully acknowledge the financial support of the Human Resources Program of the National Agency of Petroleum, Natural Gas and Biofuels (PRH/ANP – PRH27/SENAI CIMATEC), with resources from the investment of qualified oil companies under the R&D&I Clause of ANP Resolution No. 50/2015; the São Paulo Research Foundation (FAPESP).

References

1. International Energy Agency. Bioenergy [Internet]. Paris: IEA; 2024. Available from: https://www.iea.org/energy-system/renewables/bioenergy
2. Empresa de Pesquisa Energética. Balanço Energético Nacional (BEN) 2024: ano referência 2023 [Internet]. Rio de Janeiro: EPE; 2024 [cited 2024 Sep 8]. Available from: https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/Balanco-Energetico-Nacional-BEN
3. International Energy Agency Bioenergy. Countries report [Internet]. 2021 [cited 2024 Sep 8]. Available from: https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountriesReport2021_final.pdf
4. International Energy Agency. CO_2 emissions 2023: executive summary [Internet]. Paris: IEA; 2024. Available from: https://www.iea.org/reports/co2-emissions-in-2023/executive-summary
5. Ministry of Petroleum and Natural Gas, Government of India. National policy on biofuels [Internet]. New Delhi: Ministry of Petroleum and Natural Gas; 2018. Available from: https://mopng.gov.in/files/Whatsnew/Website.pdf
6. World Resources Institute. Interactive chart shows changes in the world's top 10 emitters [Internet]. Washington (DC): WRI; 2023. Available from:https://www.wri.org/insights/interactive-chart-shows-changes-worlds-top-10-emitters
7. Ritchie H, Rosado P, Roser M. Breakdown of carbon dioxide, methane and nitrous oxide emissions by sector [Internet]. Our World in Data; 2020. Available from: https://ourworldindata.org/emissions-by-sector
8. International Energy Agency. Emissions of nitrogen oxide (NOx) by sector and scenario, 2015 and 2040 [Internet]. Paris: IEA; 2018. Available from: https://www.iea.org/data-and-statistics/charts/emissions-of-nitrogen-oxyde-nox-by-sector-and-scenario-2015-and-2040
9. Hemansi G, et al. Second generation bioethanol production: the state of the art. In: Srivastava N, et al., editors. Sustainable approaches for biofuels production technologies. Cham: Springer International Publishing; 2019. p. 121-146. (Biofuel and Biorefinery Technologies; vol. 7).
10. Ramírez V, et al. Chromium hyper-tolerant Bacillus sp. MH778713 assists phytoremediation of heavy metals by mesquite trees (*Prosopis laevigata*). Front Microbiol. 2019;10:1833.
11. Damasceno GADB, et al. *Prosopis juliflora* (Sw.) DC., an invasive species in the Brazilian Caatinga: phytochemical, pharmacological, toxicological and technological overview. Phytochem Rev. 2017;16(2):309-331.
12. González-Montemayor ÁM, et al. Prosopis spp. functional activities and their applications in bakery products. Trends Food Sci Technol. 2019;94:12-19.
13. Henciya S, et al. Biopharmaceutical potentials of Prosopis spp. (Mimosaceae, Leguminosae). J Food Drug Anal. 2017;25(1):187-196.
14. Fabricia M, et al. Obtainment and characterization of lignin from enzymatic hydrolysis of sugarcane bagasse from a second-generation ethanol process at pilot scale. Chem Eng Trans. 2016;50:397-402.
15. Nascimento DSCE, et al. The introduced tree *Prosopis juliflora* is a serious threat to native species of the Brazilian Caatinga vegetation. Sci Total Environ. 2014;481:108-113.
16. Gupta R, Sharma KK, Kuhad RC. Separate hydrolysis and fermentation (SHF) of *Prosopis juliflora*, a woody substrate, for the production of cellulosic ethanol by *Saccharomyces cerevisiae* and *Pichia stipitis* NCIM 3498. Bioresour Technol. 2009;100(3):1214-1220.