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WORLDWIDE SURVEY ON THE CO-PRODUCTION OF BIOGAS AND BIOHYDROGEN: A BIBLIOMETRIC ANALYSIS

AUTORES:

Larissa S. C. de Miranda, Gisele B. T. Goes, Victor L. S. Dias, Tatiana O. do Vale, Fernando L. P. Pessoa, Ana L. B. Souza

INSTITUIÇÃO:

SENAI CIMATEC University Center

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Resumo

O artigo examina a produção de biogás e biohidrogênio a partir de resíduos de águas residuais, utilizando um método de análise bibliométrica e o VOSviewer para visualização de dados. Identifica aproximadamente 1.865 estudos sobre digestão anaeróbica, enfatizando sua eficácia na gestão de resíduos e geração de energia renovável. A importância da inovação tecnológica e da pesquisa contínua é destacada para enfrentar desafios técnicos e econômicos, visando melhorar a eficiência, segurança e viabilidade econômica da coprodução de biogás e biohidrogênio, contribuindo para um futuro mais sustentável.

Palavras-chave: Biogás, Biohidrogênio, Biometano, Produção de biogás, Digestão anaeróbica.

Abstract

The article examines biogas and biohydrogen production from wastewater residues, using a bibliometric analysis method and VOSviewer for data visualization. It identifies approximately 1,865 studies on anaerobic digestion, emphasizing its effectiveness in waste management and renewable energy generation. The importance of technological innovation and continuous research is highlighted to address technical and economic challenges, aiming to improve the efficiency, safety, and economic feasibility of biogas and biohydrogen co-production, and contributing towards a more sustainable future

.Keywords: Biogas. Biohydrogen. Biomethane. Biogas production. Anaerobic digestion

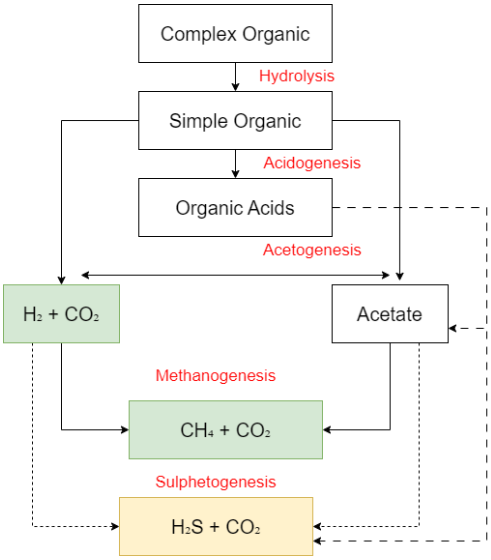
Introduction

Biogas emerges as a renewable biofuel, derived from natural or artificial processes, primarily composed of CO_2 and CH_4. The effectiveness of biogas production depends on the organic matter and adopted procedures, highlighting the importance of processing parameters for obtaining biohydrogen, a vital energy component already adopted in the energy sector to improve combustion engine efficiency and encourage the use of greener electric vehicles.[1]

Anaerobic digestion, responsible for biogas production from various substrates, involves specialized bacteria offering a sustainable and economical alternative. This process not only facilitates the transition to cleaner energy sources but also underlines the viability of biogas production as a renewable energy resource.[2]

The anaerobic digestion process is segmented into four phases: hydrolysis, acidogenesis, acetogenesis, and methanogenesis, enabling solid waste decomposition and optimized production of biohydrogen and biogas. This productive cycle not only emphasizes the sustainable nature of biogas but also positions it as a pillar for advancing renewable energy technologies, as shown in figure 1.

Figure 1. Biogas Production Flowchart



Source: Author, (2023)

The objective of this work is to perform a bibliometric analysis to assess the advances in biogas production technology, with an emphasis on Biomethane and Biohydrogen.

Metodology

Bibliometric analysis is a robust tool for hamessing scientific data from publications to assess progress, trends, and gaps in specific fields or research topics. This method, as Ampese et al.[1] highlight, offers future research directions and policy-making insights. It systematically and quantitatively enhances understanding and knowledge advancement across areas, guiding both scientific and practical development.

The study carried out data collection on biogas production through anaerobic digestion using the Scopus and Lens databases for articles and patents. This approach sought to identify the main research in the area, guided by the selection of keywords. The research was categorized into 'Product', 'Method/Route', 'By-product', and 'Application'. After collection, VOSviewer© was used as a visualization tool to map the main relationships between keywords to identify significant trends and collaborations in the field of biogas production.

Table 1. Selected Keywords About Biodegestion Process

Produt	Method/Route	Subproduct	Application
Biogas	Anaerobic Digestion	Hydrogen	Production
	Microorganism		
Biomethane	Anaerobic Process	Biohydrogen	Technological Routes
	Organic Matter		
	Acetanogenis	Green Hydrogen	

Source: Author, (2023)

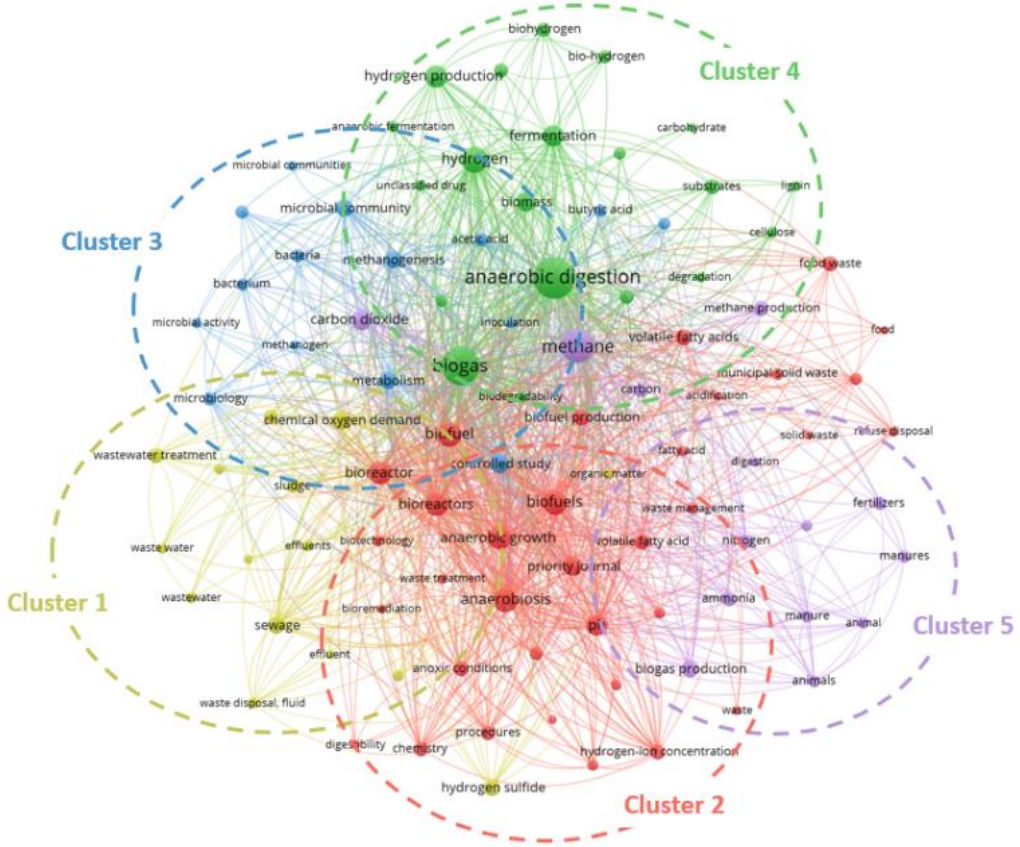
A systematic review was conducted on the set of documents obtained for publications in the last 10 years, from 2013 to 2023, to understand current trends in biogas production associated with hydrogen.

The dataset was extracted from the Scopus database and analyzed using VOSviewer© software. This research identified a total of 154 patent publications, considering only the active and undetermined patents in the period from 2013 to 2023 and 1,865 scientific papers.

Results and Discussion

For the bibliometric study of this research, the clustering of the 100 most used keywords in bibliometric search publications over the last ten years, dividing them into five distinct clusters, each representing a specific area of research within the context of biogas and biohydrogen production from wastewater. The analysis reveals a significant concentration of studies on sewage treatment, effluents, and sewage sludge, highlighting anaerobic digestion as an effective process for treating these organic wastes and generating biogas.

Figure 2. Network of keywords according to the number of occurrences



Source: VOSViewer, (2023)

Challenges in biogas production from sewage sludge are highlighted, exploring various types of digesters and processes that vary in operational parameters and feed sources. The research focuses on optimizing these processes to improve the efficiency and viability of biogas as a renewable energy source. The bibliometric analysis combined with technical knowledge aims to provide insights into emerging research areas and future directions for advancements in sustainable energy production.

The first Cluster, highlighting keywords "Wastewater", "sewage", "effluents", "sludges", focuses on studies about sewage and wastewater treatment, demonstrating the importance of these substrates in

biogas production. Anaerobic digestion emerges as an effective technique for treating these organic wastes. However, biogas generation from sewage sludge presents challenges, leading to the exploration of various types of digesters, such as solid-state, semi-continuous reactors, hydrothermal processing, thermophilic digesters, two-phase systems, and bioelectrochemical digesters, varying in operational terms and feed sources, from treatment stations to food waste and municipal plants.[3]

After that, Cluster 2 addresses biogas production through biodigesters and bioreactors, emphasizing the importance of co-digestion and pre-treatment in optimizing the production of hydrogen and volatile fatty acids. The research seeks to enhance these aspects to increase the production of biohydrogen, a key component for the viability of renewable green hydrogen. Microorganisms, especially acetogens, play a crucial role in the co-production of hydrogen, influenced by various factors that can be optimized to maximize production. [4]

Exploring the intricacies of microbial roles in anaerobic digestion, Cluster 3, with keywords such as "microbial communities", "bacteria", "methanogen", "microbiology", "metabolism", and "microbial community", unveils the fundamental part that microorganisms play, especially in the domain of hydrogen production. Acetogenic microorganisms, capable of producing hydrogen within their metabolic pathways, are at the heart of this process. The potential for hydrogen production hinges on a myriad of factors, including the nature of the organic substrate, digester operational conditions, and microbial ecosystem composition. Fine-tuning these elements can lead to an enhanced proportion of hydrogen over methane. This insight ushers in the innovative concept of hydrogen co-production during anaerobic digestion, where hydrogen emerges as a byproduct of organic material decomposition. Particularly during the acidogenic phase, acetogenic microorganisms transform organic compounds into organic acids, paving the way for hydrogen generation.[5]

The fourth Cluster focuses on the technological route for biogas production with hydrogen, exploring biomass composition and methods for obtaining hydrogen. Current research investigates the potential of biohydrogen, examining the anaerobic digestion process to improve efficiency and contribute to the production of renewable green hydrogen. The fifth Cluster, related to biogas post-treatment, highlights anaerobic digestion as an economically viable management for bioenergy recovery, integrating knowledge on pre-treatment of raw materials and process optimization.[6]

Finally, the study underlines the challenges faced in biogas production, including the development of safe and efficient systems for storage and transportation, and the need to reduce costs through technological innovations. Moreover, it emphasizes the importance of evaluating the long-term environmental impacts and continuing research and development of new technologies to improve the efficiency, safety, and economic viability of biogas and biohydrogen as sustainable alternatives to fossil fuels.

Conclusion

The bibliometric analysis on biogas and biohydrogen production from wastewater residues reveals approximately 1,865 studies focused on anaerobic digestion processes for the treatment of sewage, effluents, and sludge, highlighting the efficiency of this methodology for both waste management and renewable energy generation. This research underscores the technical and economic challenges in process optimization, including the need to develop safe systems for storage and transport, and the importance of technological innovation to reduce costs. Co-digestion, pre-treatment, and the exploration

of new technological routes are identified as key elements to increase biohydrogen production, evidencing the crucial role of microorganisms in this process.

The study emphasizes the importance of continuing research and the development of new technologies to improve the efficiency, safety, and economic viability of biogas and biohydrogen production, while assessing the long-term environmental impacts. The search for sustainable energy solutions and attention to environmental challenges reflect the global urgency of transitioning to clean energy alternatives. Progress in this area has the potential to significantly contribute to the diversification of energy matrices, promoting a more sustainable future and reducing dependence on fossil fuels.

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Referências Bibliográficas

[1] AMPESE, L. C. et al. Research progress, trends, and updates on anaerobic digestion technology: A bibliometric analysis. Journal of Cleaner Production, v. 331, December 2021. Doi: 10.1016/j.jclepro.2021.130004

[2] JUNGGREN, L. M. et al. "Techno-economic analysis of a two-step biological process producing hydrogen and methane", Bioresource Technology, Vol. 101, Issue 20, October 2010, Pages 7780-7788, doi: 10.1016/j.biortech.2010.05.009.

[3] Li, Y., Chen, Y., Wu, J., 2019. "Enhancement of methane production in anaerobic digestion process: A review", Applied Energy, Vol. 240, 15 April 2019, Pages 120-137, Doi: 10.1016/j.apenergy.2019.01.243

[4] MIRANDA, L. S. C., PESSOA, F. L. P., SOUZA, A. L. B.. "Technological Prospection and Flowchart for Production of Biogas Enriched with Hydrogen: A Proposal for Renewable Energy Sources" Journal of Bioengineering, Technologies and Health, Vol 6 No 3, November 2023, Doi: 10.34178/jbth.v6i3.317]

[5] PEREZ, M. Co-digestão anaeróbica de lodo de esgoto, vinhaça de vinho e esterco de aves para produção de biohidrogênio. Energia de Hidrogênio Int J, 2021.

[6] SALOMON, K., R. (2007), Avaliação Técnico-Econômica e Ambiental da Utilização do Biogás Proveniente da Biodigestão da Vinhaça em Tecnologias para Geração de Eletricidade, Itajubá, 219 p. Tese de Doutorado (Doutorado em Conversão de Energia) - Instituto de Engenharia Mecânica, Universidade Federal de Itajubá. Doi: https://repositorio.unifei.edu.br/jspui/handle/123456789/1721