

Bibliometric Analysis of Publications from 2010-2024 on the Recovery of Agricultural Residues to Obtain Biodiesel*

Nelson Contreras Coronel^a ■ Lina M. Orozco^b ■ Nathalia Cardona Hurtado^c

Abstract: The rapid increase in global energy consumption in recent decades has significantly contributed to higher CO₂ emissions, thereby intensifying environmental challenges. In this context, biofuels—particularly those derived from agricultural residues—have emerged as sustainable alternatives to fossil fuels. These residues, typically regarded as inedible and biodegradable, represent a valuable resource for biodiesel production while simultaneously supporting the principles of a circular economy and enhancing energy security. In this study, a bibliometric analysis was conducted using the Scopus and Web of Science databases, complemented by tools such as Bibliometrix and VOSviewer. The search encompassed the years 2010–2024 and focused on publications addressing the recovery of agricultural waste for biodiesel production. A total of 895 relevant articles were identified. The leading research areas included environmental sciences (18%), energy (13.6%), and chemical engineering (10.2%). The most prolific journals were Waste and Biomass Valorization (102 articles) and Green Chemistry. Among the most influential authors in the field were Kwon E. E. and Jung S. Highly cited works included Naik et al. (2010), which provided a foundational discussion on biofuels, and Sheldon (2014), which emphasized catalysis for biomass recovery. Recent studies have increasingly focused on the development of novel technologies and catalysts aimed at improving the efficiency and cost-effectiveness of biodiesel production. The bibliometric analysis highlights not only the growing scholarly interest in the recovery of agricultural waste for biodiesel but also the broader emphasis on sustainability and the circular economy. The observed increase in publications and international collaborations further reflects significant advancements in research and development within this domain.

Keywords: Biomass; bibliometrix; biofuels; catalysis; Scopus; VOSviewer; wos

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- a** Doctor in Agrochemistry/Inorganic Chemistry. Oleoquímica Research Group. Universidad Tecnológica de Pereira, Pereira, Colombia. Email: ncontrer@utp.edu.co; ORCID: <https://orcid.org/0000-0002-2264-8225>
- b** Doctor in Sustainable Chemistry. Group, Faculty of Technologies. Universidad Tecnológica de Pereira, Pereira, Colombia. Email: marcely@utp.edu.co; ORCID: <https://orcid.org/0000-0001-8721-1262>
- c** Magister in Ecotechnology. Research Group, Faculty of Technologies, School of Chemistry, Universidad Tecnológica de Pereira, Pereira, Colombia.
Email: nathacardona@utp.edu.co; ORCID: <https://orcid.org/0000-0002-3814-4726>

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Análisis bibliométrico de publicaciones de 2010 a 2024 sobre la valorización de residuos agrícolas para la obtención de biodiésel

Resumen: El rápido aumento del consumo energético mundial en las últimas décadas ha contribuido significativamente al aumento de las emisiones de CO₂, intensificando así los desafíos ambientales. En este contexto, los biocombustibles, en particular los derivados de residuos agrícolas, han surgido como alternativas sostenibles a los combustibles fósiles. Estos residuos, generalmente considerados incombustibles y biodegradables, representan un valioso recurso para la producción de biodiésel, a la vez que respaldan los principios de la economía circular y mejoran la seguridad energética. En este estudio, se realizó un análisis bibliométrico utilizando las bases de datos Scopus y Web of Science, complementadas con herramientas como Bibliometrix y VOSviewer. La búsqueda abarcó los años 2010-2024 y se centró en publicaciones que abordaban la recuperación de residuos agrícolas para la producción de biodiésel. Se identificaron un total de 895 artículos relevantes. Las principales áreas de investigación incluyeron ciencias ambientales (18%), energía (13,6%) e ingeniería química (10,2%). Las revistas más prolíficas fueron Waste and Biomass Valorization (102 artículos) y Green Chemistry. Entre los autores más influyentes en el campo se encuentran Kwon E. E. y Jung S. Entre los trabajos altamente citados se encuentran Naik et al. (2010), que proporcionó una discusión fundacional sobre los biocombustibles, y Sheldon (2014), que enfatizó la catálisis para la recuperación de biomasa. Estudios recientes se han centrado cada vez más en el desarrollo de nuevas tecnologías y catalizadores para mejorar la eficiencia y la rentabilidad de la producción de biodiésel. El análisis bibliométrico destaca no solo el creciente interés académico en la recuperación de residuos agrícolas para la producción de biodiésel, sino también el mayor énfasis en la sostenibilidad y la economía circular. El aumento observado en publicaciones y colaboraciones internacionales refleja además avances significativos en investigación y desarrollo en este ámbito.

Palabras clave: biomasa; Bibliometrix; biocombustibles; catálisis; Scopus; VOSviewer; WOS

Análise bibliométrica de publicações de 2010 a 2024 sobre a valorização de resíduos agrícolas para a obtenção de biodiesel

Resumo: O rápido aumento do consumo energético mundial nas últimas décadas contribuiu significativamente para o crescimento das emissões de CO₂, intensificando os desafios ambientais. Nesse contexto, os biocombustíveis, em particular aqueles derivados de resíduos agrícolas, surgiram como alternativas sustentáveis aos combustíveis fósseis. Esses resíduos, geralmente considerados não comestíveis e biodegradáveis, representam um recurso valioso para a produção de biodiesel, ao mesmo tempo em que apoiam os princípios da economia circular e melhoram a segurança energética. Neste estudo, realizou-se uma análise bibliométrica utilizando as bases de dados Scopus e Web of Science, complementadas com ferramentas como Bibliometrix e VOSviewer. A busca abrangeu os anos de 2010 a 2024 e concentrou-se em publicações que abordavam o aproveitamento de resíduos agrícolas para a produção de biodiesel. Identificaram-se um total de 895 artigos relevantes. As principais áreas de pesquisa incluíram ciências ambientais (18%), energia (13,6%) e engenharia

química (10,2%). As revistas mais prolíficas foram Waste and Biomass Valorization (102 artigos) e Green Chemistry. Entre os autores mais influentes no campo estão Kwon E. E. e Jung S. Entre os trabalhos altamente citados encontram-se Naik et al. (2010), que apresentou uma discussão fundamental sobre biocombustíveis, e Sheldon (2014), que enfatizou a catálise para a recuperação de biomassa. Estudos recentes têm se concentrado cada vez mais no desenvolvimento de novas tecnologias e catalisadores para melhorar a eficiência e a viabilidade econômica da produção de biodiesel. A análise bibliométrica destaca não apenas o crescente interesse acadêmico no aproveitamento de resíduos agrícolas para produzir biodiesel, mas também uma maior ênfase na sustentabilidade e economia circular. O aumento observado nas publicações e nas colaborações internacionais reflete ainda avanços significativos em pesquisa e desenvolvimento nessa área.

Palavras-chave: biomassa; Bibliometrix; biocombustíveis; catálise; Scopus; VOSviewer; WOS

Introduction

In recent decades, global energy consumption has risen significantly, driven primarily by population growth, industrialization, and economic development. This surge in energy demand has resulted in a considerable increase in carbon dioxide (CO₂) emissions, thereby contributing to diverse environmental challenges worldwide [8]. In response, renewable energy sources have been widely recognized as viable alternatives to mitigate the adverse environmental impacts associated with fossil fuel use [25].

Within this framework, biofuels—derived from plant- or animal-based organic biomass—have attracted increasing attention due to their potential to reduce greenhouse gas emissions, foster sustainable economic practices, and enhance energy security [5, 21]. Among the various biomass sources, agricultural residues, generated as by-products during crop harvesting and processing, are of particular significance. Globally, large quantities of such residues are produced annually, posing challenges for their management and recovery for biodiesel production. In many cases, these residues are incinerated or disposed of in landfills (Jamil et al., 2024; Ng et al., 2017). However, a major advantage of agricultural residues

lies in their inedibility, which eliminates competition with the food supply and minimizes potential impacts on food security.

Consequently, biodiesel production from agricultural waste simultaneously addresses waste management concerns and contributes to the advancement of a circular economy and energy security. Agricultural residues thus represent promising resources for the sustainable development of biofuels. Accordingly, the objective of this study was to conduct a bibliometric analysis using data from the Scopus and Web of Science (WoS) databases, complemented by the vosviewer and Bibliometrix software, in order to identify leading journals and research trends associated with the valorization of agricultural residues for biodiesel production.

Materials and methods

The data used in the bibliometric analysis were extracted from the Scopus database hosted by Elsevier and the WoS. The search focused on the period between 2010 and 2024.

The search equation was constructed from the keyword combination, which allowed us to characterize the profiles of the articles chosen. The selected search equations are given in Table 1.

Table 1. Search equations used for the Scopus and WoS databases

Databases	Search equation	Documents found
Scopus	ALL ((("agricultural by-products") OR (agrowaste) AND (catalysis) OR (catalyst) AND biodiesel AND (valorization) OR ("value added"))) AND PUBYEAR > 2010 AND PUBYEAR < 2025	446
WOS	(agricultural by-products OR fruit waste or biomass OR agrowaste) (All Fields) and (catalysis OR catalyst) (All Fields) and (biodiesel) (All Fields) and (value added OR valorization) (All Fields) and 2010-01-01/2024-08-20 (Publication Date)	449

Source: Data obtained from the Scopus and WoS databases.

A total of 895 articles were retrieved from the Scopus and WoS databases in the file formats required by the software and subsequently imported into Bibliometrix [3] and vosviewer [13]. The full records of each article, including the cited references, were also considered.

The data were processed in R using Bibliometrix under the following selection criteria: (i)

publications related to agricultural by-products, agrowaste valorization, and biodiesel; (ii) articles published between 2010 and 2024; (iii) documents classified strictly as scientific articles, excluding reviews, editorials, conference papers, and other non-research materials; and (iv) publications written in English. Duplicate records were removed, and the names of authors and institutions

were standardized to avoid inconsistencies in the analyses.

Basic descriptive metrics were calculated, such as the total number of articles and the average number of citations per article. In addition, temporal evolution plots were generated to identify trends in scientific production, and visual maps were developed to explore co-citation and co-occurrence networks.

Results and Discussion

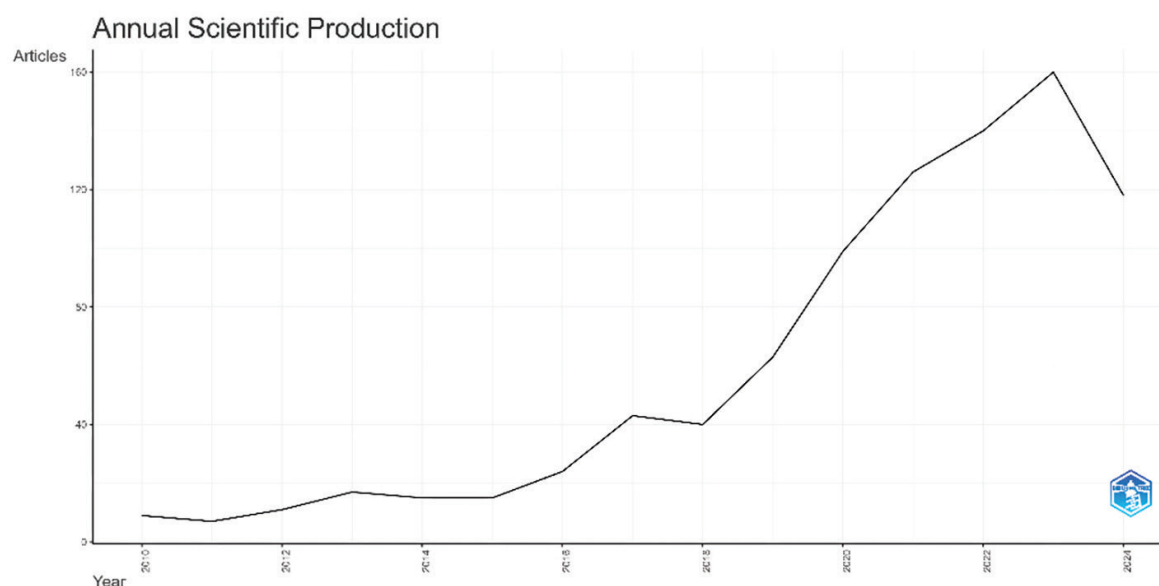
Between 2010 and 2024, a total of 895 articles were published on the recovery of agricultural waste for biodiesel production. Figure 1 illustrates the annual distribution of publications. From 2010 to 2018, fewer than 40 articles were published each year on this topic. However, a sharp increase was observed

in 2023, with more than four times the number of publications compared to previous years. These findings highlight the substantial growth of research in this field over the analyzed period.

The distribution of research areas identified in the Scopus database is presented in Figure 2. The most prominent fields were environmental sciences (18%), energy (13.6%), and chemical engineering (10.2%). Additionally, a wide range of other disciplines, including agriculture, biochemistry, and materials science, were also represented.

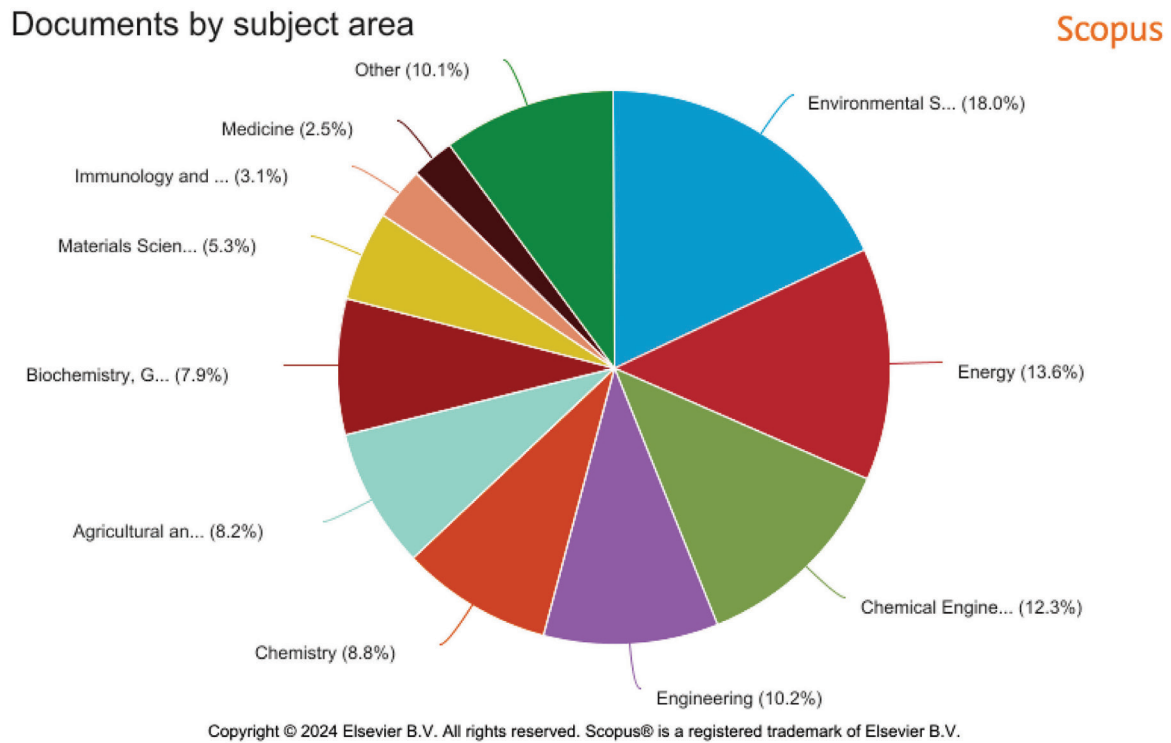
The five journals with the highest number of publications on this subject are presented in Table 2, each contributing more than 17 articles. Waste and Biomass Valorization ranked first, with 102 publications, representing 11.5% of the total output and establishing itself as the leading journal in terms of publication volume.

Figure 1. Annual scientific production from 2010 to 2024 in journals related to the valorization of agricultural residues for biodiesel production



Source: The Bibliometrix application from R studio was used to develop the graph with data obtained from Scopus and WOS.

Figure 2. Research areas identified from the Scopus database related to the recovery of agricultural waste for biodiesel production



Source: Scopus database.

Table 2. The five leading journals in terms of publication volume on the recovery of agricultural waste for biodiesel production

Journal	TP	Percentage (%)	H-index	SRJ 2023	QC
1 Waste and Biomass Valorization	102	11.5	68	0.61	Q2
2 Biomass Conversion and Biorefinery	24	2.7	45	0.6	Q2
3 Fuel	20	2.3	256	1.45	Q1
4 Catalysts	17	1.9	90	0.69	Q2
5 Green Chemistry	17	1.9	272	1.88	Q1

Percentage of 895 (%)

Source: Data obtained from www.scimagojr.com TP: Total publications; H-index: H-index of the journal; QC: Quartile in category; SRJ: measure of the scientific influence of the average article in a journal.

Although *Fuel* and *Green Chemistry* reported fewer publications than *Waste and Biomass Valorization*, their H-indices are substantially higher (256 and 272, respectively). This indicates that the articles published in these journals exert a greater impact on

the scientific community. Both journals are classified in quartile Q1, reflecting their high quality and prestige. The highest SRJ value recorded in 2023 was 1.88 for *Green Chemistry*, positioning it as a high-impact journal and a key reference in this field.

The inclusion of journals such as *Catalysts* and *Biomass Conversion and Biorefinery* in this ranking highlights the growing relevance of research on biomass conversion, bioenergy, and catalysis. Although these journals report fewer publications, their presence in quartiles Q1 and Q2 indicates that they still serve as relevant and high-quality platforms for disseminating research in this area.

The quartile classification (Q1 and Q2) reflects the quality distribution among the journals, with *Fuel* and *Green Chemistry* standing out for their Q1 ranking. While journals in Q2 may exert relatively less influence, they continue to contribute significantly to the field.

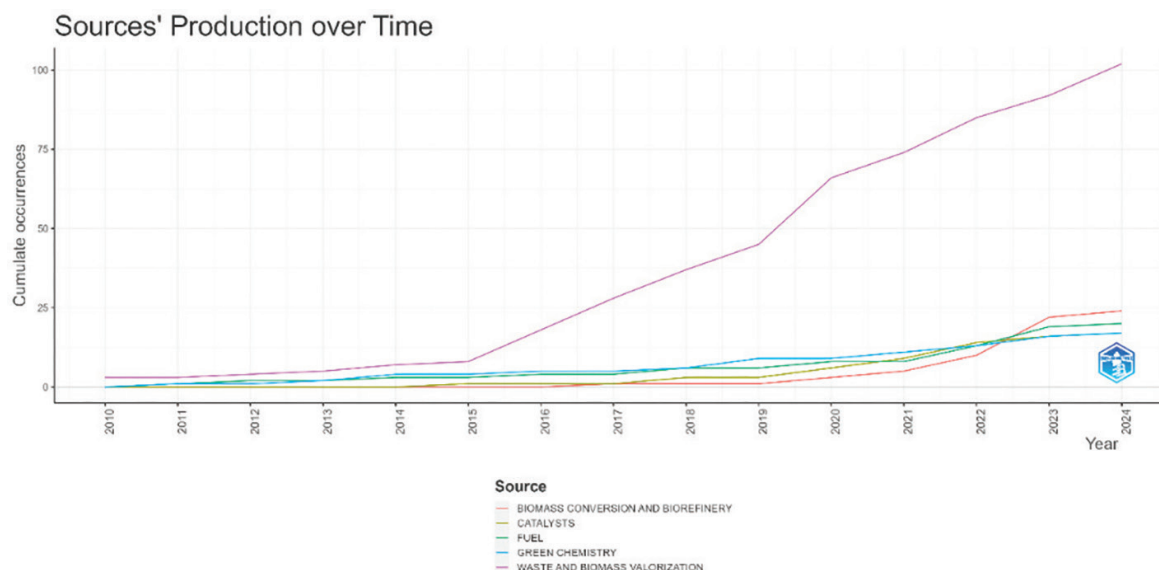
Figure 3 presents the cumulative production of articles in the five leading journals from 2010 to 2024. A consistent increase in publications was observed across all journals. *Waste and Biomass Valorization* has shown particularly significant and sustained growth since 2015, with a more

pronounced increase beginning in 2019. By 2024, this journal had published nearly 100 articles, clearly distinguishing itself above the others in the trend.

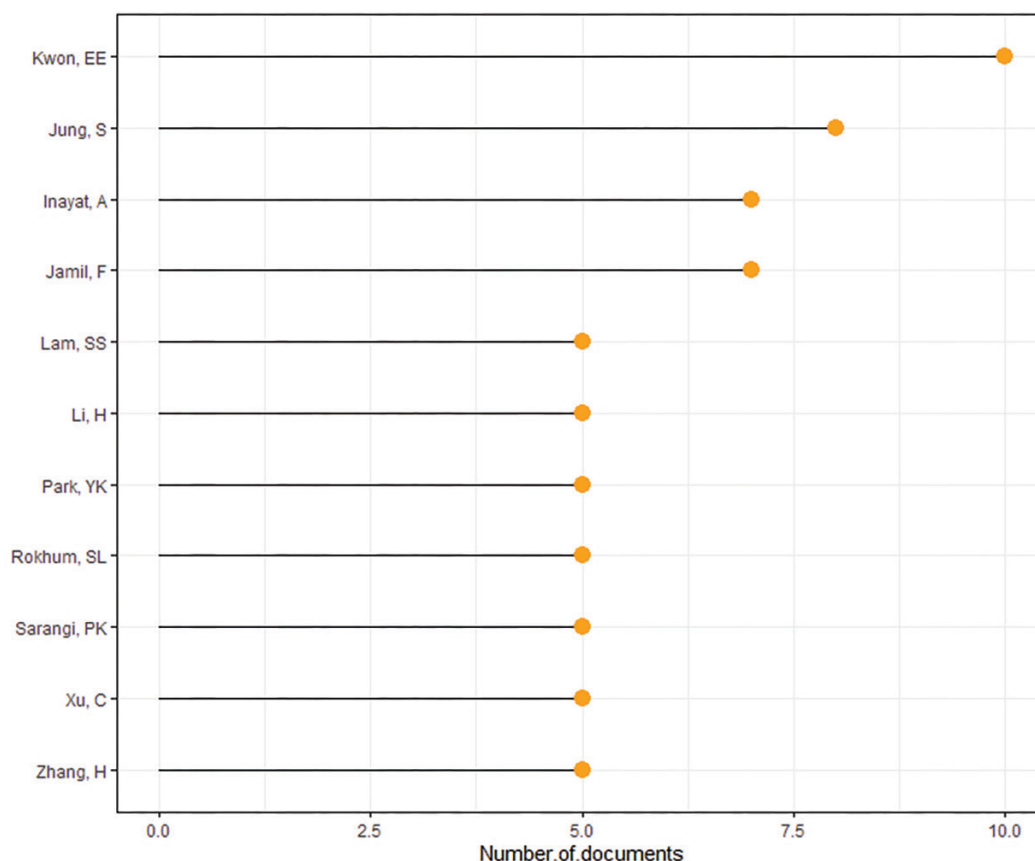
Fuel (green line in Figure 3), *Green Chemistry* (blue line), and *Catalysts* (orange line) exhibited more moderate growth in publication volume compared with *Waste and Biomass Valorization*. Nonetheless, from 2019 onward, these journals also recorded a notable increase in cumulative publications, although not at the same pace as the leading journal.

Figure 4 presents the authors with the highest number of publications in this field, each contributing between 5 and 10 articles. The most prolific author is Kwon EE, with a total of 10 publications, followed by Jung S, with 8. These two researchers have made substantial contributions and are among the most active scholars in the field, suggesting that they are likely leading research efforts in this area.

Figure 3. Cumulative number of articles published from 2010 to 2024 in the five leading journals addressing the recovery of agricultural waste for biodiesel production.



Source: The Bibliometrix application from R studio was used to develop the graph with data obtained from Scopus and WoS databases.

Figure 4. Number of documents by author related to the recovery of agricultural waste for biodiesel production

Source: The Bibliometrix application from R studio was used to develop the graph with data obtained from Scopus and was databases.

The most frequently cited article is by Naik et al. (2010) [21], which examines cost-effective technologies and processes for converting biomass into liquid biofuels and value-added chemicals. This review emphasizes the biorefinery concept, drawing on various raw materials to promote their integral use in the production of higher-value products.

Another highly relevant work is [27], which analyzes strategies for valorizing residual biomass into chemical products. This study also discusses advances in chemical and biological catalysis that enable biomass recovery and highlights a complete deoxygenation strategy for obtaining petroleum hydrocarbons by leveraging existing technologies.

Additionally, reference [2] provides a global overview of biomass production and utilization. The article identifies approaches to enhance

biomass production, including agronomic practices, the use of beneficial microorganisms, genomic editing, and the selection of optimal technologies. It further proposes an integrative framework whereby food security is maintained while simultaneously reducing greenhouse gas emissions and promoting the substitution of fossil fuels with bioenergy.

Table 4 presents the top 10 countries or regions in terms of total publications, each contributing more than 10 articles. The table also includes the total link strength of associations and citation counts. In this regard, India emerges as the most productive country, followed by China, Malaysia, and the United States. With respect to citations, China, India, and Spain rank highest in citations per article.

Table 4. Main countries/regions publishing articles on the recovery of agricultural residues for biodiesel production

	Country	Number of publications	Cluster	Citations	Overall link strength
1	India	122	2	3437	90
2	China	60	3	3612	62
3	United States	32	1	1154	44
4	Malaysia	43	3	2059	42
5	Australia	22	1	2074	41
6	South Kores	22	2	1580	36
7	Saudi Arabia	17	3	385	30
8	United Kingdom	16	1	806	28
9	Pakistan	16	3	613	26
10	Spain	29	1	2206	25

Source: VOSviewer and Scopus and wos databases.

An international coauthorship network was generated using vosviewer software (Figure 5). A minimum threshold of 10 publications was applied, resulting in the inclusion of 24 countries or regions. vosviewer organized these countries into four distinct clusters, each represented by a different color. In the visualization, the size of each circle corresponds to the total number of publications, while the distance between circles reflects the strength of the collaborative relationships among countries.

As shown in Figure 5, the first cluster (red) consists of 10 countries/regions: Spain, Greece, Mexico, Portugal, Poland, Australia, Brazil, Italy, the United States, and the United Kingdom. The second cluster (green) is composed of 7 countries/regions: India, Belgium, France, Vietnam, Canada, Iran, and South Korea. The third cluster (blue) includes 5 countries/regions: China, Pakistan, Malaysia, Saudi Arabia, and Thailand. Finally, the fourth cluster (yellow) contains 2 countries/regions: Nigeria and South Africa.

India demonstrates the strongest collaborative associations, particularly with China, the United States, and Malaysia, highlighting intensive cooperation between Indian researchers and institutions in these regions.

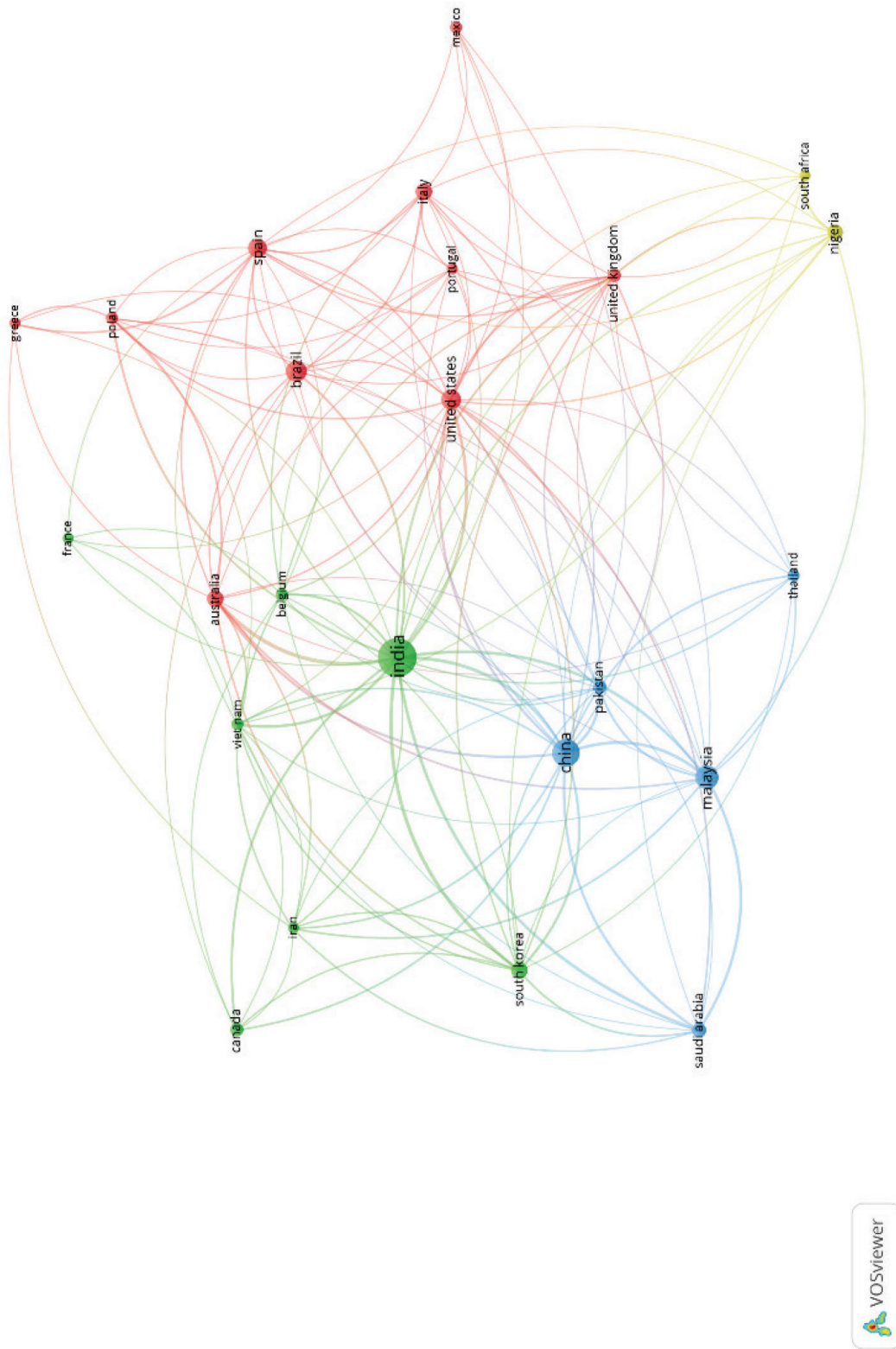
From the analysis of 1,343 keywords identified in Scopus publications on the recovery of

agricultural residues for biodiesel production, only 43 surpassed the minimum co-occurrence threshold of five. As illustrated in Figure 6, these keywords were distributed into seven clusters. The most frequently occurring terms included *biomass*, *agricultural waste*, *biofuel*, and *biorefinery*. The relationships among these keywords primarily reflect research on the use and valorization of agricultural waste within the framework of the circular economy, emphasizing connections between *biomass*, *biorefinery*, and *biofuel*.

The same dataset was subsequently organized into an overlay visualization (Figure 7), where blue represents older research topics, while yellow and green correspond to more recent areas of investigation [13]. Topics shown in blue reflect fields that were previously the focus of extensive research but have since given way to emerging directions.

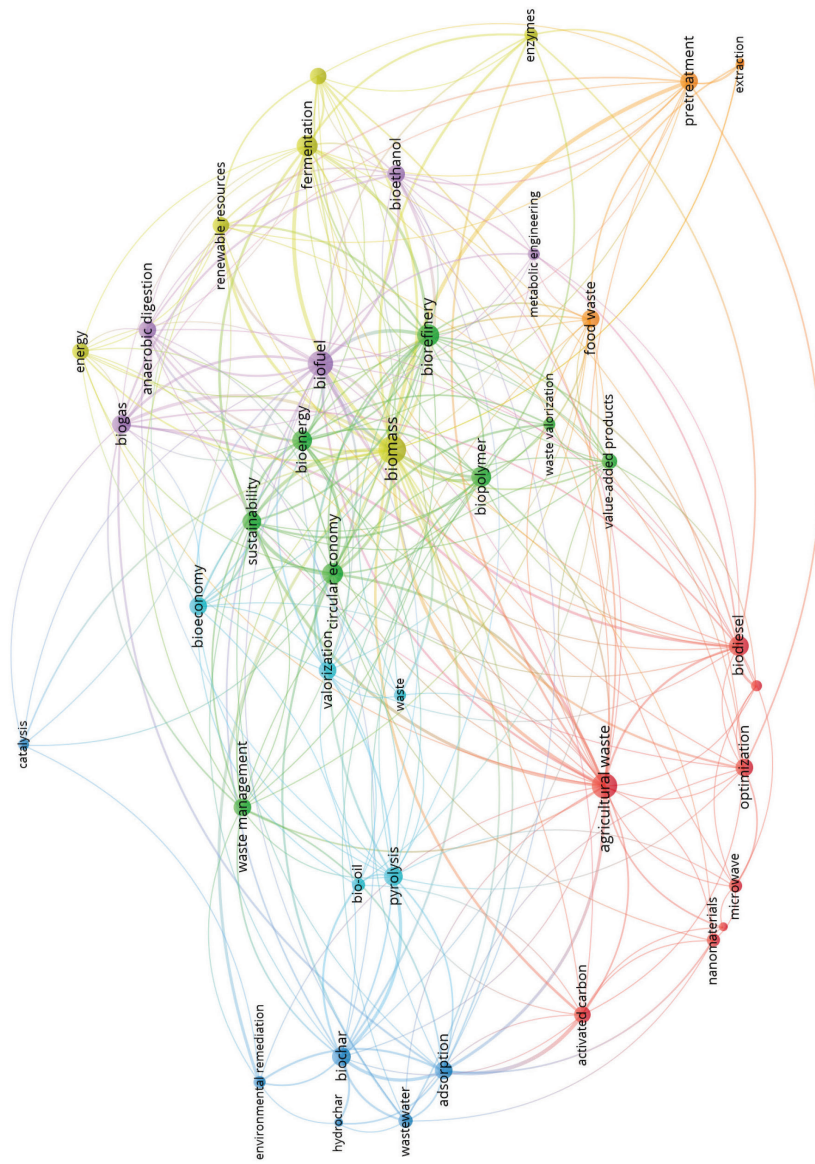
A notable current area of inquiry concerns the utilization of agricultural residues for the production of biofuels within the framework of a circular economy. This approach contributes to global sustainability by maximizing resource value, reducing pollution, and supporting rural development. Furthermore, it fosters innovation and promotes the efficient and ethical use of natural resources, which is essential for addressing future environmental and energy challenges.

Figure 5. Coauthorship network of countries/regions that publish research on the recovery of agricultural residues for biodiesel production.



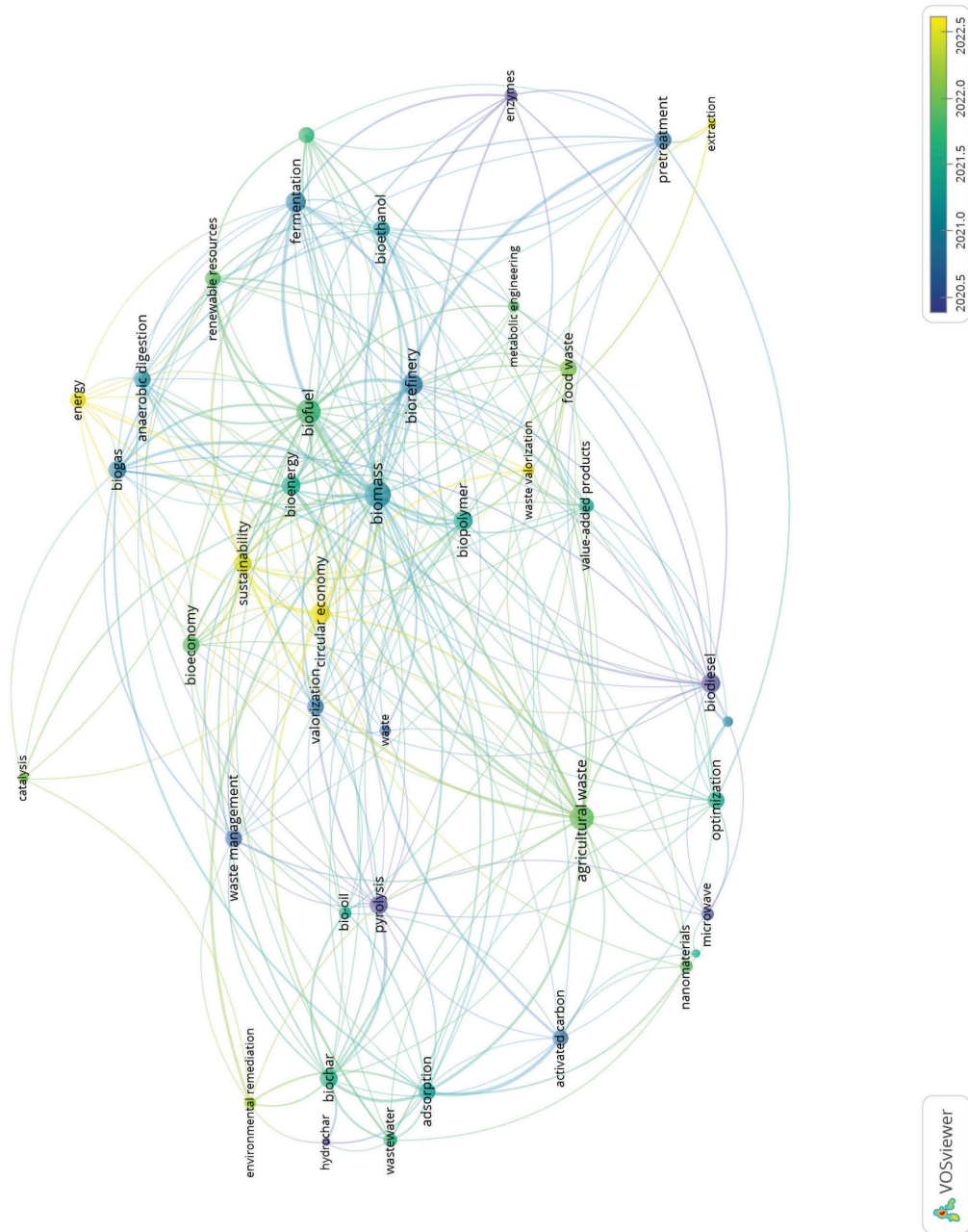
Source: The data were obtained from Scopus, and the network comprises 24 nodes and 4 clusters.

Figure 6. VOSviewer co-occurrence network map of authors' keywords (minimum of 5 occurrences) in publications related to the recovery of agricultural residues for biodiesel production



Source: VOSviewer and Scopus and WOS databases.

Figure 7. VOSviewer co-occurrence overlay map of authors' keywords (minimum of 5 occurrences) in publications related to the recovery of agricultural residues for biodiesel production



Source: VOSviewer and Scopus and wos databases.

Alternatives for Biomass Recovery, Conversion into Biodiesel, and Current Applications

Biomass valorization encompasses multiple technological alternatives, among which the production of biofuels, the generation of electrical and thermal energy, and the synthesis of high-value-added chemicals are particularly noteworthy [1, 11, 23, 29]. The production of biofuels represents one of the most relevant applications, as they are derived from renewable resources, exhibit environmental degradability, and emit fewer pollutants than conventional fossil diesel. Nevertheless, several challenges remain, including competition with food production, potential contributions to deforestation due to crop expansion, and production costs that may exceed those of fossil fuels [9, 16, 23].

In the context of the circular bioeconomy, biodiesel production has emerged as a key strategy to exploit biomass resources and minimize waste. The environmental and social impacts of different biomass valorization alternatives have been widely studied, with emphasis placed on the identification of sustainable long-term options. Recent advances have focused on the development of novel technologies to enhance efficiency and reduce recovery costs, as well as on the integration of multiple technological processes to optimize components and broaden the spectrum of final products [23, 24, 30]. Collectively, these developments support the optimization of biomass valorization pathways and promote energy solutions that are both economically viable and environmentally sustainable [26].

A notable byproduct of biodiesel production is glycerol, which accounts for approximately 10% of the total volume. Given its abundance, efficient valorization is essential. Studies have demonstrated the potential for converting glycerol into high-value-added products—including hydrogen, acetol, acrolein, glycols, 1,3-propanediol, lactic acid, and biopolymers—through diverse technological routes such as biological, chemical, and thermochemical processes. These strategies not only maximize the utilization of glycerol but also

address management challenges within the biodiesel industry [4, 10, 12, 14, 17, 20].

Parallel research has concentrated on the development of catalysts derived from agricultural waste mixtures for oil transesterification, thereby contributing to waste management. For instance, Basumatary et al. (2023, 2024) [6, 7] synthesized catalysts from agricultural waste combined with potassium carbonate, which were successfully applied to the transesterification of oils extracted from *Jatropha curcas* and *Pongamia pinnata*. Similarly, biochar obtained from peanut residues through pyrolysis has been reported as an effective porous catalyst, capable of enhancing reaction kinetics and lowering reaction temperatures in biodiesel production compared with conventional methods [18, 19].

Additional research has explored the sustainable reuse of food waste with high lipid content for the production of biodiesel and other value-added byproducts. For example, Rajendran et al. (2022) [24] developed a biochar catalyst derived from citron peel (*Citrus medica*), which, owing to its high carbon content, demonstrated significant improvements in the biodiesel production process. Likewise, solid acid catalysts such as molybdenum oxide (MoO₃) and tungsten oxide (WO₃) have exhibited high acidity, stability, and catalytic efficiency for biomass valorization into biofuels and valuable chemicals [28].

Finally, specific catalysts such as KSBG-K₂CO₃ (derived from agricultural residues) and CMCP-550 (derived from *Musa champa* shells) have achieved notable efficiency under optimized reaction conditions, further underscoring the potential of waste-derived materials in biodiesel production [28].

Conclusion

The analysis revealed a significant increase in the number of scientific publications on the valorization of agricultural residues to produce biodiesel since 2019. This growth suggests a rising interest and development in this field, driven by the urgent need for sustainable alternatives to fossil fuels. Compared with previous years, the number

of scientific publications from China quadrupled in 2023, indicating an accelerated expansion in both research activity and the publication of new studies.

Research has primarily focused on key areas such as environmental sciences, energy, and chemical engineering. This reflects the interdisciplinary nature of agricultural waste recovery and its potential to address environmental, energy, and engineering challenges.

Waste and Biomass Valorization stands out as the leading journal in terms of publication volume, consolidating its role as the main platform for disseminating research on the valorization of agricultural residues. In terms of contributions and citations, India, China, and Malaysia have emerged as the leading countries, highlighting their central role in advancing biodiesel research. The international coauthorship network also revealed strong collaboration among these nations.

The keyword co-occurrence analysis emphasized the relevance of terms such as *biomass*, *agricultural waste*, *biofuel*, and *biorefinery*. These thematic clusters demonstrate a growing focus on the circular economy and the valorization of agricultural waste. The shift toward topics related to

the circular economy underscores an evolution in research, pointing to more sustainable and efficient strategies for biofuel production.

The valorization of biomass for biodiesel production encompasses several technological alternatives, each presenting specific challenges. While biofuel production offers a promising pathway to reduce polluting emissions, it also faces issues such as competition with food resources and high production costs. Recent research has therefore focused on improving efficiency and reducing costs through technological innovation and the integration of sustainable practices. Additionally, the valorization of glycerol—a byproduct of biodiesel production—has attracted growing attention for its potential to generate high-value products and contribute to more efficient byproduct management.

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Conflict of interest

The authors declare that they have no potential conflicts of interest with respect to the research, authorship, or publication of this article.

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