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OPTIMIZATION OF BIOFUEL PRODUCTION PROCESSES FROM LIGNOCELLULOSIC BIOMASS USING HETEROGENEOUS CATALYSTS

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Abstract
Through this document, it was possible to analyze the main characteristics of the volume of scientific production related to the study of the variables Biofuels, Biomass, Production Processes and Heterogeneous Catalysts. A bibliometric analysis was proposed to analyze the details such as Year of Publication, Country of Origin of the publication, Area of Knowledge in which the published research is carried out and the Type of Publication most frequently used by the authors of each document published in high-impact journals indexed in the Scopus database during the period between 2018 and 2023. Among the main findings, it was possible to determine that, for the execution of the different research methodologies, the report of 143 scientific documents related to the study of the aforementioned variables was achieved. The maximum number of publications made in a year was 35 documents submitted in 2023. The country of origin of the institutions that reported the highest number of records in Scopus was India with 41 documents. The area of knowledge with the greatest influence when executing the research projects that resulted in scientific publications was Energy, which contributed great theoretical material in a total of 69 publications. Finally, the type of publication most frequently used to present findings from the analysis of the aforementioned variables was the Journal Article, which represented 50% of the total scientific production.
Keywords: Biofuels, Biomass, Production Processes, Heterogeneous Catalysts

1. Introduction

The growing awareness of environmental problems, arising from the development and strengthening of environmental legislation, has driven the use of biomass as a source of energy in general, and of biofuels. The current production of biodiesel and bioethanol is based on oilseed feedstocks, this fact has presented several debates about sustainability. . (Gorter H., 2013)

Currently, most of the energy consumed in the world comes from oil, natural gas and coal, which comes from fossil sources, which apart from being non-renewable resources, have an unequal geographical distribution. Likewise, environmental problems such as global warming, air pollution and water sources caused by the gases that come from their combustion and the increase in energy demand in the last decade by industrialized countries have encouraged society's interest in the search for alternative sources of energy through the integration of sustainable technologies based on renewable resources. Among these alternatives, emphasis is placed on the use of biomass.

lignocellulosic biomass, which is considered a renewable raw material with greater potential in obtaining biofuels and synthesis of molecules for industrial application, is not a viable economic raw material to compete with fuels from fossil resources, mainly due to the move away from a low-income technology that overcomes scientific and engineering challenges that guarantee its economic viability. (Gómez E.A., 2013)

The current biorefinery considers that biomass in its different classes can be transformed not only through biological processes, but that it is necessary to integrate other thermochemical technologies in which we find heterogeneous catalysis, this variable allows many chemical

and energy molecules to be represented more effectively in new processes and reduce the environmental impact.

In this context, the availability of lignocellulosic biomass from agro-industrial and forestry waste and energy crops represents enormous potential for the development and implementation of renewable green technologies, thus contributing to minimising the links of dependence on fuels and chemical products that come from the extraction of fossil materials, as well as guaranteeing energy security in the future.

Finally, we will analyze the integration of heterogeneous catalysis to the concept of the transformation of agro-industrial resources for the formation of lignocellulosic biomass, this with the aim of being able to generate biofuels, energy and chemical products through a much more efficient and environmentally friendly process. For this reason, this article seeks to describe the main characteristics of the compendium of publications indexed in the Scopus database related to the variables Biofuels, Biomass, Production Processes and Heterogeneous Catalysts, as well. Such as the description of the position of certain authors affiliated with institutions, during the period between 2013-2023.

2. General objective

To analyze, from a bibliometric approach, the characteristics in the volume of scientific production related to the variables Biofuels, Biomass, Production Processes and Heterogeneous Catalysts, recorded in Scopus during the period 2017-2022.

3. Methodology

This article is carried out through a mixed orientation research that combines the quantitative and qualitative method.

On the one hand, a quantitative analysis of the information selected in Scopus is carried out under a bibliometric approach of the scientific production corresponding to the study of the variables Biofuels, Biomass, Production Processes and Heterogeneous Catalysts.

On the other hand, examples of some research works published in the area of study indicated above are analyzed from a qualitative perspective, based on a bibliographic approach that allows describing the position of different authors regarding the proposed topic.

It is important to note that the entire search was carried out through Scopus, managing to establish the parameters referenced in *Figure 1*.

3.1 Methodological design

Figure 1. *Methodological design*
Source: Own elaboration

3.1.1 Phase 1: Data Gathering

Data collection was carried out from the Search tool on the Scopus website, where 143 publications were obtained from the choice of the following filters:

TITLE-ABS-KEY (biofuels, AND biomass, AND production AND processes, AND heterogeneous AND catalysts) AND PUBYEAR > 2017 AND PUBYEAR < 2024

- Published documents whose study variables are related to the study of the variables Biofuels, Biomass, Production Processes and Heterogeneous Catalysts
- Works published in journals indexed in Scopus during the period 2017-2022.
- No distinction by country of origin
- Without distinction in areas of knowledge.
- Without distinction of type of publication.

3.1.2 Phase 2: Construction of analysis material

The information collected in Scopus during the previous phase is organized and then classified by graphs, figures and tables as follows:

- Co-occurrence of Words.
- Year of publication.
- Country of origin of the publication.
- Area of knowledge.
- Type of publication.

3.1.3 Phase 3: Drafting of the conclusions and final document

In this phase, the analysis of the results previously yielded is carried out, resulting in the determination of conclusions and, consequently, the obtaining of the final document.

4. Results

4.1 Word co-occurrence

Figure 2 shows the co-occurrence of keywords found in the publications identified in the Scopus database.

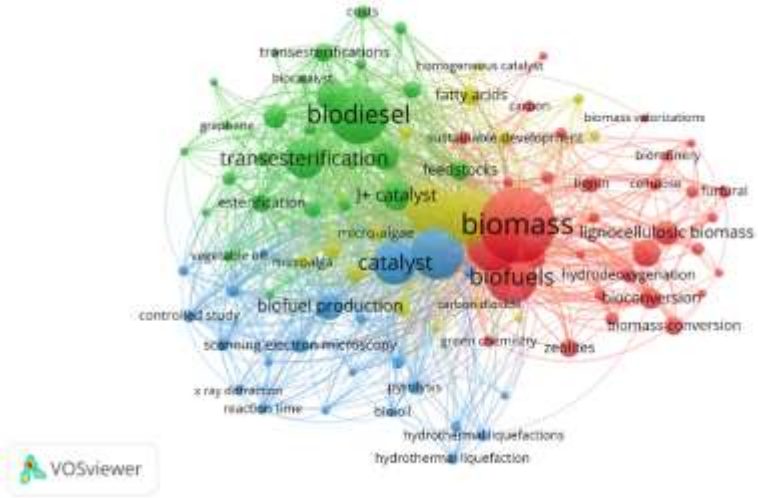

Figure 2. *Word co-occurrence*

Source: Own elaboration (2024); based on data exported from Scopus.

Biomass was the keyword most frequently used within the studies identified through the execution of Phase 1 of the Methodological Design proposed for the development of this article. Catalysis is among the most frequently used variables, associated with variables such as Biodiesel, Lignocellulosic Biomass, Energy Catalysts, Sustainable Development, Energy Transformation, Homogenic Catalysts. Of the above, it is noteworthy that among the renewable energy options, biomass has been considered as an alternative to reduce the use of fossil fuels due to its energy content and the technological possibility of its transformation into fuels, which allows it to be used for several industrial sectors.

The term biomass groups all components of organic origin that are available on a renewable basis. This availability includes waste of animal and vegetable origin, types of crops and organic waste from industrial processes. Biomass as a raw material is lignocellulosic biomass which is made up of organic matter, one of its characteristics is that it constitutes a source of

renewable energy, greater availability and low cost, allowing to obtain biofuels, bioenergy and biomolecules of added value.

4.2 Distribution of scientific production by year of publication

Figure 3 shows how scientific production is distributed according to the year of publication.

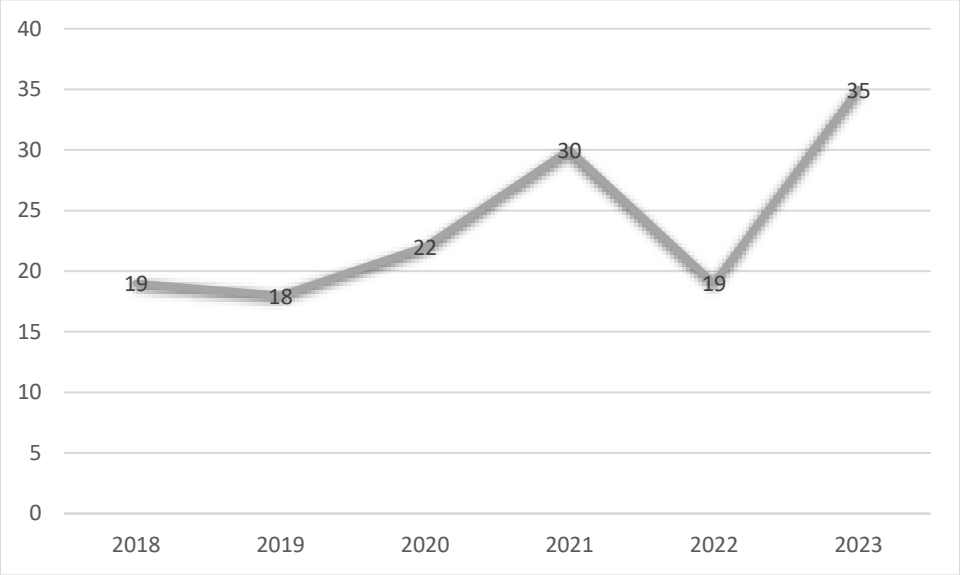

Figure 3. *Distribution of scientific production by year of publication.*

Source: Own elaboration (2024); based on data exported from Scopus

Among the main characteristics evidenced by the distribution of scientific production by year of publication, an increase in the number of publications registered in Scopus during the years 2023 is notorious, reaching a total of 35 documents published in journals indexed on this platform. This can be explained thanks to articles such as the one entitled "Process optimization and kinetic studies of biodiesel production catalyzed by Musa glauca." In this study, a new biomass catalyst was developed from Musa glauca stem ash as a clean catalyst for biodiesel production. For the first time, the potential of calcined ash from the stem of Musa glauca as a heterogeneous catalyst for biodiesel production using soybean oil as feedstock was investigated. The activity of both burned and calcined Musa glauca catalysts in transesterification was studied. Calcination increased catalytic activity more than open burning. The catalyst obtained by calcining the stem of Musa glauca at 500 °C was used as the optimal catalyst. This catalyst was comprehensively characterized using the FT-IR, XRD, XPS, XRF, SEM, and BET surface area analyzer. Biodiesel production was optimized through response surface methodology (RSM) studies. A maximum of 96.7 % biodiesel was produced using optimal reaction conditions of methanol to soybean molar ratio of 24:1, catalyst loading of 8 % by weight (with respect to soybean oil) for 3 h at room temperature. The biodiesel produced was analyzed using nuclear magnetic resonance imaging (NMR) and gas chromatography (GC) studies. The catalyst was reused and showed satisfactory reuse producing 80% biodiesel in the fifth reaction cycle. From the kinetic study, it was determined that the activation energy of the reaction was 27.71 kJ mol-1.(Saikia, 2023)

4.3 Distribution of scientific production by country of origin.

Figure 4 shows how scientific production is distributed according to the nationality of the authors.

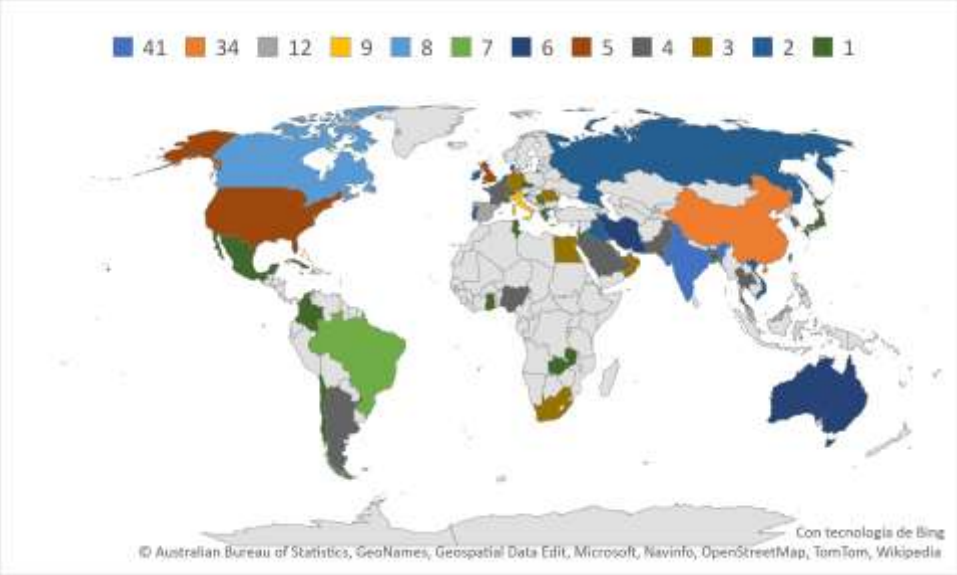

Figure 4. *Distribution of scientific production by country of origin.*
Source: Authors' elaboration (2024); based on data provided by Scopus.

Within the distribution of scientific production by country of origin, records from institutions were taken into account, establishing India as the country of that community, with the highest number of publications indexed in Scopus during the period 2018-2023, with a total of 41 publications in total. In second place, China with 34 scientific papers, and Malaysia taking third place presenting to the scientific community, with a total of 12 papers among which is the paper entitled "Synthesis and application of barium tin oxide reduced graphene oxide nanocomposites as a highly stable heterogeneous catalyst for biodiesel production" This research provided a simple approach to synthesize barium tin oxide (BTO) and its Reduced graphene oxide (RGrO) decoration to manufacture BTO@RGrO as an efficient catalyst in the production process of biodiesel from waste cooking oil (WCO). The BTO and BTO@RGrO prepared nanocomposites were characterized by Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDX), BET (Brunauer, Emmett and Teller), temperature-programmed desorption. of NH3/CO2 (NH3/CO2-TPD), and power X-ray diffraction (XRD). The response surface methodology (RSM) based on central composition designs (CCD) was employed to optimize influencing factors, including reaction temperature (40–90 °C), reaction duration (10–50 min), catalyst amount (1–5 % by weight).), and molar ratio of methanol to oil (MeOH/Oil) (5-25). The optimal yield of the generated biodiesel was acquired on the nanocomposite BTO@RGrO at a reaction temperature of 68.83 °C, a reaction duration of 27.95 min, a catalyst amount of 3.21% by weight and a MeOH/Oil molar ratio of 14.93, which led to the generation of biodiesel. with a purity of 97.03%.(Safaripour, 2023)

4.4 Distribution of scientific production by area of knowledge

Figure 5 shows the distribution of the preparation of scientific publications based on the area of knowledge through which the different research methodologies are implemented.

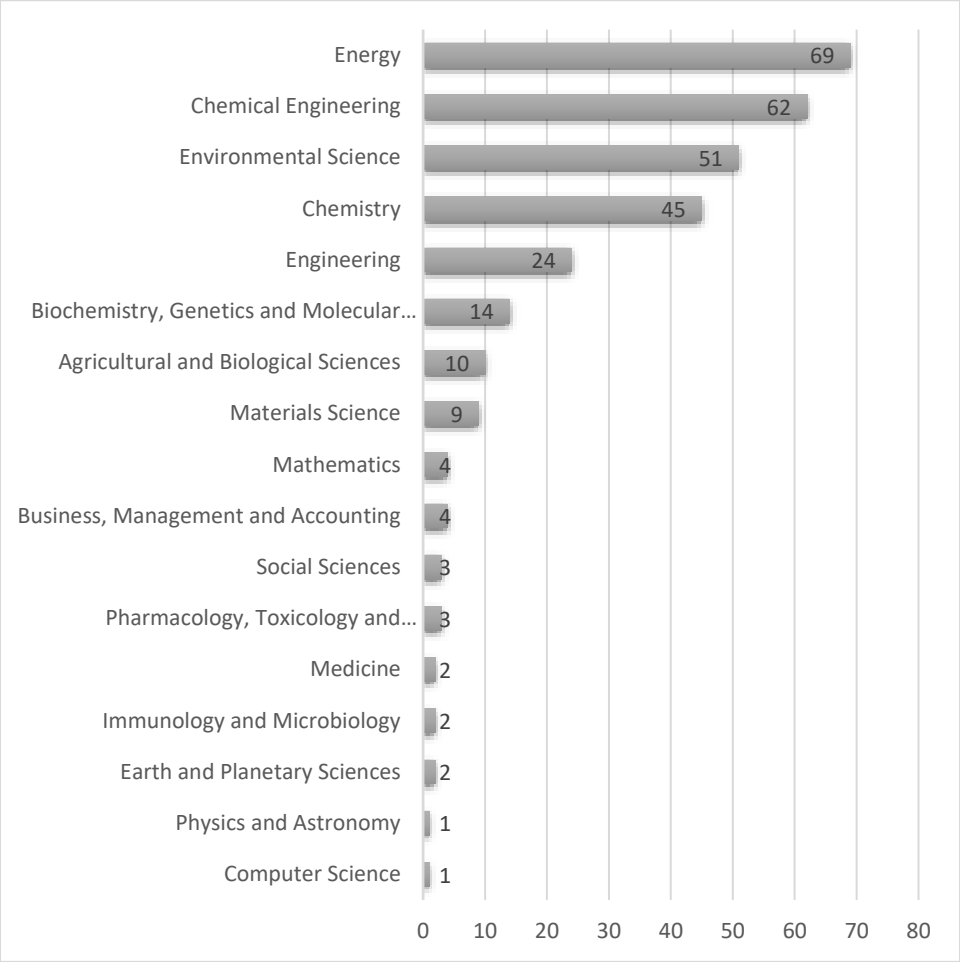

Figure 5. *Distribution of scientific production by area of knowledge.*
Source: Authors' elaboration (2024); based on data provided by Scopus.

Energy was the area of knowledge with the highest number of publications registered in Scopus with a total of 69 documents that have based its methodology Biofuels, Biomass, Production Processes and Heterogeneous Catalysts. In second place, Energy Chemistry with 62 articles and Environmental Sciences in third place with 51. The above can be explained thanks to the contribution and study of different branches, the article with the greatest impact was registered by Energía entitled "Confinement of redox active metal sites in acidic porous scaffolds for the catalytic transformation of lignin-derived phenols in naphthenes" In this document, we present a porous metal silicate (PMS) material, PMS-36, consisting of metallic nickel and Lewis acid AlIII sites within the pores, demonstrating high efficiency in catalyzing the hydrodeoxygenation transformation of guaiacol under mild conditions. PMS-36 also exhibits robust stability, which can be attributed to the strong interaction and charge transfer between the Lewis acid sites of metallic Ni and AlIII within the confined pores. This study shows the importance of synergistic and confinement effects in the development of stable, high-performance heterogeneous catalysts for the chemical transformation of biomass and its derivatives.(Li, 2023)

4.5 Type of publication

In the following graph, you will see the distribution of the bibliographic find according to the type of publication made by each of the authors found in Scopus.

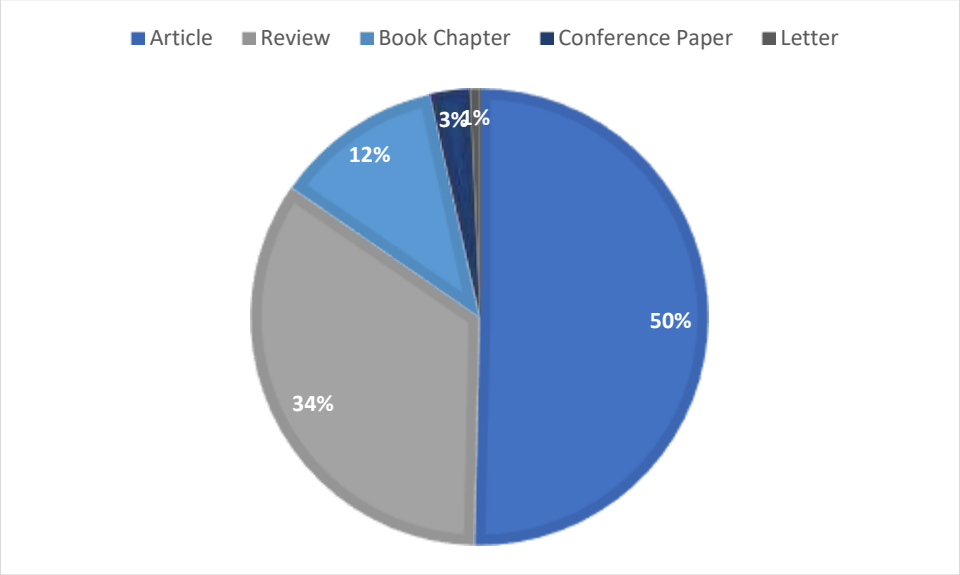

Figure 6. *Type of publication.*
Fountain: Own elaboration (2024); based on data provided by Scopus.

The type of publication most frequently used by the researchers referenced in the body of this document was the Journal Article with 50% of the total production identified for analysis, followed by Journal with 34%. Book Chapter are part of this classification, representing 12% of the research papers published during the period 2018-2023, in journals indexed in Scopus. In the latter category, the one entitled "Production of butyl levulinate from high-gravity fructose solvolysis on a heterogeneous catalyst: in-depth kinetic modeling" stands out. Butyl levulinate (BL) is a biofuel and a promising additive for oxygenated fuels. Among the various ways to produce this ester, the alkolysis of simple sugars has more advantages than the traditional esterification of levulinic acid, as it requires fewer processing units in post-treatment operations, making it more sustainable in terms of cost, even on a large scale. industrial scale. In this study, the solvololysis of fructose to butyl levulinate in a solid acid catalyst, Amberlite IR120, was experimentally investigated at high initial concentrations, and different kinetic models were developed, including the kinetics of fructose dissolution and degradation, tested and validated at different initial levels. fructose concentrations, temperatures, and catalyst loads. The Akaike information criterion and the booking method evaluated the most reliable model developed.(Di Menno Di Bucchianico, 2023)

5. Conclusions

Through the bibliometric analysis carried out in this research work, it was possible to establish that India was the country with the highest number of published records for the variables Biofuels, Biomass, Production Processes and Heterogeneous Catalysts. With a total of 41 publications in the Scopus database. In the same way, it was possible to establish that the application of theories framed in the area of Energy, The advances that are obtained in the coming years, in the development of alternative fuels through renewable resources, both in the basic aspects for their production and in industrial development, are essential to achieve the objectives of reducing the environmental and energy impact set by industries at a global level. Based on this context, the conversion of lignocellulosic biomass through the incorporation of heterogeneous catalysis turns out to be more environmentally friendly, reducing its impact on ecosystems and allowing the use of green technologies.

Heterogeneous catalysis contributes to an alternative to achieve biomass in a more comprehensive and efficient way towards value-added products derived from non-renewable resources. Both the refining of biomass into biochemical products, which allows different levels to be obtained, and the direct thermochemical transformation are observed today with

heterogeneous catalysis, which allows biofuels, clean energy, food additives, materials and the production of chemical products to be obtained.

It is necessary to state that heterogeneous catalysis allows to increase the transformation of biomass-derived products compared to new processing lines based on microorganisms. However, there are still a number of challenges, as problems such as the poor stability of the catalysts, or variations in the composition of the process feed, pose a major drawback to their establishment on an industrial scale. Overcoming these challenges is critical to optimize production processes and reform heterogeneous catalysis as a viable and efficient alternative fuel for the production of biofuels from lignocellulosic biomass.

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