Bibliometric Analysis of Publications Related to the Production of Furfural from Lignocellulosic Biomass in the Period 2015-2021

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Abstract

The objective of this research article is to present the results of the literature review of furfural production, to determine the optimal production conditions, potential uses and relevance for the scientific community between 2016 to 2021. To analyze the problem, 2-time horizons were defined, from 2015 - 2018 and 2019 - 2021 with which a systematic mapping was performed. For the results and discussion of the findings, the 11 most relevant articles of the total collected were chosen, considering the number of citations per article and their percentile of prominence from databases such as Scopus and Web of Science. Then, the VOSviewer software was used to generate the co-occurrence network of the topics present to visualize the most relevant keywords for each year and in each database. Finally, the research work is concluded by commenting on the scope of furfural use in industries, the raw materials with the highest pentose content and the development of improvements in production to optimize furfural yield.

Keywords

Furfural industry, Systemic mapping, Xylose, Pentose.

1. Introduction

Currently in Peru, agriculture is registered as one of the most important sectors, since it represents 6% of the country's GDP. since it represents 6% of the country's GDP. However, when carrying out the activity, it triggers a grat negative environmental impact due to solid waste that is left as a waste without a clear destination.

Additionally, oil reserves are forecast to be deplet by the 2040s due to the world's high energy demand (Vazques, 2019). Therefore, it is of vital importance to find substitutes for fossil fuels that have similar characteristics, uses and functions to those derived from it without the polluting factor that possesses. Thus, several researches have been developed around the world considering agricultural crop residues as raw material due to their renewable characteristics and high production volume, with the only goal of developing eco-friendly alternatives to the products coming from oil refineries.

According to INEI (2019) data, the largests impacts generated by the misuse of biomass residues from agriculture and industry are as follows:

- Solid waste derived from the production of products with agronomic elements as raw material.
- Atmospheric pollution from agricultural burning for energy production.
- Agrochemical residues (fertilizers and pesticides).

Due to the problems mentioned above, it was decided to reuse natural waste to obtain great benefits and to be able to take advantage of this product. Specifically, this research paper has as main objective to determine the optimal conditions for furfural production through a comparative analysis. In addition, it will describe the impact generated by the agricultural industry and the raw materials to be used for the elaboration of the compound.

1.1 Objectives

Determine the optimal conditions for furfural production based on the description of the properties and characteristics of the sugarcane plant, using information search strategies and tools to establish a relevant theoretical framework for comparision of the percentage of furfural production efectiveness as a result of the analysis of research conducted in the Scopus and Web of Science (WOS) database.

2. Literature Review

Furfural can be defined as a heterocyclic structure and the simplest aldehyde from furan. Also, it has the characteristics of being a colorless fluid with a boiling point of 161.7°C, density higher than water (d=1.15) and a solubility of 8.3% in water. Although it is not very known, according to Garcia - Rodrigues (2015), it has several uses such as: production of medicines, furan production, furfuryl alcohol production, bioethanol, insecticides, pesticides and chemical industry.

In order to obtain furfural, it is essential that the main component to be used has a high presence of D-xylose, which is a type of pentose very abundant in nature in the form of polymers with the five carbon atoms in chain, and which will define the orientation on the level of yield that can be obtained in the production of furfural according to the type of procedure applied, as shown in the equations below 1, 2 y 3.

Pentosan hydrolisis

$$(C_5H_8O_4)_n + nH_2O \rightarrow nC_5H_{10}O_5 \quad (1)$$

Pentosan dehydration

$$C_5H_8O_5 - 3H_2O \rightarrow C_5H_4O_2 \quad (2)$$

Global reaction

$$I_F = I_B = -I_C = A^2 I_{A1} + AI_{A2} + I_{A0}$$
$$(C_5H_8O_4)_n - 2H_2O \rightarrow C_5H_4O_2 \quad (3)$$

Inventio Magazine (Leticia Montes et al., 2018), carried out and investigation on how to obtain furfural with the use of 20% sulfuric acid, a temperature not higher than 130°C and constant monitoring by UV-vis spectrophotometry applied to the ATEMEX-9640 variety (sugarcane bagasse), reaching an optimum concentration of furfural according to the raw material. This research can be complemented by the findings of Yan Jin y Zhengjun Shi (et al.,2020), who found that applying a pretreatment to acid hydrolysis production leads to an improvement in the hydrophilic nature and enzymatic accessibility, which increases the maximum furfural yields by 1,3 times. However, in Ecuador (García et al., 2017), a comparative research was conducted to obtain this by using a simple distillation applying reagents such as dinitrophenylhydrazine and aniline in acetic medium. This analysis concluded that corn stover, as shown in Figure 1, has a higher yield of about 30% to 32% over sugarcane bagasse and rice husks.

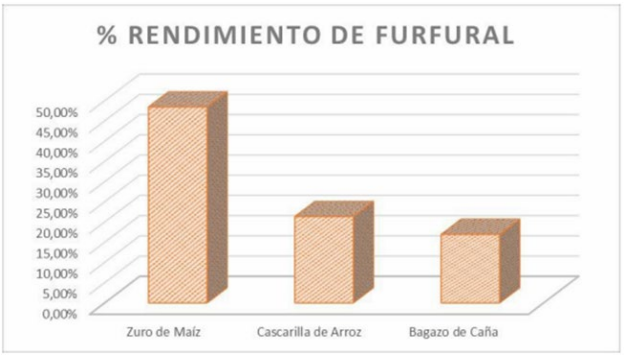

Figure 1. % Yield of furfural, Montes, L. (2019)

The Cuban Research Institute of Sugarcane Derivates published an article detailing the importance of sugarcane in the industry as a substitute of fossil compounds, helping to make more and more discoveries about the production methodologies and elements to be used (Gomez-Estevez et al., 2020).

According to an studio made by the doctor Maireles-Torres (2016) about biofuels production; details the most important catalytic transformations in the elaboration of furfural, a compound called “platform molecule” because it is a chemical intermediate in a wide spectrum of uses in the so-called lignocellulosic biorefinery. This is highly intriguing because it supplies an eco-friendly alternative to fuels with the use of biomass as feedstock instead of petroleum (Souza et al.,2020). Even so, not everything points to be only benefits, because, he points out that biorefineries based on furfural require large investments, since, being a relatively new study in the sector, there are technological risks that may arise from the transition from the use of oil to biomass.

In the last decade, there has been an increase in the use of alternative energy sources to replace the use of oil and its derivatives. In addition, both companies and communities themselves try to reduce the waste generated by their daily activities, work and food. In a recent investigation, it was found that Uruguay, being one of the countries with the highest rice production, has as a consequence a large amount of husk waste, causing great solid contamination (Bariani et al., 2017). This led to research being carried out to obtain furfural, reducing the level of environmental impact generated by agricultural activity and producing a compound with great benefits for the industry.

3. Methods

The research conducted is non-experimental, due to the evaluation of the literature, collection of information and subsequent assessment of the impact and importance of the topic to be addressed. It presents an interpretative paradigm because it intends to develop the concepts related to the production of furfural, with the establishment of a conceptual framework integrating the social and cultural reality for the explanation of the factors to be studied. In addition, it has a qualitative approach, which aims to present the results of the systematic literature review, with the objective of establishing the importance of the potential uses that can be developed in the country. It is exploratory and descriptive

in scope, because it covers the general information regarding the production of furfuraldehyde and the detailed analysis of the dimensions present in the study.

This article was based on a longitudinal (evolutionary) non-experimental research design since the articles reviewed, are in a range of years from 2015 to the present. In addition, a comparison was made with this data collection with respect to our variables.

The strategy used for the scientific literature review is based on obtaining secondary information from scientific research articles published in journals registered in Scopus, L.A. Reference, Scimago, DIALNET, Google Scholar, Web of Science (WOS) and INEI data. The methodology begins with the definition of the research topic; subsequently, the requirements for the selection of articles and the bibliographic analysis are established. Finally, the conclusions drawn from the analysis of the research work are developed.

4. Results and Discussion

4.1 Analysis of Results

From the bibliographic review of the procurement of furfural, according to Table 1, approximately 191 articles indexed to journals found in Latin American databases between 2015 and 2018 were detected. From the results, it is detected that research related to furfural is found with a low rate of publications compared to other similar topics in the use of biomass as feedstock. From 2016 onwards, a peak in the number of publications is detected, being this year the year with the highest number within the first research horizon.

Table 1. Investigations per year on the first horizont

Year	Number of published investigations
2015	38
2016	53
2017	50
2018	50
Total	191

On the other hand, for the second horizon, which is detailed in Table 2, approximately 70 scientific articles in the Spanish language were detected. This result was provided in the range of years from 2019 to 2021; this was obtained due to the search of databases in a Latin American context since we wanted it to be as similar as possible to the context in which we live.

Table 2: Investigations per year on the second horizont

Year	Number of published investigations
2019	44
2020	19
2021	7
Total	70

This subsection presents the countries in which the most research is being conducted on the furfural issue, corresponding to both study horizons, with a total of 261 projects identified in the scientific literature. From the results shown below in Figure 2, it can be seen that the amount of investigations made by Brazil (131) greatly exceeds those carried out by the other countries. It was found that the number of research studies carried out by Peru reached 5 publications of articles with a thematic focus on furfuraldehyde. This reveals the level of importance given to scientific research in each country, as well as the level of development of the industry in each nation. Hence the importance of encouraging scientific research and promoting industrial development in the country.

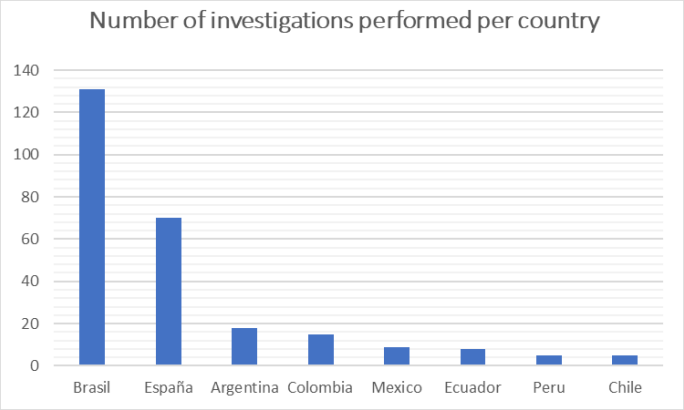

Figure 2. Number of investigations performed per country

From the bibliographic review, authors, prominence percentile, quartile and number of citations are recognized in Table 3. The prominence measures the current importance of the research topic, taking into account the impact of the journals and the article in various databases. To detect these data, the Scimago source was used, which has a database of international journals of various categories. Of the research articles reviewed, the eleven most relevant from different countries and subcategories were selected. Yan Jin (et al.,2020) presents an experimentation applying the improvement of the hydrolysis process by combining an alkaline pretreatment and hydroxymethylation post-treatment to improve the hydrophilic nature of the compound, facilitating the yield of glucose. In a second research by de Souza (et al.,2020), they tell us about the production of biofuel through the liquid phase hydrodeoxygenation of furfural over a bifunctional catalyst Ru / RuOx / C in the presence of a direct source of H2, which allows us to know one of the scopes of furfural in the production of sustainable alternative energies.

Table 3: Most important articles in the research

Title	**Magazine**	**Q**	**Índice H**	**N° citations**	**Year**	**Percentile**
Furfural production from sugarcane bagasse along with co-production of ethanol from furfural residues (Ntimbani, et al., 2021)	Biomass Conversion And Biorefinery	Q2	27	2	2021	0,593
Furfural Derivatives as Fuel Components (Nikul'shin, et al., 2020)	Chemistry And Technology Of Fuels And Oils	Q3	15	1	2020	0,183
Furfural: a renewable and versatile platform molecule for the synthesis of chemicals and fuels (Mariscal, et al., 2016)	Energy & Environmental Science	Q1	343	681	2016	14,49
Rice husk as renewable energy for biogas production from biomass: prospect and challenges (Ayudya, et al., 2020)	E3S Web of Conferences	-	22	120	2020	0,203

Compostaje de bagazo de caña de azúcar a escala comercial: cinética de decaimiento de materia orgánica, metagenómica y capacidades bacterianas para la promoción del crecimiento de plantas (Velásquez Fernándes, 2020)	Revista internacional de contaminación ambiental	Q4	19	180	2020	0,19
A stepwise pretreatment of sugarcane bagasse by alkaline and hydroxymethyl reagent for bioethanol production (Yan Jin, et al., 2020)	Industrial Crops And Products	Q1	129	6	2020	1,066
Preparation of furfural and reaction kinetics of xylose dehydration to furfural in high-temperature water (De-Run, et al., 2016)	Petroleum Science	Q2	31	16	2016	0,679

4.2 Graphics of Results

In order to have a more complete analysis of the articles and databases used for the research carried out, with the help of the VOSviewer software, it allows us to visualize through a bibliometric network a relationship between authors, year of publication and keywords of the Web Of Science (WOS) and Scopus databases.

Regarding the WOS articles in Figure 3, 150 articles and researches were chosen to perform the co-occurrence analysis between the years 2015 and 2021; likewise, the same procedure was done in Figure 4 for the Scopus base.

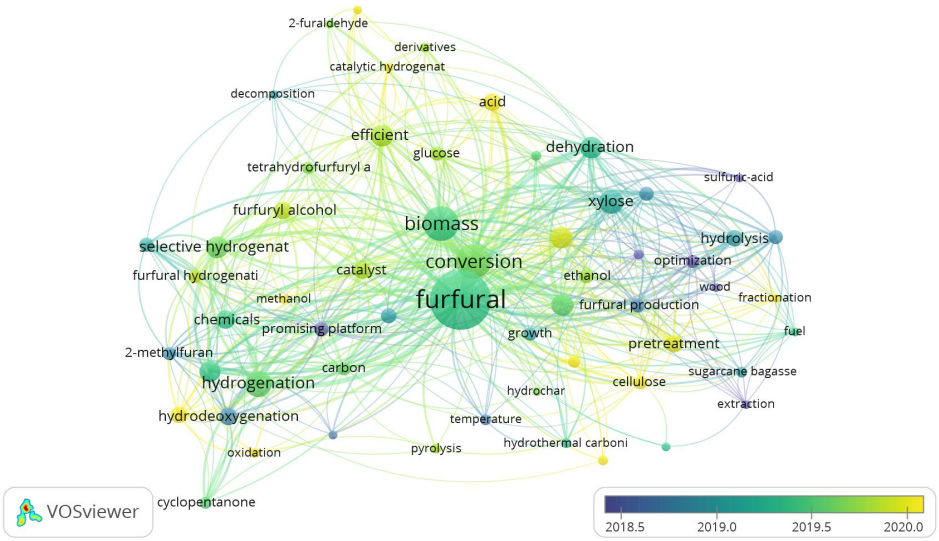

Figure 3. Web of Science database bibliometric network

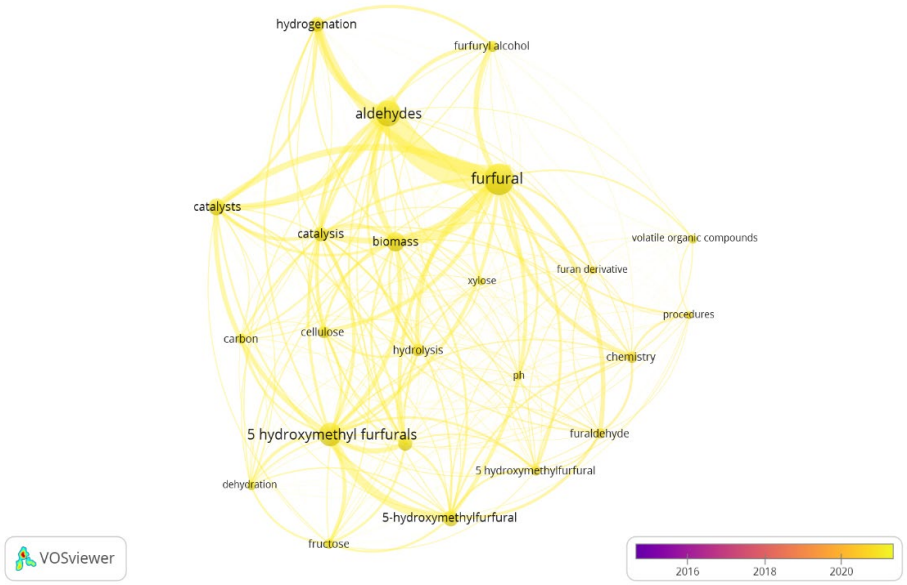

Figure 4. Scopus database bibliometric Network

The articles investigated dealt with the various methods to obtain furfural with different raw materials, and also lay the foundations of the benefits that the use of furfural as a platform product can bring to obtain various products; among the most outstanding ones, biofuel (Mariscal et al., 2016).

The articles found within the first horizon of study demonstrate their concern for the environment and the interest in finding eco-friendly alternatives that can help in a potential energy crisis in case the oil industry is affected in the future. In addition, they establish the uses of furfural, emphasizing the reduction of greenhouse gas pollution and the use of organic waste from the agricultural industry.

However, although their experiments were highly successful in determining the best process for obtaining furfural (acid hydrolysis) and the raw material with the highest xylose value, their scope is limited, since they do not go beyond their discoveries and the benefit of reducing environmental impacts.

On the other hand, for the range of years from 2019 to 2021, a concern for the current environmental context is also observed. However, there is a shift with respect to the production of furfuraldehyde. In this interval, it focuses on improving the process for obtaining this product, such as changing the raw material, different types of acid as a catalyst, the number of processes for treatment, among others. The research is progressively being carried out because they not only see furfural as a use for the chemical and pharmaceutical industry, etc., but also explore the world of biofuels, opting for a more environmentally friendly and lower cost solution (Ntimbani et al., 2021).

5. Conclusion

From the bibliographic review and the exhaustive analysis of scientific research of the highest category quartiles, it can be seen that obtaining furfural has been a topic with little relevance in recent years compared to other research on biofuels. However, its importance and industrial value has led to the development of more and more projects, since it is a platform product on which many valuable products can be produced in different industries.

The production of furfural is a potential focus of opportunities to optimize the performance of companies. Its value is centered on its versatility of benefits, reduction of environmental impact as it is a product derived from the treatment of residual biomass and a substitute for petroleum derivatives, improving the performance of the activities to be employed.

From the articles reviewed, it is concluded that the interest in developing products that can substitute petroleum and its derivatives is a latent and continuous theme. The aim is to optimize the production of furfural with alternative processes and various catalysts in order to develop the best way to obtain this compound and use it to solve the current energy problem.

According to what was reviewed with the use of tools such as Vosviewer and databases such as Scopus and Web of Science, the articles with the characteristic of quartile 1 had a greater informative value for the development of the research. Because they used data, keywords and metrics that could be aligned with the proposed objectives.

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