Life Cycle Assessment in The Wine Industry – A Bibliometric Analysis

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Abstract

This article presents a bibliometric review of life cycle analysis in the wine industry, focusing only on the ten most critical grape-based beverages. A consultation was carried out in databases such as Scopus, Web of Science, Dimensions, Sciencedirect, from which only 121 scientific articles from all databases were analyzed, discarding other types of documents. The analysis was performed using the VOSviewer software. The results indicate that four countries generate approximately 50% of the wine produced globally: Italy, France, Spain, and the United States of America. In addition, the authors with the highest number of documents and citations from 2000 to 2020 were identified, highlighting Feijoo G. with the highest number of documents and Vázquez Rowe I. with the highest number of citations. The journals that most publish topics on LCA to viticultural processes are the Journal of Cleaner Production and the International Journal of Life Cycle Assessment; the most important topics regarding LCA are environmental science, energy and engineering; the most cited countries are Italy, Spain and Luxembourg; and the most productive countries are Italy, Spain and USA.

Keywords
LCA, Viticulture, Environmental impact, Production process.

1. Introduction
LCA (life cycle analysis) is methodology companies use to identify and quantify the environmental impacts generated during the transformation of their raw material into a marketable product (Salvador et al., 2021). In LCA, waste and the amount of energy required are examined, allowing companies to gain a holistic view of all stages of the

manufacturing process, both internal and external. This scenario is because some materials are sent out of the industry, assuming that this solves the problem. However, this is not the case because the use these materials receive until they degrade is considered a result of the transformation. Therefore, LCA is a study that aims to bring all these factors together and produce impact statistics (Usón, Usón, & Bribián, 2010). In conclusion, LCA focuses on applying environmental management, and its main objective is to comprehensively analyze the environmental impact of a manufacturing process from start to finish (Leiva, 2016).

The alcoholic beverage industry has extensively used life cycle analysis (LCA) because the manufacturing process requires several stages, demonstrated by the increasing number of publications annually. They start from land preparation for cultivation, the ripening, and the grapes' maintenance stage, to the point where the bottles are delivered to the customers. The application of LCA provides a perspective of the environmental impact it generates from start to finish.

Some studies on LCA in wine have found significant findings. For example, Requena et al. (2008) point out the importance of growing grapes; however, they then ask about the extraction, processing, bottling, and transportation method. These questions are because each of these processes generates an environmental impact and can be carried out in different ways, so it is necessary to know them and choose the most environmentally friendly one.

1.1 LCA regulatory standards

The LCA allows environmental management of the production process and requires monitoring the established standards and implementing a plan to control pollutant emissions and not exceed the limits specified in the laws and national standards to avoid administrative and economic sanctions. Two standards are essential in LCA since they make known the principles that must be adopted and the requirements to execute it, which are ISO 14040:2006 (Finkbeiner, Tan, & Reginald, 2011)) and ISO 14044:2006 (Finkbeiner, 2014).

In addition to the above standards, other continuously evolving standards help industries have a better chance of success in implementing an LCA by providing tools that detail fundamentals, labels, inventories, among others. Table 1 summarizes these standards.

Table 1 LCA Standards

Norm	Approach
ISO 9000:2005, Quality Management Systems	Fundamentals and vocabulary
ISO 14001:2004, Environmental Management Systems	Requirements with guidance for use
ISO 14021, Environmental labels, and declarations	Environmental self-declarations (Type II Environmental Labelling)
ISO/TR 14047, Environmental management	Life cycle impact assessment - Examples of application of ISO 14042
ISO/TS 14048, Environmental management	LCA - Data documentation format
ISO/TR 14049, Environmental management	LCA - Examples of application of ISO 14041 to goal and scope definition and inventory analysis
ISO 14050, Environmental Management	Vocabulary

According to Figure 1, France is the country that collected the most significant amount of millions in the analyzed period with 8552 million, obtaining more than 2000 million euros than Italy, which is in second place. Similarly, a data that is important to highlight is that obtained in Spain, since only 2611 million euros income was presented, being a meager amount compared to the countries that have the first and second position, knowing that they are the primary producers and therefore surprising the amount so different from one country to another.

2. Studies on recent LCA reviews, problem, and objective

The above data indicate the importance of the wine sector, and currently, there are works in which a literature review of the application of LCA techniques in the wine and alcoholic beverage industry, in general, is carried out. For example, Rugani, Vázquez-Rowe, Benedetto, and Benetto (2013)) present a critical review of carbon footprint analysis in wine companies, indicating that only specific methodological issues are addressed from an attributional LCA perspective, ignoring aspects associated with the market, so they consider that more comprehensive studies should be

conducted in the future. Then, Pattara, Russo, Antrodicchia, and Cichelli (2017)also review carbon footprint analysis applied to the wine, olive oil, and cereal sector, focusing on their supply chain.

Arvanitoyannis, Kotsanopoulos, and Veikou (2014), in a review of the implementation of ISO 14040 in agricultural and livestock sectors, indicates that the wine sector requires to be studied concerning the emission of pollutants generated. Similarly, Morais, Teixeira, and Domingos (2016) report LCA applications in the Portuguese wine industry and propose a series of recommendations to improve production practices.

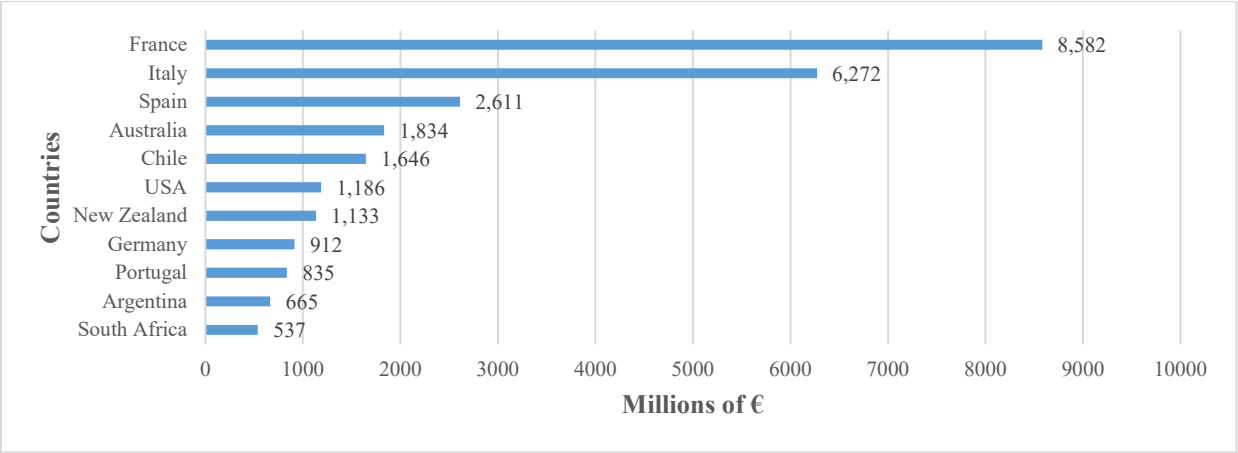

Figure 1 Income by country

Recently, Carmen Ferrara and De Feo (2018)reported a critical analysis of the application of LCA in the wine industry, analyzing the types of impacts analyzed in the different activities of the manufacturing process, including the agricultural, winemaking and bottling and packaging process, differentiating from conventional and organic wines.

However, all the above studies are interesting literature reviews that can complement bibliometric analyses performed with software since they do not answer questions such as the most productive, most cited, and influential authors and institution and country they are located? What is the scientific output of a country, and what are the most cited papers? What are the co-citation networks of authors in this research and the histogram regarding research in wine LCA? How are collaborative networks between researchers and research groups integrated? What is the academic productivity of authors over time?

This paper aims to answer the above questions and complement the literature reviews already reported, giving a better insight into the LCA application in the wine industry. After this introduction, section two presents the methodology followed, section three reports the results, and section four the conclusions, limitations, and future research.

3. Methods

3.1 Prisma Method

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) method is used to identify, screen, select and include articles. Figure 2 graphically illustrates the stages and activities carried out in each of the sub-stages. This methodology is chosen since it has been successfully used in other literature reviews, such as performance in manufacturing (Battesini, ten Caten, & Pacheco, 2021)and industry 4.0 (Hajoary, 2020).

A literature review is carried out in databases such as Web of Science, Scopus, and Dimensions from 2000 to 2021 (August 14). The search equation consists of searching in the title, abstract, and keywords the string "life cycle assessment" and the following words: brandy, beer, champagne, gin, and wine, since all of them are distillates from grapes. An example of a search equation is (TITLE-ABS-KEY ("life cycle assessment") AND TITLE-ABS-KEY (wine)). A CSV and a RIS file are downloaded for each of the searches associated with the types of beverages. At this stage, 206 documents were identified from both databases.

For the "Screening" sub-stage, an analysis is carried out using EndNnote V.20 software with all RIS files unified into one to identify duplicate documents, allowing 35 records to be excluded, resulting in 181 remaining items.
In the third sub-stage, the eligibility of the documents is carried out, for which exclusion criteria were used. The first criterion consisted of purging those articles that did not contain the word LCA in the title and abstract, then those that did not fit the central theme of the research were eliminated. Finally, the third criterion included only documents containing the complete text, giving 35 excluded items and leaving 146.
The other exclusion rules are applied in the fourth stage, so conference papers, books, chapters, and reviews are not analyzed, focusing on research with a deep scientific review process. In addition, the number of items in these categories was very low. In the same way, the analysis is limited only to articles published in English that had the abstract available and whose central theme was the analysis of the life cycle of one of the processes required in the production of grape-based beverages. This process allowed us to eliminate 21 documents to obtain a total of 125 final documents.

In the same way, the analysis is limited only to articles that are published in the English language, that had the abstract available and whose central theme was the analysis of the life cycle of any of the processes required in the production of grape-based beverages, which allowed eliminating other four documents, being 121 the ones that are analyzed in this report.

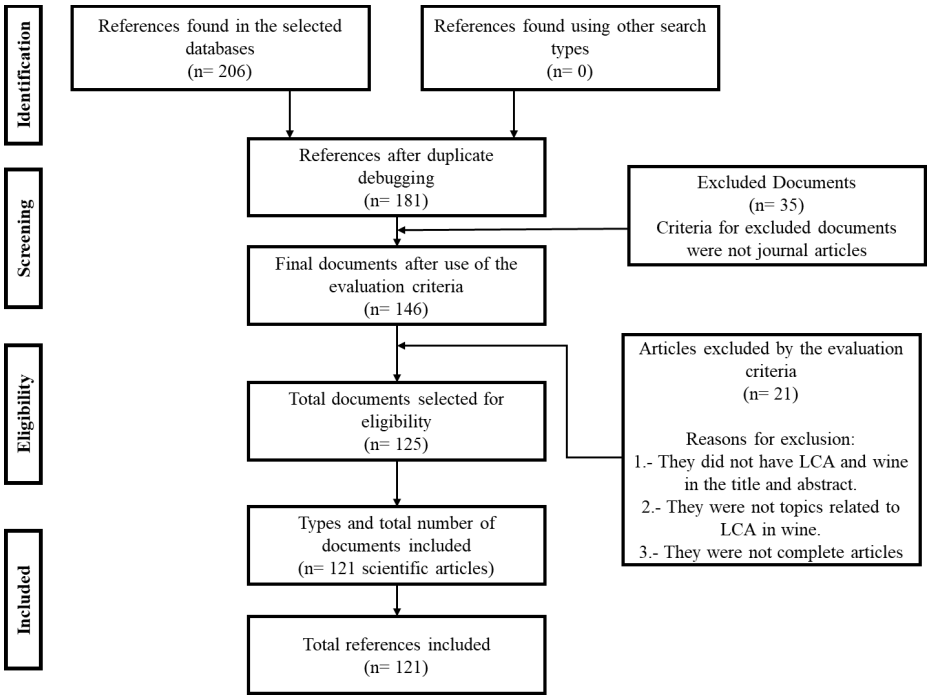

Figure 2 Prism method

3.2 Analysis of the information

The unified file in CSV extension is analyzed in the software VOSviewer v1.6.17, where it is sought to identify the following:

- The number of publications per year on LCA applied to the wine industry.
- The 15 most relevant journals were publishing on LCA in grape wine.
- Most cited or influential authors.
- Countries and institutions that publish the most on the topic
- List of co-authors analyzing the authors, their affiliations, and countries.
- Co-occurrence of all keywords, author keywords, and index words
- Citing documents, sources, authors, organizations, and countries

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It is essential to mention that to carry out the final analysis, made some thesaurus since many authors had homonyms; depending on the journal in which they published, it is possible that they used only one surname or had the full name or initials. The thesaurus aimed to unify the different names of an author into one.

4. Results and Discussion

4.1 Article published by year

The application of LCA has provided positive results with the calculations of the environmental impact within the industries of beverages derived from grapes, resulting in that day by day the authors decide to investigate further the operation. The results in different stages of the elaboration process, obtaining research papers through articles that disclose in different databases and its number tend to high, as shown in Figure 3, which shows the number of articles from 2000 to 2020.

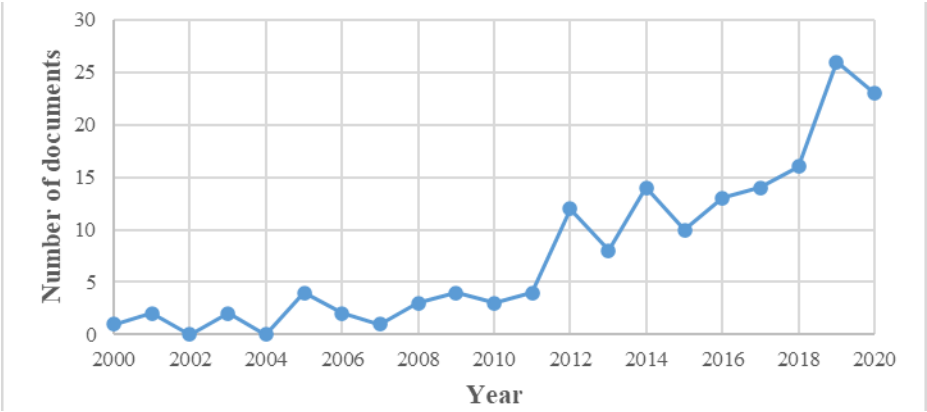

Figure 3 Articles focused on LCA

From the year 2012 appears the most significant growth in the number of publications. For example, from 2011 to 2012, there was an advance of 8 documents, giving productivity of 12, subsequently, in the following five years reflects an oscillation not greater than 5, but it is considerable. From 2017 to 2020, the most significant number of articles is in 2019, with 26 documents.

4.2 Authors who most publish on LCA in the wine sector

Other authors work on general topics of LCA. Their research papers are read by other people, to whom they are helpful to develop additional research, such as "Feijoo G" and "Vázquez - Rowe," which have a total of 11 and 10 papers, likewise more authors are working on this type of topics so according to the databases. The ten authors with the highest number of articles can be seen in Figure 4.

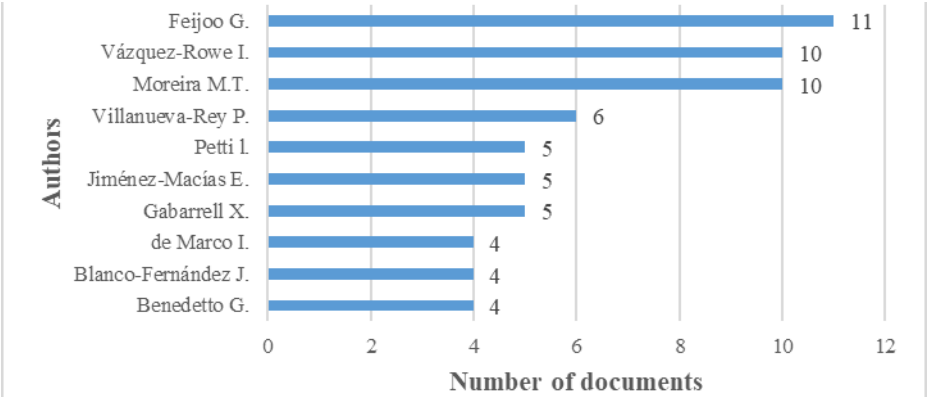

Figure 4 Articles by author

4.3 Institutions that publish the most on LCA in the wine sector

Three hundred ninety institutions publish about the LCA applied to the production of alcoholic beverages from grapes, and there are three main groups, those with 3, 2, and 1 document. The three papers are Catalan Cork Institute, University of Santiago de Compostela, and the University Of La Rioja, all in Spain. Some of the 23 institutions that have two papers published are Aalborg University (Denmark), Aimen (Spain), Arbikie Distilling LTD (United Kingdom), University of Porto and University of Aveiro (Portugal), Iowa State University (United States of America), Trinity College Dublin (Ireland), Roma Tre University (Italy), Autonomous University of Ciudad Juárez, among others.

4.4 The countries that publish the most on LCA in the wine sector

Figure 5 illustrates the number of documents by country. Thirty-nine countries were identified in which the first author or correspondent was attached. Although Spain is the country in which three of its universities have published at least three papers, at the national level, it occupies second place since the first place is occupied by Italy. In third place in the United States of America, although there is a great difference between Spain and this country about the number of articles published. In general terms, of the fifteen countries that appear in Figure 5, six are European, indicating concern for the wine sector's environmental impact.

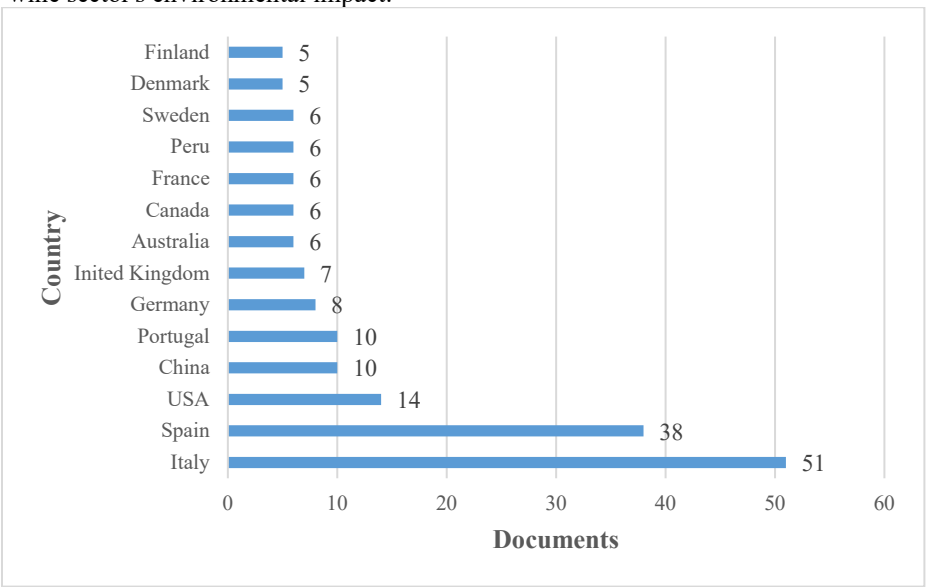

Figure 5 Top Publishing countries

4.5 Area of study and keywords

One aspect that is important to consider is the central topics on which the life cycle analysis applied to the wine industry is focused, since as can be seen in Figure 6, the main topics are those related to environmental issues, being the most relevant, since 100 of the 121 documents address them and represent 82.64%. Another topic of interest in wine LCA is the energy consumed in the production process, representing 42.97% of the publications. Finally, positions three and four are associated with business and agriculture; however, social aspects also appear in the fifth position and are related to safety at work and social responsibility.

Observe that the most important keyword in Figure 7 is the "life cycle assessment" and wine, vineyard; however, several new words are appearing, as global warning, circular economy, biomass gasification, among others and that indicates that environmental impacts are gaining importance.

4.6 Journals that publish the most about LCA in the wine sector

Many journals can find LCA articles; however, not all expose the same topics, so it is essential to know those with the most significant publications. Figure 8 shows the leading journals that publish topics associated with LCA in the wine industry, highlighting that the Journal of Cleaner Production has 37 publications, which is more than twice as many as the next one, the International Journal of Life Cycle Assessment, with only 13, which allows us to have a perspective that green and clean production is a trend.

Figure 8 shows that several environmental journals are already beginning to publish on LCA in the wine industry, not only those specialized journals. In the same way, international conferences and congresses in which wine and its environmental impact is a topic of interest are beginning to be presented.

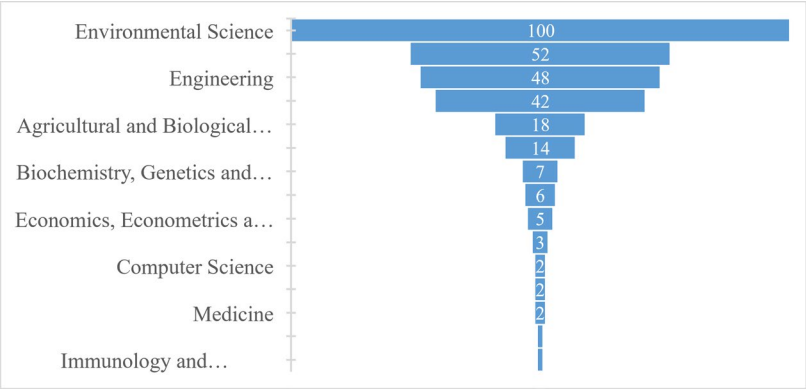

Figure 6. Main research areas

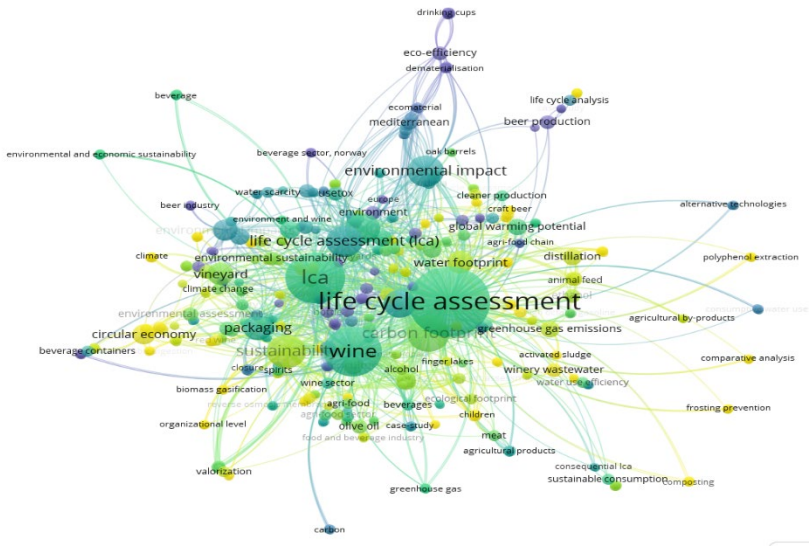

Figure 7 Keywords and their trend

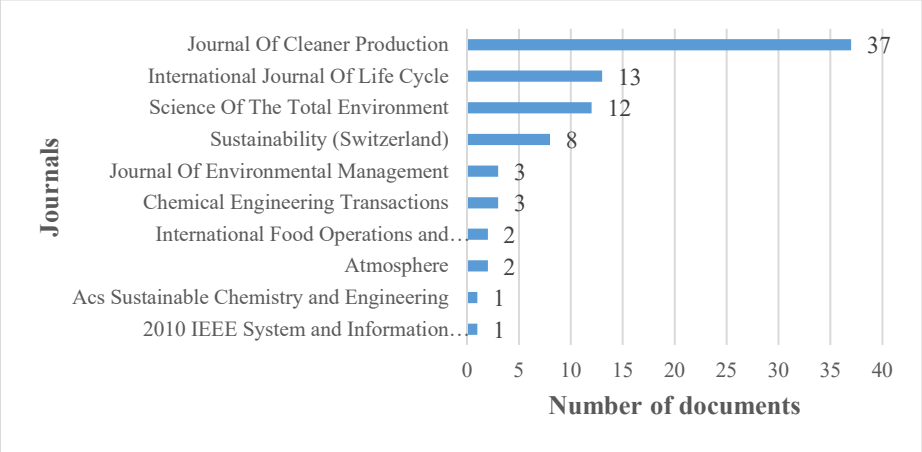

Figure 8 Source title

4.7 Most cited authors, countries, documents, and journals

4.7.1 Most cited authors

The study of LCA applied to the wine industry includes activities ranging from planting and preservation of the crop, harvesting, fermentation, packaging, and distribution (Cámara, Macías, Fernández, & Alcaraz, 2012). The first findings of the success of life cycle analysis in the wine industry are observed in the work of Schorb (2000), who estimated the environmental impact generated in a wine cellar, and three years later, B. Notarnicola, Tassielli, and Nicoletti (2003) focused only on the production process.

The works focused on a single stage of the production process were increasing because they concentrated on specific topics and provided more detailed information. Table 2 shows the papers with the highest number of citations concerning different stages of the process.

However, not all papers on LCA in the wine industry have had an equal impact, reflected in the number of citations they receive. Figure 9 illustrates the ten authors who have received the most citations in this area of knowledge and shows that "Vázquez-Rowe I" is the most cited, with a total of 519 sources. At the same time, second place is occupied by "Feijoo G," with 468 citations.

Table 2 Primary LCA research in the wine industry

Process	Author
Complete process	Pizzigallo, Granai, and Borsa (2008), Pattara, Raggi, and Cichelli (2012)
Sowing or cultivation	Alvarez (2007), Bosco et al. (2011)
Production	Gazulla, Raugei, and Fullana-I-Palmer (2010), Point, Tyedmers, and Naugler (2012)
Bottling	Aranda, Zabalza, and Scarpellini (2005), C. Ferrara and De Feo (2020)
Waste (by-products)	Ruggieri et al. (2009)
Packaging	González-García et al. (2011), Rives, Fernandez-Rodriguez, Rieradevall, and Gabarrell (2011), Ramos, Berzosa, Clarens, Marin, and Rouboa (2020)

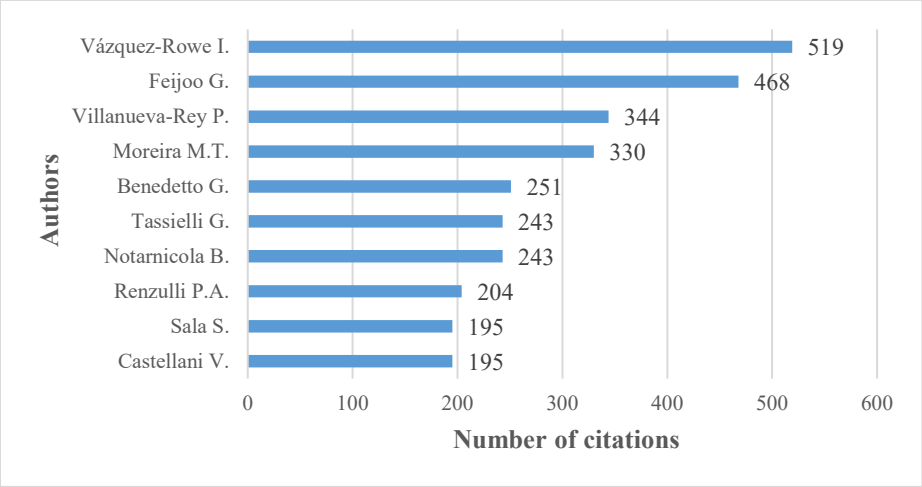

Figure 9 Most cited authors

4.7.2 Most cited countries

Figure 10 illustrates the 15 most cited countries in the world. In this case, we can see that Italy has the highest number with a total of 1452, and that country is one of the countries that generate the most articles and one of the leaders in the production of grape-based beverages. The second place is occupied by Spain with 903 citations, reflecting the importance of the wine industry in these countries. In this case, it is observed that the sum of citations of these two countries represents the sum of the citations of the other thirteen countries analyzed. It is also observed that Luxembourg occupies third place with 241 citations. This country does not occupy a position within the top 10 wine producers and is not a generator of documents.

It is important to remember that France is the country that occupies the first place concerning wine production in liters; however, it is the country that occupies the 14th position in the list of most cited countries. Even in that list, it is observed that countries such as Peru, where Pisco is produced, have more citations than France as the first wine producer.

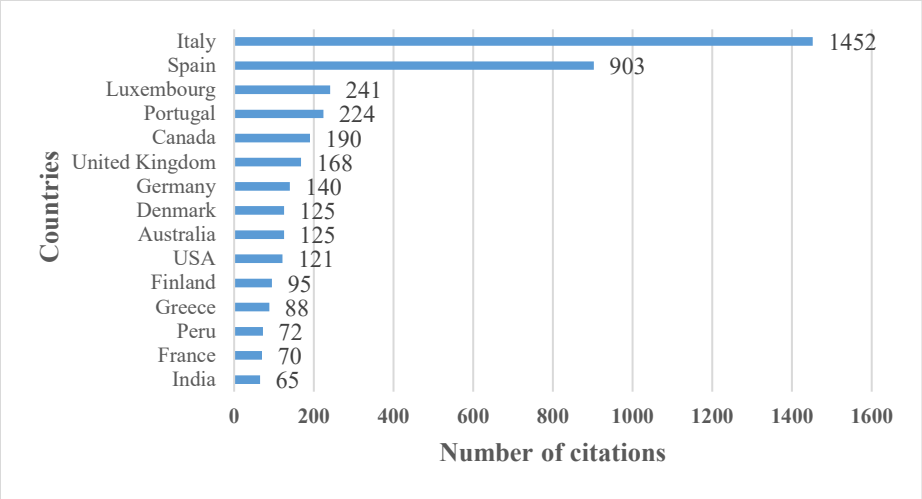

Figure 10 Most cited countries

4.7.3 Most cited documents

Not all published articles have the same number of citations, so Table 3 illustrates the list of those most cited. Analyzing the papers, it can be observed that the first three top-five articles have more than one hundred citations, leading the list Bruno Notarnicola et al. (2017), with 195 citations, Vázquez-Rowe, Villanueva-Rey, Moreira, and Feijoo (2012)with 138 and (Rugani et al., 2013) with 132 citations. Subsequently, two more authors are found to be above 100, and all the remaining authors have values below this parameter.

Table 3 Most cited documents

Document	Cites
The role of life cycle assessment in supporting sustainable agri-food systems: A review of the challenges (Bruno Notarnicola et al., 2017)	195
Joint life cycle assessment and data envelopment analysis of grape production for vinification in the Rías Baixas appellation (NW Spain) (Vázquez-Rowe, Villanueva-Rey, Iribarren, Teresa Moreira, & Feijoo, 2012)	138
A comprehensive review of carbon footprint analysis as an extended environmental indicator in the wine sector (Rugani et al., 2013)	132
The joint use of LCA and emergy evaluation for the analysis of two Italian wine farms (Pizzigallo et al., 2008)	116
Life cycle environmental impacts of wine production and consumption in Nova Scotia, Canada (Point et al., 2012)	112
Taking a life cycle look at crianza wine production in Spain: Where are the bottlenecks? (Gazulla et al., 2010)	91
Comparative life cycle assessment in the wine sector: Biodynamic vs. conventional viticulture activities in NW Spain (Villanueva-Rey, Vázquez-Rowe, Moreira, & Feijoo, 2014)	91
Environmental analysis of Ribeiro wine from a timeline perspective: Harvest year matters when reporting environmental impacts (Vázquez-Rowe, Villanueva-Rey, Moreira, et al., 2012)	86
Life cycle assessment of the supply chain of a Portuguese wine: From viticulture to distribution (Neto, Dias, & Machado, 2013)	81
The ecology of scale: Assessment of regional energy turnover and comparison with global food (Schlich & Fleissner, 2005)	78

5. Conclusion

It can be concluded that the life cycle analysis is a methodology that is very useful for companies to identify the environmental impact that is being caused by the production of beverages. In addition, due to the multifunctional nature of the tool, several areas can be treated, since, according to the research that was consulted, they show results

in several phases, taking into account from the grapes, this is one of the few things that were thought not to be included in the environmental damage caused by the production of beverages derived from grapes. However, by carrying out the LCA, it is possible to identify all the critical aspects, making it very useful to correctly manage the study to obtain relevant and valuable data to implement improvement plans.

It is possible to identify a small group of countries that are the leading producers of beverages, which serves as segmentation for researchers to know the places they can visit and gather information more easily. As seen in the research development, countries like Italy, France, and Spain have many wine industries. Therefore, it is not necessary to move to other parts of the world to find extensive information regarding its development. In addition to having time with the implementation of LCA, it is a good option for consultation.

Concerning the LCA, once the theoretical and practical information was analyzed, it can be highlighted how important it is for the wine industry. However, once observed how it operates, it can be concluded that it is feasible to implement the methodology in companies of other industries since its field of application is very broad. Hence, it is feasible to adapt the tool within the phases of companies wishing to know their environmental impact and implement improvement plans to reduce environmental damage.

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