Bibliometric study on carbon footprint in aquaculture

Estudo bibliométrico sobre pegada de carbono na aquicultura

Estudio bibliométrico sobre huella de carbono en acuicultura

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Abstract
Carbon footprint is the term that identifies the amount of carbon in the atmosphere emitted by individuals, companies or any type of activity, such as agricultural production. Production chains increasingly need research and actions to mitigate the damage caused to the environment by the emission of greenhouse gases, such as research and actions to adopt methods that sequester these gases from the atmosphere to achieve carbon neutrality. The objective of the article was to carry out a bibliometric study on scientific production, in international journals from the Scopus base, to visualize the trend of research on the topic of carbon footprint and sustainability applied to aquaculture. Research methodology is quantitative, the terms carbon footprint, sustainability and aquaculture were searched in the SCOPUS article base. Research results showed 631 articles, the first article dated 2009 and showed a growing scientific interest in the subject. The conclusion of the study points to the importance of studying solutions to achieve sustainable aquaculture.
Keywords: Carbon neutralization; Sustainability of the production process; VoSViewer.

Resumo
Pegada de carbono é o termo que identifica a quantidade de carbono na atmosfera emitida por indivíduos, empresas ou qualquer tipo de atividade, como a produção agrícola. As cadeias produtivas necessitam cada vez mais de pesquisas e ações para mitigar os danos causados ao meio ambiente pela emissão de gases de efeito estufa, como pesquisas e ações para adoção de métodos que sequestrem esses gases da atmosfera para alcançar a neutralidade carbônica. Objetivo do artigo foi realizar um estudo bibliométrico sobre a produção científica, em periódicos internacionais da base Scopus, para visualizar a tendência das pesquisas sobre o tema pegada de carbono e sustentabilidade aplicada à aquicultura. Metodologia de pesquisa é quantitativa, os termos pegada de carbono, sustentabilidade e aquicultura foram pesquisados na base de artigos do SCOPUS. Resultados da pesquisa apresentaram 631 artigos, sendo o primeiro artigo datado de 2009, esses resultados demonstraram um crescente interesse científico pelo assunto. Conclusão do estudo aponta para a importância de estudar soluções para alcançar a aquicultura sustentável.
Palavras-chave: Neutralização de carbono; Sustentabilidade do processo produtivo; *VoSViewer*.

Resumen
La huella de carbono es el término que identifica la cantidad de carbono en la atmósfera emitida por individuos, empresas o cualquier tipo de actividad, como la producción agrícola. Las cadenas productivas necesitan cada vez más investigaciones y acciones para mitigar los daños causados al medio ambiente por la emisión de gases de efecto invernadero, como investigaciones y acciones para adoptar métodos que secuestren estos gases de la atmósfera para

lograr la carbono neutralidad. El objetivo del artículo fue realizar un estudio bibliométrico sobre la producción científica, en revistas internacionales de base SCOPUS, para visualizar la tendencia de las investigaciones en el tema de huella de carbono y sustentabilidad aplicada a la acuicultura. La metodología de investigación es cuantitativa, los términos huella de carbono, sustentabilidad y acuicultura fueron buscados en la base de artículos SCOPUS. Los resultados de la investigación arrojaron 631 artículos, el primer artículo con fecha de 2009 y mostró un creciente interés científico en el tema. La conclusión del estudio apunta a la importancia de estudiar soluciones para lograr una acuicultura sostenible.
Palabras clave: Neutralización de carbono; Sostenibilidad del proceso productivo; VoSViewer.

1. Introduction

Concern about the relationship between greenhouse gas emissions and Earth's temperature is growing, as shown by the intense global movement on the subject during the United Nations Conference on Climate Change, 2021 edition, COP-26. As one of the results of this conference, significant greenhouse gas-emitting countries such as the United States and China, previously significantly refractory to the ONU 2030 Agenda for Sustainable Development, pledged to control their greenhouse gas emissions, among other actions (United Nations, 2021). Initiatives like this should greatly increase the demand for carbon credits in the world in the coming years. Carbon dioxide (CO_2) is one of the gasses responsible for the greenhouse effect, and its concentration in the atmosphere contributes to climate change on our planet. The impact caused by human activities that emit carbon dioxide into the atmosphere form the so-called Carbon Footprint (Radu et al., 2013). Carbon Footprint consists of a value of CO_2 emission, measured in tons, usually monthly or annually, information used to project actions for the mitigation of emissions, and enable actions to compensate for current emissions (Ferreira, 2011). In 2020, fossil CO_2 emissions even decreased due to the COVID-19 pandemic, but remained around 34 gigatonnes, 2.4 billion tonnes less than in 2019. However, in Brazil, the reality was different, and gross GHG (Greenhouse Gas) emissions during 2020 reached 2.16 billion tons of CO_2 equivalent (tCO_2e), an increase of 9.5% compared to the previous year (Deutsche Welle, 2021).

Every country that seeks its development must consider sustainability as the structuring of this development, taking into account current needs without compromising natural resources for future generations, requiring that this development be "economically efficient, socially equitable and ecologically tolerable" (Soares & Signor, 2021). For some time, efforts have been made to understand the profile of the Carbon Footprint in productive activities, through the analysis of the life cycle of its production (Galindro et al., 2019). LCA is a standardized method, developed to assess potential environmental impacts associated with production, quantifying and analyzing resources consumed and emissions to the environment at all stages of production, from raw material extraction to waste and packaging disposal (Kimpara et al., 2012). Many activities have a negative carbon balance, and mitigation measures must be identified through emission reductions, or seeking to neutralize them with the acquisition of carbon credits from surplus production systems. Thus, the need for research aimed at understanding the emission of greenhouse gasses in production systems and mainly, viable methods for sequestering the carbon emitted by these systems, including aquaculture. Sustainable development has led countries to the challenge of seeking a balance between growth and the preservation of their natural resources.

With the evolution of the environmental issue and the conditions that the planet presents, the rational cultivation of aquatic organisms, an activity known as aquaculture, also faces the challenge of adapting to the concept of sustainability, which implies adding new knowledge to production and sector practices (Eler & Millani, 2007). It is crucial to know that climate change is a threat to the availability of water resources (United Nations, 2010).

Aquaculture is one of the largest and fastest growing food production sectors in the world, so it is important and desirable to assess the sustainability of its production systems, achieving sustainability is not a trivial task, and interventions must be carried out step by step by sustainable systems (Valenti et al., 2018). The Food and Agriculture Organization of the United Nations (FAO) proposes a code of conduct for Responsible Fisheries with principles and provisions that support

sustainable practices for the development of aquaculture (FAO, 1995). Among the principles for an ecosystem approach to freshwater aquaculture are the development and management of aquaculture, which must take into account the full range of functions and services of this ecosystem (Allsopp et al., 2013).

In this context, through a bibliometric study, the objective of this work is to understand the current trajectory of international research that presents works on the Carbon Footprint and aquaculture production, taking into account aspects of the sustainability of the productive chain.
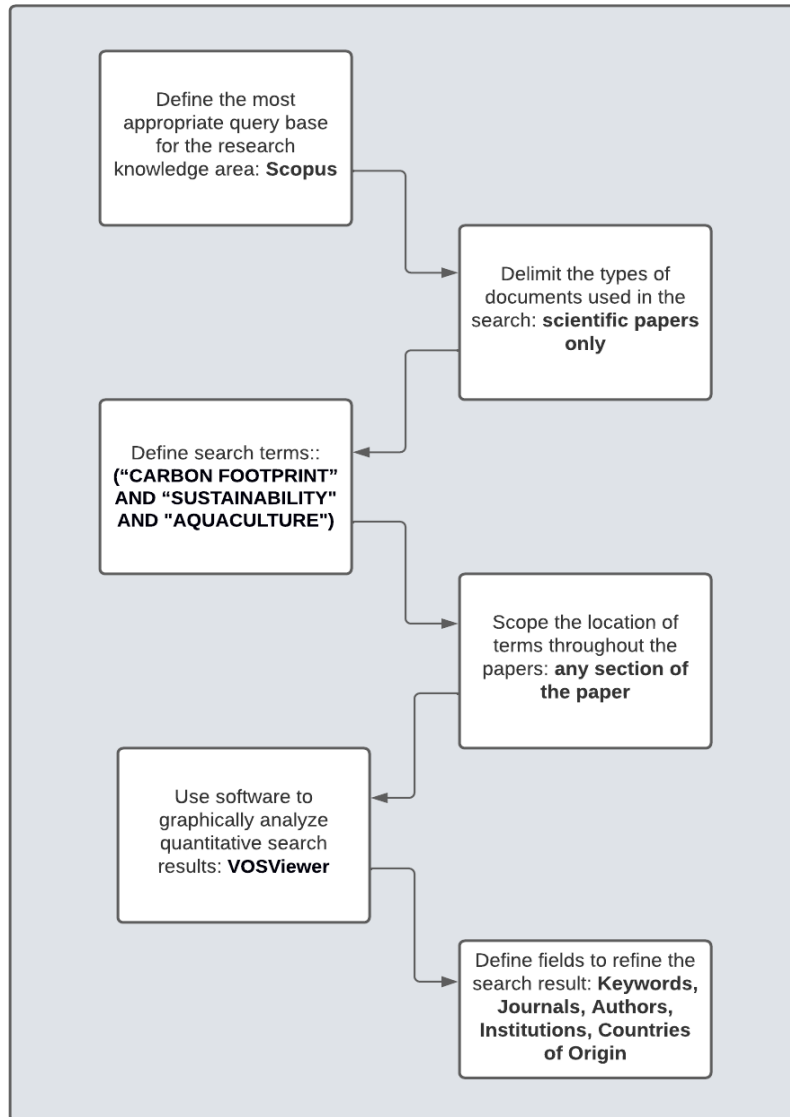
2. Methodology

The research carried out can be classified as descriptive in terms of its objective. In this type of research, the researcher analyzes and correlates facts or phenomena, seeking the enumeration and ordering of data or the establishment of relationships between variables, without your interference (Gil, 2020), (Barros & Lehfeld, 2007). The research approach is quantitative, carried out through a bibliometric study, a technique that seeks to analyze an extensive base of published research using statistical tools in order to obtain indicators on authors, journals, year and country of publication, among others, in order to observe trends regarding a particular research topic (Gil, 2020), (Paul & Criado, 2020).

By means of software viewers, it is also possible to carry out a graphical bibliometric review, creating some comparatives that help in the analysis (Paul & Criado, 2020). One of these software is VoSViewer, Visualizing of Similarities, free software available on the Internet (Van Eck & Waltman, 2010, 2014). VoSViewer was used in this work to confirm and analyze some research metrics.

Data collection was carried out during the year 2021, through a search for existing scientific articles in Scopus, an extensive database of peer-reviewed publications that has bibliometric tools to monitor, analyze, and visualize the object of investigation. The premise of the research was to investigate publications, specifically scientific articles, that presented research related to the Carbon Footprint theme associated with the Sustainability theme. These issues should still be related to aquaculture. To fully identify the breadth of published articles, it was determined that the search terms were present in any field of the article, and not delimiting the year of publication. Thus, the search expression used was ("CARBON FOOTPRINT" AND "SUSTAINABILITY" AND "AQUACULTURE"). The categories listed for identification in the result were: number of annual productions, areas of knowledge most adherent to the articles, most used keywords, journals in which the articles were published, countries of origin of the studies and institutions that the authors represent. Figure 1 outlines the methodology used in the study and summarizes the actions of a bibliometric research.

Figure 1. Roadmap for bibliometric study.

Source: Authors.

3. Results and Discussion

The first occurrence observed in the search for articles in the Scopus database, according to the work methodology occurred in 2009, with only one article published that year. In this first paper, the authors propose a methodology to track the ecological impact of the supply, production and distribution of each product in order to account for ecological impacts rather, than financial costs (Limnios et al., 2009). Since then, the research presents publications in all years, including articles already accepted for publication, in editions of scientific journals for the year 2022. Adding the publications of all these years, we reach a total of 631 articles. The Histogram based on the results of the investigation is shown in Figure 2, where the rise of the investigated topic can be observed, from the first observation in 2009 to 2021.

Figure 2. Increase in publications that have the search terms.
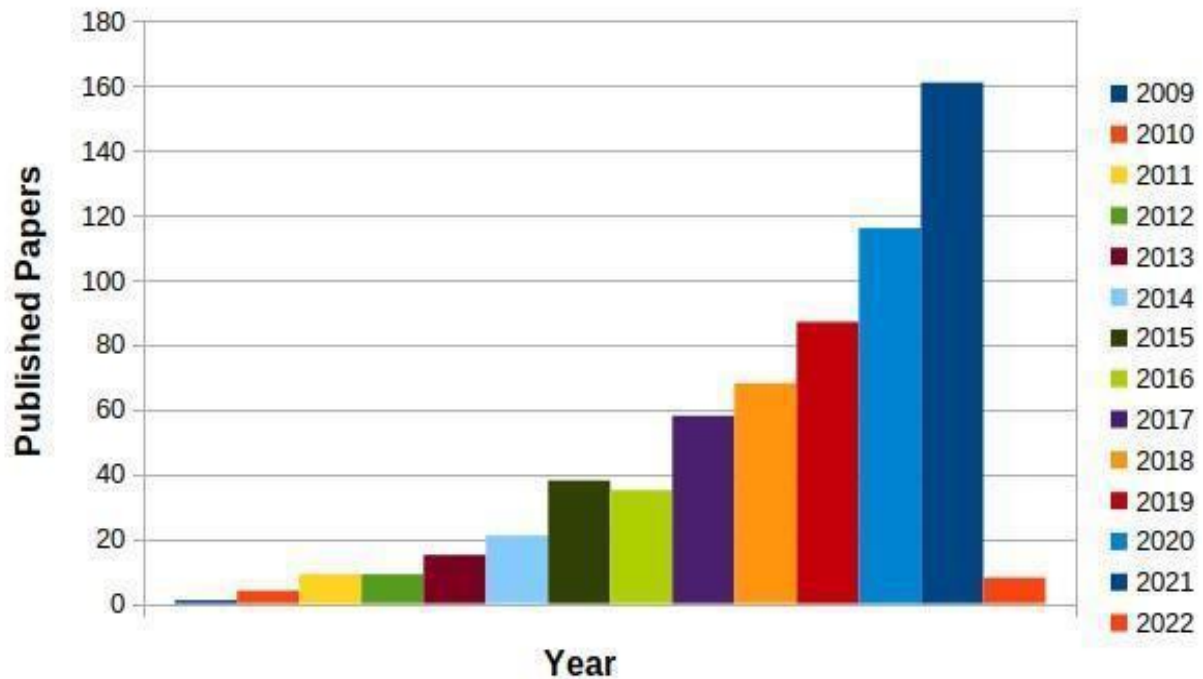
Source: Authors.

Regarding the research areas of the articles, the five most approached were Environmental Sciences, Agricultural Sciences, Energy, Engineering and Social Sciences, and we also found publications in 21 other areas. The ten keywords included by the authors that presented the highest number of occurrences were, in order of number of events: life cycle assessment; carbon footprint; aquaculture; seafood; sustainability; fishing; water footprint; climate changes; environmental impact and emission of greenhouse gasses.

Regarding the five journals that had the highest number of publications in the research, we consolidated the information in Table 1. In which the Journal of Cleaner Production stands out, with 82 articles and an impact factor greater than 9.

Table 1. Journals with the highest number of publications.

Journal	Number of articles	% Of total articles	Impact Factor	Description
Journal of Cleaner Production	82	13.0	9.297	(1)
Science of the Total Environment	41	6.5	7.963	(2)
Journal Sustainability	39	6.2	3.251	(3)
International Journal of Life Cycle Assessment	30	4.8	4.141	(4)
Journal of Environmental Management	17	2.7	6.789	(5)

Description of the newspapers:
(1) focus on research and practices of Clean Production, Environment and Sustainability.
(2) publication of innovative research, based on hypotheses about the total environment, which interface with the atmosphere, lithosphere, hydrosphere, biosphere and anthroposphere.
(3) journal on environmental, cultural, economic, and social sustainability of the human being, providing an advanced forum for studies related to sustainability.
(4) dedicated to Life Cycle Assessment, an instrument to assess the ecological impacts of the stages of a production system.
(5) publishes original research related to the management of environmental systems and the improvement of environmental quality
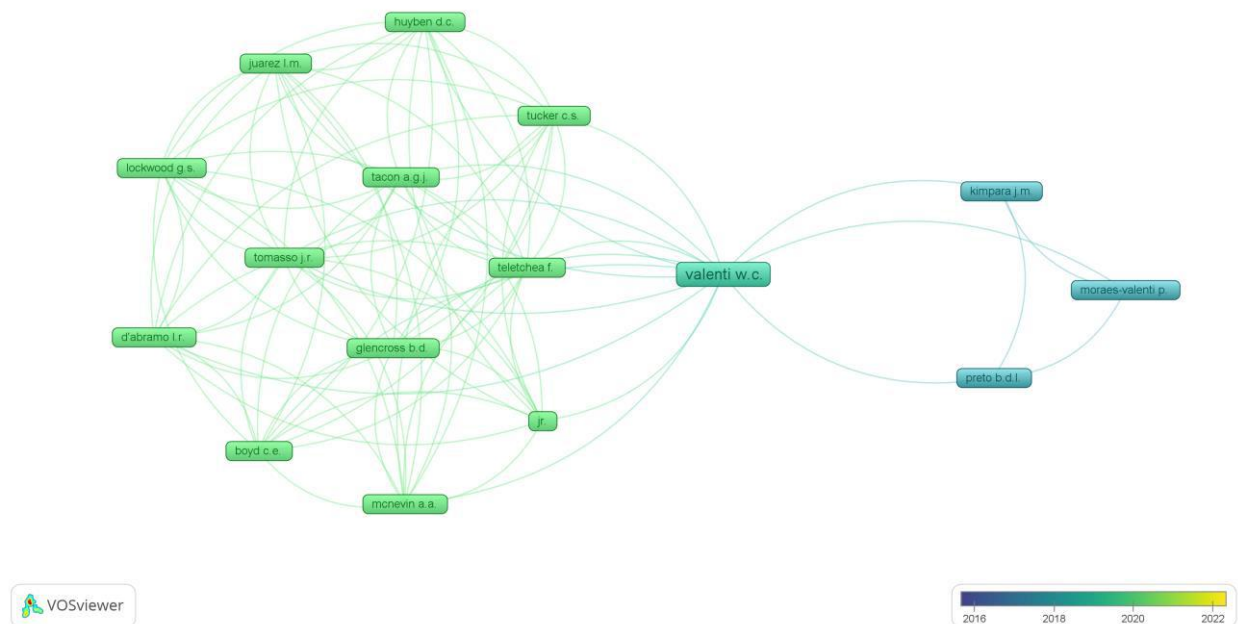Source: Authors.

As an indication of the five countries that presented the most researchers among the published articles are the United States (10.2%), Spain (7.6%), China (6.2%), Italy and Great Britain (5.4% both). Brazilian researchers contributed with the authorship of 24 publications, 2.1% of the total. Additionally, the five most outstanding research institutions in terms of

number of publications were: University of Santiago de Compostela (Compostela-Spain, 43 articles), University of Tasmania (Hobart-Australia, 17 articles), Norwegian University of Science and Technology (Trondheim - Norway, 16 articles), Institute for Marine and Antarctic Studies (Hobart-Australia, 16 articles) and Wageningen University (Wageningen-Netherlands, 15 articles). Regarding the five Brazilian research institutions present in the study, we mention the University of São Paulo (5 articles), Empresa Brasileira de Pesquisa Agropecuária - Embrapa (4 articles), Federal University of Santa Catarina (3 articles), Federal University of Ceará (3 articles) and Federal University of Espírito Santo (3 articles).

This first study achieved the objective of quantitatively presenting information on the total number of searches related to the terms chosen for the search, through the indicators presented in this section. It was observed, from the keywords, that most of the works focused on the evaluation of the life cycle of different aquaculture productions, in an attempt to understand the equivalent carbon emission of each one.

With the aim of identifying works and researchers that went further, dedicating themselves more directly to the study and implementation of sustainability aspects in aquaculture production, with regard to the Carbon Footprint, a new filter was applied to the research through the search expression ("CARBON FOOTPRINT" AND "SUSTAINABILITY OF AQUACULTURE"). This filter restricted the result to 15 articles found in the Scopus database. Using the VoSViewer software to analyze and identify the relationship between these works, we arrived at the two groups of researchers that have cooperated most directly in Aquaculture Sustainability research (Figure 3). These groups are connected by the group of the Brazilian researcher Wagner Cotroni Valenti, doctor of the UNESP Aquaculture Center in Jaboticabal (CAUNESP).

Figure 3. Collaboration network between researchers who published on Aquaculture Sustainability with respective years of publication (authors' elaboration).

Source: Authors.

Among the articles selected for this search, Table 2 presents the studies that have been most cited by the scientific community with respect to the sustainability of aquaculture. The article Sustainability Indicators for Assessing Aquaculture

Systems by Valenti et al receives our highlights, since it proposes a set of indicators to measure the sustainability of aquaculture production.

Table 2. Papers with the highest number of citations.

Paper	Authors	Journal	Citations
Indicators of sustainability to assess aquaculture systems	Valenti, Wagner Cotroni et al	Ecological Indicators	82
Comparative life cycle assessment (LCA) of raising rainbow trout (Oncorhynchus mykiss) in different production systems	Samuel-Fitwi, Biniam et al	Aquacultural Engineering	47
Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges	Boyd, Claude E. et al	Journal of the World Aquaculture Society	37
Environmental assessment of seabass (Dicentrarchus labrax) and seabream (Sparus aurata) farming from a life cycle perspective: A case study of a Tunisian aquaculture farm	Abdou, Khaled et al	Aquaculture	35
Environmental sustainability assessment of a microalgae raceway pond treating aquaculture wastewater: From up-scaling to system integration	Sfez, Sophie et al	Bioresource Technology	29

Source: Authors.

The research group led by Professor Valenti has long stood out in the scientific production on aquaculture production and sustainability. We highlight other articles published by researchers of the group, such as: Valenti, et al. (2011) and Valenti, et al. (2021).

4. Conclusion

The study showed that the topics used in the bibliometric analysis proposed by this work have aroused the progressive interest of researchers. An initial analysis shows that most of the studies carried out were in the areas of mariculture and shrimp farming, which have been the most studied in Europe and Australia. When it comes specifically to the area of fish-farming, we observed that studies are reduced, opening up potential research opportunities. Several of these studies were carried out to define the Carbon Footprint of productive activities through the Life Cycle Assessment.

The growing importance of addressing the sustainability of production chains and the still limited number of studies on the potential for carbon sequestration linked to aquaculture, more specifically to fish farming, demonstrate that research related to the study of solutions to achieve the sustainability of sustainable aquaculture, in that concerns about the neutrality of CO_2 emissions are promising and necessary to advance the issue.

This paper carried out a bibliometric analysis with the aim of mapping the scientific production in international journals on the carbon footprint and sustainability of aquaculture production, using the Scopus database. It is suggested to replicate the study in other databases, including the repository of thesis and dissertations of Capes, expanding the contribution for the elaboration of theoretical references on aquaculture and carbon footprint.

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