Current Status, Development and Future Directions of Scenedesmus Research: A Bibliometric Analysis

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Abstract

Scenedesmus sp. is a colony green microalga, commonly found in freshwater and brackish waters. It has recently attracted the interest of researchers in its high potential application to biofuels, biomaterials, and bioremediation. Global research trends in the Scenedesmus study are therefore crucial for understanding this scenario. In this study, a bibliometric analysis was used to quantify 5359 Scopus databases to identify the Scenedesmus sp. global research activity between year of 1926 and early 2021. Quantitative and qualitative evidence from the bibliometrics analysis was then used to conduct an in-depth statistical analysis. Results have shown that the number of published papers on Scenedesmus has increased significantly since 2008. Bioresource Technology and Alga Research are the most relevant journals on this subject. Although most of the papers come from USA, institutions with more publications are from China and Germany. Keywords mapping has also shown that there is three main clusters related to Scenedesmus research which were biomass, bioremediation and toxicology. Overall, bibliographic analysis confirms that Scenedesmus research is a very active field in which scientific productivity has increased exponentially over recent years in conjunction with industrial production. As a result, expectations in this field are high for the near future.

Keywords:
Scenedesmus; bibliometric analysis, biomass, biofuels

1. INTRODUCTION

Scenedesmus is a colonial green microalgae genus consisting of approximately 70 species and present as a major component of freshwater plankton (Baudelet et al., 2017). The cells of this species are elliptical or spindle-shaped and usually consist of 2, 4, 8 or 32 cells in one, two or four rows. The cells may be more cylindrical, more ellipsoidal, or more fusiform. End cells have two long combs with a length of 200 μm and four spines at the end part of each cell. The main habitat of Scenedesmus is the freshwater rivers, the wetlands and the brackish environments (Baudelet et al., 2017). The presence of comb and spine in Scenedesmus morphology has allowed them to absorb more light and nutrients in a harsh environment. Moreover, some of the Scenedesmus become larger colonies with protective thorns and harder primary cell walls when threatened by predators.

Scenedesmus research began in western countries in the end of 1920s, when small-scale plant production was first developed (Baudelet et al., 2017). Since this pioneering work,

research has grown, changed and expanded in many areas. Scenedesmus can be grown in nutrient-rich waters without affecting its growth. Researchers have identified it as a typical bio-indicator for physical and chemical changes in environmental conditions (Japar et al., 2021). The gene is widely used to determine the presence of nutrients or toxic substances from anthropogenic inputs to aquatic ecosystems, such as their ability to grow in high polluted water or sewage.

Several studies have revealed species of Scenedesmus can grow in wastewater systems, enhance biomass, and potentially establish an efficient wastewater treatment and biodiesel integration system (Mohd Udaiyappan et al., 2020). Due to its ability to adapt to the harsh environment, Scenedesmus is a major biodiesel candidate because it does not have a significant or adverse impact on the ecosystem when it is grown in large quantities of industrial wastewater. Under a concentration of 3.02g/L of nitrogen, algae show an optimum growth in biomass and lipid content, producing biodiesel that meets the requirements of the National Petroleum Agency, the European biodiesel standard, the German standards and the South African standards (Mandotra et al., 2014). Therefore, the production of biodiesel from Scenedesmus is an incredibly attractive research area and interest.

Research on Scenedesmus has been conducted for the last nine decades. However, rapid progress in Scenedesmus research might also be misinterpreted. To date, no systematic study was recorded to evaluate the outcomes of the journal during its nine decades. Therefore, recent trends in Scenedesmus research activities need to be assessed using established databases of literature. Nowadays, bibliometric analysis is a method for mapping published documents and has been widely accepted as an alternative technique for analysing academically detailed topics in bibliography and material science, has become one of the most popular tools for assessing and predicting study patterns in particular subjects (Zhao et al., 2018). Bibliometrics analysis includes qualitative and quantitative analysis of databases indexed publications based on statistics and computing technology (Aleixandre et al., 2017; Liu et al., 2019). Furthermore, knowledge graphs combine information visualisation technology with traditional scientometrics citation analysis to visually display the knowledge of a subject or field through data mining, information processing, scientific measurement and graphical drawing.

Knowledge graphs can therefore be used to explore the development of and relationships between different parts of scientific knowledge (Shiffrin and Börner, 2004; Chen et al, 2008).

This study then becomes the first attempt to use the Scopus database in bibliometric analysis and mapping to provide a better understanding of global trends in Scenedesmus research over the past 95 years. Our review employed systematic methods to identify 5359 Scopus-indexed documents related to Scenedesmus. Based on bibliometric method, the current status, development and future research directions of Scenedesmus sp. were analysed. Generally, the bibliometric software includes Microsoft Excel, Harzing's or Perish and VOSviewer, as an analytical methods that focused on statistics, bibliometric, dynamic social networks and information mapping. In this study, basic characteristics such as document type and language, subject categories and journals and specific performance (publication outputs, growth rate, countries, institutions, keywords) were analysed. Using bibliometric analysis, we not just obtained the publication types, countries, institutions and journals, but also analysed author keywords, and further extracted some of the research hotspots and perspectives in this field to allow us to learn directly about the field. In this project, we present an in-depth analysis in current status, development and future research directions of Scenedesmus sp.

2. METHODOLOGY

2.1 Data Sources

Scopus is the largest database of scholarly works compared to Pubmed or the Web of Science (Aghaei Chadegani et al., 2013; Ahmi, Elbardan, & Raja Mohd Ali, 2019). Therefore, this study used this database as a basis for extracting previous scientific publications on Scenedesmus research. In order to obtain reliable and accurate results, a complete search was carried out using [TITLE-ABS-KEY (scenedesmus*)]. This query produced a total of 5359 documents for the period from 1929 to January 2021. The review has offered a comprehensive scope in terms of document types, including journal articles, books, book chapters and conference papers. No start date was specified for the Scopus search, allowing the search engine to identify the earliest documents in the literature. This study has implemented the PRISMA guideline and the detailed flow chart of the research framework are shown in Figure 1.

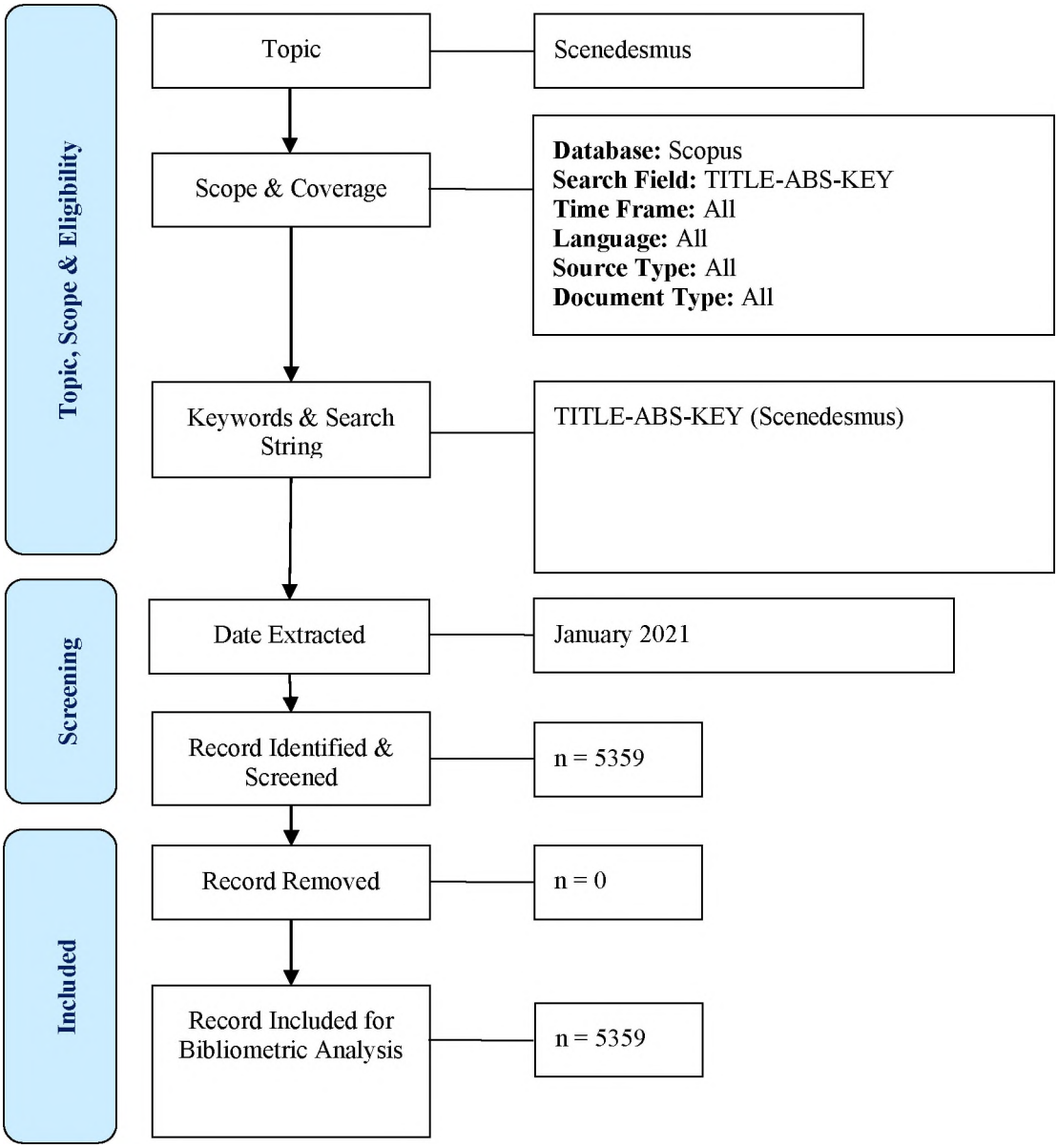

Figure. 1: PRISMA Flow Diagram (Ahmi, A., and Mohamad, R., 2019)

2.2 Analysis Method

All published documents related to *Scenedesmus* sp in the Scopus database have been analysed using Microsoft Excel 2013, Harzing's Publish or Perish (version 5.3.R4) and VOSviewer (version 1.6.13) software. First, all citation information items (e.g., authors, document title, year, citation count), bibliographical information (e.g., affiliations) and abstract and keywords (e.g., abstracts, author keywords) of documents published between 1929 and January 2021 were selected and exported in CSV and RIS formats. Then, the general research performance such as document type, source type, language, subject category, journal, year of publication, countries and institutions were analysed using Microsoft Office Excel 2013. Subsequently,

bibliometric indicators were evaluated using Harzing's Publish or Perish Software. Total publications (TP), total citations received (TC), citations per paper (CPP) and h-index (Hirsch index) were the general bibliometric indicators which has been accepted by the scientific community. The h-index considers both the number of articles and the number of citations. For this analysis, the h-index was applied to countries, authors, institutions, and year of publications data. Overall, significant of bibliometric indicators shows the productivity and influence of *Scenedesmus* sp. on the global research (Garfield, 1955; Hirsch, 2005; Ding, Rousseau & Wolfram, 2014; Kamdem et al., 2018). Furthermore, a cluster analysis using VOSviewer software has been conducted to generate the social network maps of keywords. Social network maps indicate importance with the size of a node and the thickness of a line. The nodes represent the number or frequency, and the lines between the nodes denote associations. The thicker the line is, the greater the relationship. Thus, trends in scenedesmus studies could be visualized using the resulting co-word network.

3. RESULTS AND DISCUSSIONS

3.1 Evaluation of scientific output

All the collected data were first analyzed based on document types and source types. This study showed 9 types of Scenedesmus-related documents, including articles, conference papers, reviews, book chapters, short surveys, editorials, erratum, letter and note. As shown in Table 1 and Figure 1, the type of document that was identified as the main contributor would be articles with 5059 of the 5359 publications resulting in a high percentage of 94.4%. Other types of documents, such as conference paper and review were in second and third position with the percentage of 2.8% and 1.4% respectively. Other documents such as book chapter, short survey, editorial, erratum, letter and note appear at a lower frequency (1.4%). Although these documents have a lower percentage contribution, they nevertheless have relative importance in the field of Scenedesmus research.

Table 1. Type of documents related to Scenedesmus.

Document Type	Total Publications (TP)	Percentage (%)
Article	5059	94.40
Conference Paper	152	2.80
Review	74	1.40
Book Chapter	32	0.60
Short Survey	15	0.30
Editorial	12	0.20
Erratum	10	0.20
Letter	4	0.10
Note	1	0.10
Total	**5359**	**100.00**