A Bibliometric Analysis of Cellulose-Based Plastics from 1984 to 2024

Shalahudin Nur Ayyubi[1,*], *Aprilina* Purbasari[2], *Aji* Prasetyaningrum[2], and *Meitri* Bela Puspa[1]

[1]Doctoral Program, Department of Chemical Engineering, Faculty of Engineering, Universitas Diponegoro, Jl. Prof. Jacub Rais, Tembalang, Semarang, Central Java, 50275, Indonesia
[2]Department of Chemical Engineering, Faculty of Engineering, Universitas Diponegoro, Jl. Prof. Jacub Rais, Tembalang, Semarang, Central Java, 50275, Indonesia

Abstract. Cellulose-based plastics have gained significant attention due to their biodegradability, renewability and potential to replace petroleum-based plastics. This study presents the first bibliometric analysis of global research trends on cellulose-based plastics using the Scopus database, covering the period from 1984 to 2024. A total of 395 documents were analyzed using VOSviewer software. The bibliometric analysis method included both quantitative information and qualitative data. The results show a significant surge in publication output over the last decade, highlighting growing interest in this field. China emerged as the leading contributor, followed by the United States and India. *Cellulose* was identified as the most productive journal, publishing 23 articles related to this topic. The most prolific authors included Xing Xiang Ji (China), Sabino De Gisi (Italy), Giovanni Gadaleta (Spain), and Michele Notarnicola (Italy). Keyword co-occurrence analysis revealed four dominant research themes: improving mechanical properties; application of cellulose-based plastics for food packaging; environmental assessment; and enhancing water and heat resistance. These themes reflect the dual emphasis on improving material performance and addressing ecological challenges. This study provides a clear overview of the research landscape, trends, and emerging topics in cellulose-based plastics research.

1 Introduction

Industrial-scale production of plastics, a broad family of polymers derived from fossil resources, began in the 1950s with a 1.5 MMT capacity and increased to 390.7 MMT in 2021. Over the next 20 years, output is predicted to double [1]. Currently, approximately 80% of the plastic produced is not recycled, and this fraction ends up as waste streams and is disposed of in landfills, posing a significant ecological hazard [2]. These concerns have triggered global efforts to transition toward more sustainable materials. One of the promising directions in this transition is the development of renewable, biodegradable alternatives derived from natural resources, especially those that can reduce environmental impact while maintaining material functionality. Among various candidates, cellulose-based plastics have emerged as a promising class of sustainable materials due to their renewable source, biodegradability, and compatibility with diverse applications [3].

Cellulose is the most abundant natural biopolymer and is mainly derived from plant biomass such as wood, agricultural waste, and certain types of algae [4]. Its unique physicochemical characteristics, including high tensile strength, water affinity, and ability to form films, make cellulose and its derivatives highly attractive for developing biodegradable plastics. In recent years, researchers have focused on combining cellulose with other biopolymers to improve its mechanical strength, barrier properties, and active functions [5]. These innovations have significantly expanded the potential of cellulose-based plastics in replacing conventional materials.

As a result, research on cellulose-based plastics has expanded rapidly over the past decade [6]. However, to date, a comprehensive bibliometric overview of the field remains limited. Bibliometric analysis provides a systematic and quantitative approach to assess the development of a research field. It enables the identification of key contributors, influential publications, thematic clusters, and collaboration networks. To the best of our knowledge, the previous bibliometric study on cellulose-based plastics was conducted by Garrido-Romero et al. (2021), which primarily focused on their application in food packaging and using the Web of Science as database [6], but there has been no analysis to date that specifically examines research trends or bibliometric analysis in the field of cellulose-based plastics using the Scopus database.

This study presents a bibliometric analysis of cellulose-based plastics research using data extracted from the Scopus database, covering the period from 1984 to 2024. The analysis aims to uncover publication trends, leading journals, productive countries and authors, collaboration patterns among authors and to

* Corresponding author: shalahudin@students.undip.ac.id

reveal major research themes and emerging topics through keyword analysis.

2 Methodology

Scopus database and search key string of TITLE-ABS KEY ("cellulose-based") AND TITLE-ABS KEY (plastic) was applied on 24/07/2025 for the selection of the documents. This study included only journal publications from 1984 to 2024 that presented original research on cellulose-based plastics. A total of 395 documents were analyzed from an initial retrieval of 669 documents, following a screening and inclusion process as illustrated in **Fig. 1.** The analysis was conducted based on quantitative and qualitative approach proposed by Wu et al. (2019) [7], with slight modifications in the selection of database, using Scopus instead of Web of Science. With a remarkable citation record and comprehensive coverage of peer-reviewed scientific literature, Scopus is significantly bigger than Web of Science or PubMed and more accurate than Google Scholar [8].

The bibliometric data were analyzed using VOSviewer software (version 1.6.20) [9] to visualize collaborative networks and thematic clusters. The analysis was separated into three stages: (1) a quantitative analysis of the research on cellulose-based plastics publication trend, including identification of the most contributing journals; (2) a social network analysis to show how various countries and authors collaborate on research; and (3) a co-occurrence analysis of keywords to determine the main research topics.

3 Results and discussion

This study focused five aspects: publication trend, top 10 journals, contributions of countries, contributions of authors, and keywords analysis (**Fig. 2**).

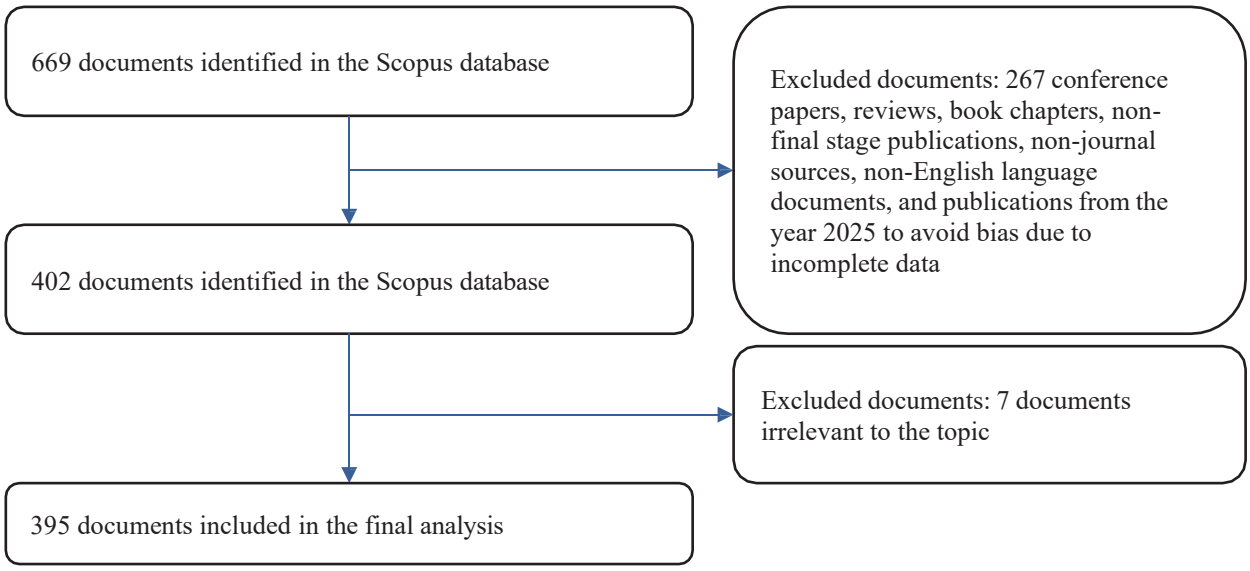

Fig. 1. Flow diagram of the inclusion process.

3.1 Publications trend

Through the research in Scopus, a total of 395 “cellulose-based plastic” related research articles were identified between 1984 and 2024 (see **Fig. 3**). Before the year 2015, the number of annual publications remained relatively low and stable, with less than 10 articles published each year. However, a noticeable increase began in 2015, followed by a sharper growth trend starting in 2020. Since then, the number of publications has continued to rise significantly, reaching more than 50 articles in 2022 and peaking at over 83 articles in 2024. This upward trajectory indicates a growing global research interest in cellulose-based plastics, likely driven by increased environmental awareness and the push for sustainable alternatives to petroleum-based plastics.

3.2 Contributions of different journals to publications

Table 1 shows the top publications on cellulose-based plastics research. A total of 195 journals publishing 395 articles were analysed. However, the top 10 journal sources contributed approximately 32.66% of the total articles published. The journal *Cellulose* has the highest number of articles (n = 23, IF = 4.8), followed by *Carbohydrate Polymers* (n = 21, IF = 12.5), and *International Journal of Biological Macromolecules* (n = 21, IF = 8.5). Additionally, the journal *Carbohydrate Polymers* has the highest number of citations with 1,059, followed by *Composites Part A Applied Science and Manufacturing* and *Journal of Applied Polymer Science* with 580 and 548, respectively. Most of journals in the top 10 list fall within the Q1 category, indicating that the research on cellulose-based plastics has been predominantly published in high-quality, reputable scientific journals.

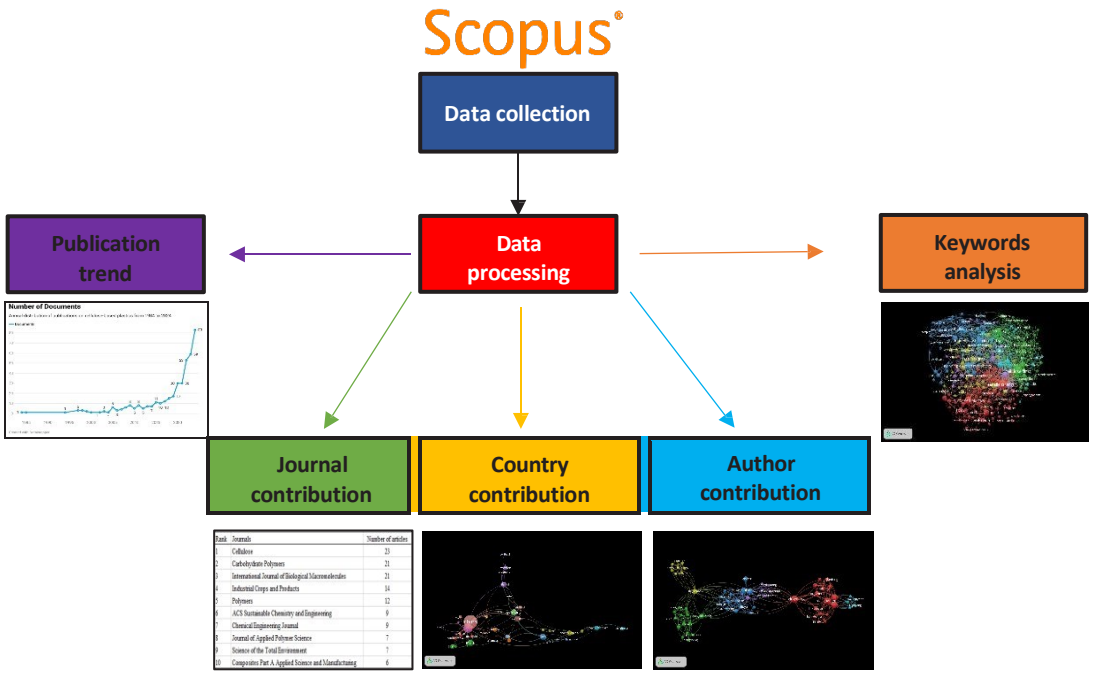

Fig. 2. Flow diagram of the bibliometric analysis process for cellulose-based plastic research.

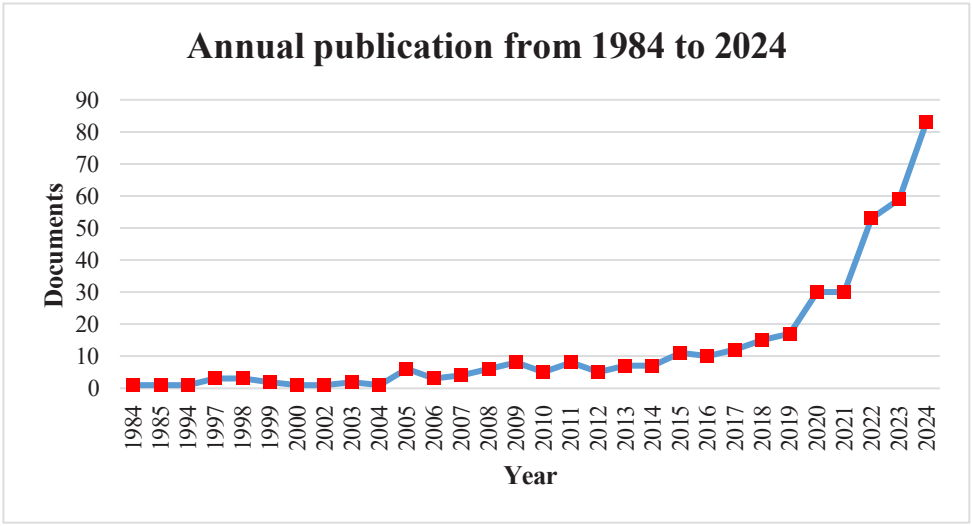

Fig. 3. Annual publication on cellulose-based plastics research from 1984 to 2024 based on data retrieved from Scopus.

Table 1. Top 10 journals with the most articles published on the topic.

Rank	Journals	Documents	Citations	IF	Quartile
1	Cellulose	23	351	4.8	Q1
2	Carbohydrate Polymers	21	1059	12.5	Q1
3	International Journal of Biological Macromolecules	21	435	8.5	Q1
4	Industrial Crops and Products	14	264	6.2	Q1
5	Polymers	12	289	4.9	Q1
6	ACS Sustainable Chemistry and Engineering	9	255	7.3	Q1
7	Chemical Engineering Journal	9	360	13.2	Q1
8	Journal of Applied Polymer Science	7	548	2.8	Q2
9	Science of the Total Environment	7	457	8.0	Q1
10	Composites Part A Applied Science and Manufacturing	6	580	8.9	Q1

IF = Impact factor

3.3 Contribution and collaboration among countries

Co-authorship network analysis was conducted to reveal collaboration patterns across geographical regions. Collaboration among twenty-five countries have contributed significantly to the publication of numerous articles on cellulose-based plastics, as shown in **Fig. 4** (minimum number: 5 articles per country). China published the most articles (115), followed by the United States (52), India (27), Italy (25), and Germany (165). A country with a larger node indicates higher number of publications. As a result, China emerges as the most prolific country with the highest number of publications and strong collaboration links, particularly with the United States and India.

The most recent contributions are marked with yellow nodes, highlighting the active and growing research participation of countries such as China, Iran, Germany, Turkey, and Indonesia in recent years. On the other hand, countries such as the United States, the United Kingdom, and South Korea show relatively earlier average publication years, as indicated by the darker node colours.

3.4 Contribution and collaboration among authors

During the study period, 1,945 authors were active in cellulose-based plastic research, with only 4 authors publishing more than 5 publications. This indicates that there are no dominant researchers focused on cellulose-based plastic research. These four authors also had the highest number of publications and the same number of documents, with six each. They are Xing Xiang Ji (Qilu University of Technology, China), Sabino de Gisi (Università degli Studi, Italy), Giovanni Gadelata (AIMPLAS - Instituto Tecnológico del Plástico, Spain), and Michele Notarnicola (Politecnico di Bari, Italy). The research of these authors focuses on the development of biodegradable plastics and their environmental impact.

The visualisation network overlay in **Fig. 5** shows the co-authorship mapping by authors with a minimum threshold of one publication per author, revealing 64 interconnected authors. Most of these collaboration networks were formed by researchers affiliated with institutions in China, indicating that research on cellulose-based plastics is currently dominated by certain research groups and has not yet spread globally. As it is still limited to closed groups, this opens up opportunities to expand international collaboration networks.

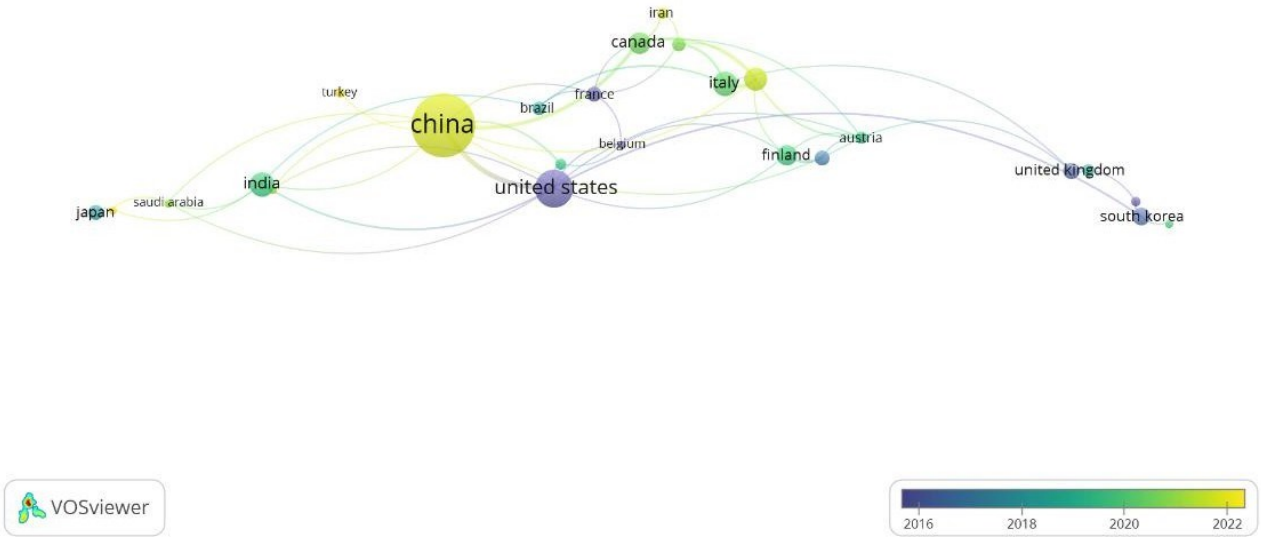

Fig. 4. Co-authorship network among countries.

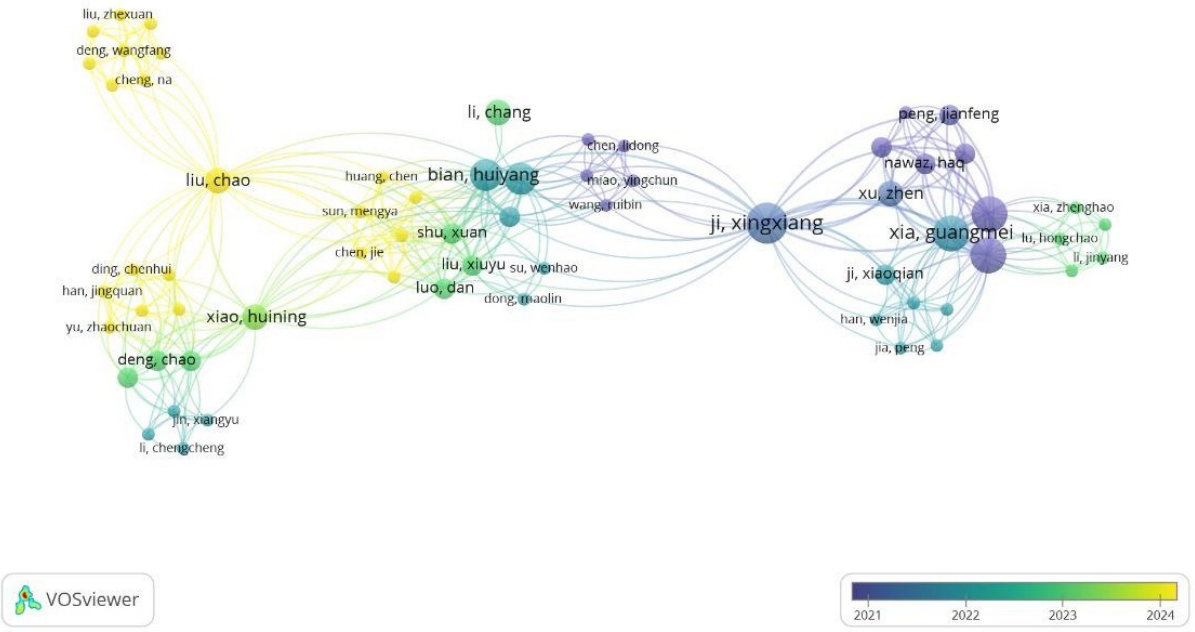

Fig. 5. Co-authorship network among authors.

3.5 Research status based on keywords analysis

The VoSviewer visualization network map (**Fig. 6**) was developed to examine the co-occurrence relationships among the keywords extracted from publications on cellulose-based plastics research. Keyword co-occurrence analysis helps identify research themes and emerging topics in the field. To make the keyword data more consistent and avoid duplication, Open Refine (version 3.9.3) and a thesaurus file were used to combine similar terms. The all-keywords dataset was selected for analysis to capture the full range of terms used in the publications. A minimum occurrence threshold of five (5) was applied. This threshold resulted in 244 keywords from a total of 4851 keywords. Then, the top 100 most frequent keywords were examined for further analysis. By focusing only on the top 100 keywords, the authors aimed to maintain coherence within the clusters by replacing synonyms with the most widely used terms. Additionally, irrelevant keywords were excluded to ensure thematic consistency.

The results of the keyword co-occurrence analysis show four main interconnected thematic clusters. In detail, the first cluster, marked in green, primarily focuses on improving the mechanical performance of cellulose-based plastics. Dominant keywords such as “mechanical properties”, “reinforced plastic”, “plasticizer”, and “chemical modification”, indicate research efforts to enhance the strength, flexibility, and durability of cellulose-based plastics. Mechanical enhancement is often achieved through the incorporation of plasticizer such as glycerol, sorbitol, polyethylene glycol to improve flexibility [10], and chemical modification such as esterification, acetylation, or crosslinking to reinforce molecular interactions [11]. Meanwhile, the presence of keywords like “biodegradability” and “sustainability” suggests that researchers strive to maintain the eco-friendly and degradable nature of cellulose-based plastics despite the ongoing efforts to improve their mechanical strength.

In the second cluster (red color), research themes mainly focus on the application of cellulose-based plastics for food packaging. Core keywords such as “food packaging”, “cellulose film”, “nanocomposite”, “*Escherichia coli*”, “antibacterial activity”, and “antioxidant activity”, highlight the cluster’s emphasis on developing active and intelligent packaging materials. These studies explore strategies to enhance packaging functionality by incorporating nanomaterials and bioactive compounds. Typically, antibacterial and antioxidant properties are improved through the addition of natural extracts such as essential oils, chitosan, or plant polyphenols [12] and nanoparticles such as silver, titanium dioxide, or zinc oxide.

Meanwhile, the third cluster (blue color) contains terms such as “eco-friendly”, “microplastic”, “marine pollution”, “waste disposal”, and “water pollutant”, which show concern for global environmental issues and the evaluation of the impact of cellulose plastic on ecosystems.

Furthermore, in the fourth cluster (yellow color), features terms such as “heat resistance”, “water resistance”, “hydrophobicity”, “differential scanning calorimetry”, and “contact angle”, indicating that research on cellulose-based bioplastics in this cluster focuses on improving the resistance of materials to external environmental conditions. The terms “heat resistance” and “water resistance” reflect efforts to improve thermal stability and moisture resistance which are common challenges for cellulose-based plastics. Therefore, recent studies continue to explore strategies to enhance the durability and overall performance of these materials under varying environmental conditions, especially their resistance to heat and moisture.

Overall, the nodes “mechanical properties” and “biodegradability” appear to be the most dominant due

to their high frequency of occurrence and extensive linkage with other keywords. This reflects the two fundamental pillars in the development of cellulose-based plastics: the enhancement of mechanical performance and the demand for materials that are biodegradable. This finding confirms that current research trends are focused on materials that are not only technically robust but also aligned with principles of sustainability.

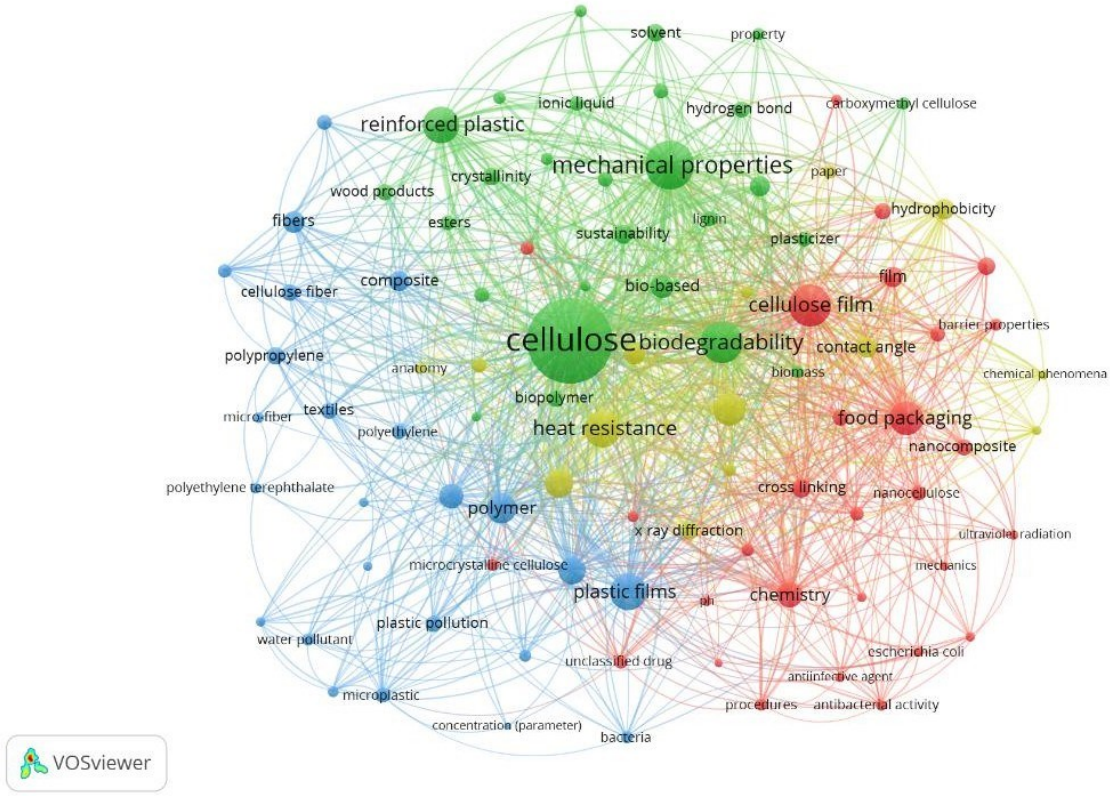

Fig. 6. Keyword co-occurrence networks involved in cellulose-based plastics research.

4 Prospects and challenges

Cellulose-based plastics have garnered increasing attention in recent years as a sustainable alternative to conventional petroleum-based polymers. Derived from the most abundant renewable biopolymer on earth, cellulose offers several advantages including biodegradability, biocompatibility, and wide availability from various agricultural residues and natural resources [13].

One of the most promising prospects of cellulose-based plastics lies in their application for sustainable packaging, particularly in the food sector. Their biodegradability aligns with global efforts to reduce plastic waste, while their natural origin supports the transition toward a circular bioeconomy. Moreover, advances in formulation techniques have enabled the incorporation of functional properties such as antimicrobial and antioxidant activity, making cellulose-based plastics suitable for active food packaging that can enhance food preservation and safety. Cellulose can be mixed with other biodegradable polymers like chitosan, polyvinyl alcohol (PVA), or starch, which makes it even more useful because it can be made to have better mechanical and barrier qualities for certain uses [14]. Another significant is the valorisation of agro-industrial biomass waste as a cellulose source. The extraction and utilization of cellulose from agricultural residues such as corn stalks, rice husks, and sugarcane bagasse helps identify more sustainable sources of raw materials [4].

However, several challenges must be addressed. Cellulose's inherent hydrophilicity limits its water resistance, making it unsuitable for humid conditions. Mechanical strength and flexibility are also critical challenges. Cellulose-based plastics often exhibit brittleness and limited elongation at break, which restricts their use in applications that require durability and toughness. Blending with other materials or incorporating plasticizers can mitigate this issue. Furthermore, scalability and industrial feasibility remain significant obstacles. The production of cellulose-based plastics at commercial scales involves challenges such as achieving uniform dispersion, maintaining consistent film thickness, and managing drying processes. Additionally, the high cost of cellulose extraction, poses economic constraints compared to synthetic plastics.

Future research should focus on enhancing material properties, improving process scalability, and standardizing biodegradation assessments to ensure environmental safety and regulatory compliance. With continued innovation, cellulose-based plastics can play a vital role in sustainable material development.

5 Conclusion

This bibliometric analysis examined the research landscape of cellulose-based plastics by extracting 395 articles published between 1984 and 2024 from the Scopus database.

The findings reveal a significant upward trend in publication output over the last decade, highlighting the growing scientific interest in cellulose-based plastics as sustainable alternatives to conventional polymers. *Cellulose* emerged as the most productive journal with 23 articles. Geographically, China leads as the most prolific contributor with 115 publications. In terms of authorship, Xing Xiang Ji (China), Sabino de Gisi (Italy), Giovanni Gadelata (Spain), and Michele Notarnicola (Italy) are the top contributors, each having authored six publications.

Keyword co-occurrence analysis reveals four major research clusters: improving mechanical properties; application of cellulose-based plastics for food packaging; addressing environmental issues or environmental assessment; and enhancing water and heat resistance. These clusters reflect the dual focus of current research on improving material performance and aligning with environmental sustainability goals.

The results of this bibliometric study provide valuable insights into the evolving trends, influential contributors, and thematic priorities in cellulose-based plastics research. Looking ahead, strengthening global collaboration, advancing functional modification strategies, and enhancing material durability are expected to be key drivers in accelerating the transition toward sustainable bioplastic technologies, especially for cellulose-based plastics to replace conventional plastics.

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