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ARTICLE

GELLAN GUM, A SPHINGOMONAS MICROBIAL POLYSACCHARIDES: BIBLIOMETRIC ANALYSIS OF TRENDS AND APPLICATIONS

[*Gellan Gum, Mikrobial Polisakarida dari Spingomonas: Analisa Bibliometrik Tren dan Aplikasinya*]

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ABSTRACT

Bacterial polysaccharides have gained considerable interest in recent years because of their wide range of applications. Gellan gum (GG) is a biodegradable microbial exopolysaccharide that has a wide range of commercial applications due to its versatility. Although GG is being used more frequently, research on it continues to evolve. This study used bibliometric analysis to examine patterns in GG application research over the last four decades. The data were obtained from the Scopus database, and the study of performance was carried out using R-Studio Biblioshiny. The important factors that were evaluated included the type of documents, the annual trends in publication, the subject areas covered, the titles of the journals, the analysis of citations, the distribution of countries, and the analysis of keywords. A total of 714 documents associated to GG were found, with articles being the most common document type. There has been a significant increase in research on GG applications since 2009. China became the primary provider, but the United States showed substantial participation in international collaborations. VOSviewer was used to show the co-authorship between countries and the co-occurrence of keywords in the field of GG research, emphasizing the predominant concentration on biomedical topics. The findings suggest that emergent research trends are primed for additional industrial growth.

Keywords: bibliometric analysis, gellan gum, gellan gum application, VOSViewer

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ABSTRAK

Dalam beberapa tahun terakhir, polisakarida dari bakteri telah menarik perhatian yang signifikan karena aplikasinya yang beragam. Gellan gum (GG), biopolimer serbaguna, adalah eksopolisakarida mikroba yang dapat terurai secara hayati dengan aplikasi industri yang terus berkembang. Meskipun penggunaannya meningkat, penelitian tentang GG terus berkembang. Penelitian ini menggunakan analisis bibliometrik untuk mengeksplorasi tren penelitian aplikasi GG selama empat dekade terakhir. Data bersumber dari database Scopus, dan analisis bibliometrik dilakukan dengan menggunakan R-Studio Biblioshiny. Parameter utama yang dianalisis meliputi jenis dokumen, tren publikasi tahunan, bidang subjek, judul jurnal, analisis sitasi, distribusi negara, dan analisis kata kunci. Sebanyak 714 dokumen terkait GG diidentifikasi dengan artikel sebagai jenis dokumen yang paling banyak ditemukan. Penelitian tentang aplikasi GG telah melonjak sejak tahun 2009. China muncul sebagai kontributor utama, sementara Amerika Serikat menunjukkan keterlibatan yang signifikan dalam kolaborasi internasional. Kolaborasi penulis, negara serta kata kunci divisualisasikan menggunakan VOSviewer, yang menyoroti fokus biomedis dari penelitian GG saat ini. Penelitian ini menunjukkan bahwa tren penelitian mengenai gellan gum yang sedang berkembang siap untuk ekspansi industri lebih lanjut

Kata kunci : *analisa bibliometrik, aplikasi gellan gum, gellan gum, VOSviewer*

INTRODUCTION

Gellan gum is a biodegradable microbial exopolysaccharide produced by fermentation of the genus *Sphingomonas* (Dev *et al.*, 2022). Gellan gum possesses several significant attributes, such as its capacity to produce gels, sensitivity to heat and ions, ability to adhere to mucous membranes, and customizable physical and mechanical properties. These traits have generated considerable research interest in this biomaterial (Palumbo *et al.*, 2020).

Gellan gum is composed of a linear and negatively charged polysaccharide. The composition consists of a tetrasaccharide structure including one β-D-glucuronate, one α-L-rhamnose, and two β-D-glucose residues. Gellan gum exists in two commercial forms: native gellan gum, also known as high acyl gellan gum, and deacetylated gellan gum, also known as low acyl gellan gum (Zia *et al.*, 2018). Native gellan gum binds to the same β-D-glucose residue through two acyl groups (glycerate and acetate). Every repeating tetrasaccharide unit contains glycerate, whereas two units include acetate. Alkaline clarification can remove acyl groups from native gellan gum, resulting in deacetylated gum. Removing acyl groups alters the rheological characteristics of the resultant gels (Gomes *et al.*, 2023). In recent years, gellan gum has gained popularity on an industrial scale due to its increased functionality and low-cost biomaterial (Gomes *et al.,* 2023).

In 2020, the global market share of Gellan gum was valued at US$238 million. It is expected to reach US$420 million by 2030, with a compound annual growth rate (CAGR) of 6% from 2021 to 2030. The market is analyzed in Europe, including Germany, the UK, France, Italy, Spain, and other European countries. It is also studied in the Asia-Pacific region, including China, India, Japan, ASEAN, Australia, and other countries in the region. Additionally, the market is examined in North America, including the U.S., Canada, and Mexico. Lastly, it is analyzed in LAMEA, which includes Brazil, Argentina, the UAE, Saudi Arabia, South Africa, and other countries in the region. The Asia-Pacific region was the leading market globally and is expected to continue its dominance over the projected time frame (Allied Market Research, n.d.).

Nowadays, identifying and analyzing large amounts of scientific data can be done using bibliometric analysis. Bibliometric analysis allows us to discover the developmental complexity of an area of study while understanding its developing areas. It also examines the intellectual structure of a field by analyzing markers, including report and publication performance, relationships, and research components (Donthu *et al*., 2021). It also evaluates publishing and citation metrics and analyzes collaborators, references, bibliography connections, and frequently used phrases. Furthermore, quantitative and qualitative approaches are used in bibliometric analysis. Bibliometric data was visualized using various software such as VOSviewer, Leximancer, CiteSpace, Bibliometrix, and Gephi (Mukherjee *et al*., 2022).

Many scientific investigations have been carried out with the aim of enhancing the yield of gellan gum. The driving force behind these endeavors stemmed from the versatile applications of gellan gum across multiple industries, including food, pharmaceuticals, biomedicine, cosmetics, agriculture (Dev *et al*., 2022), and petroleum (Zia *et al*., 2018). Furthermore, it has unveiled prospects for doing novel research pertaining to the utilization of gellan gum. Hence, the objective of this study is to ascertain the latest progress in the utilization of gellan gum. In this study, the bibliometric analysis method was employed to ascertain the trajectory of gellan gum utilization during the past forty years. This study serves as a valuable resource for future research and the most recent utilization of gellan gum in the industrial sector.

MATERIALS AND METHODS

We used bibliometric approaches to obtain a comprehensive overview of the gellan gum application. Figure 1 illustrates the bibliometric analysis procedure for this study. Generally, the bibliometric analysis in this study consists of three stages: data searching, data extraction, and data analysis.

Data Searching

Data retrieval was conducted utilizing the Scopus database on January 10, 2024. The data retrieval specifically targeted 'gellan gum' or 'gellan gum application'. The subsequent query was executed: TITLE-ABS-KEY ("Gellan Gum" AND "Gellan Gum Application"). In the culmination, a total of 714 documents have been acquired.

Data Extraction

In this stage, data were taken from the Scopus database and analyzed statistically. Performance analysis and citation metrics were conducted using the software R-Studio Biblioshiny. The data was then performed science mapping using VOSViewer.

Data Analysis and Interpretation

Based on performance analysis and science mapping, data analysis and interpretation were carried out in the last stage. Analyzed were the document type, annual publishing trend, subject area, journal title, citation analysis, nation distribution, and keyword. An analysis of country co-authorship and keyword co-occurrence was conducted using science mapping techniques.

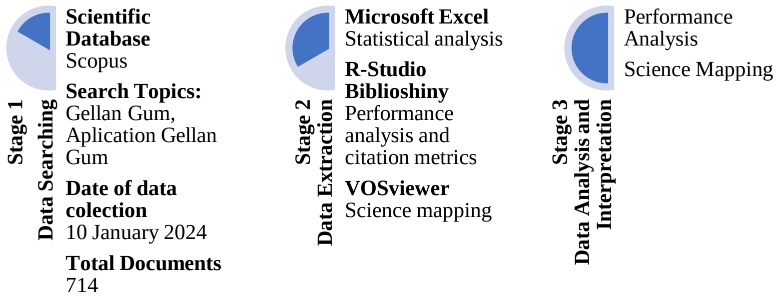

Figure 1. Bibliometric Analysis Process for the Application of Gellan Gum (*Analisa Bibliometrik untuk Aplikasi Gellan Gum*).

RESULTS

Type of Document

It comprises a total of 714 papers that have been classified into eight different types from the search results obtained from the Scopus database. The three most often published forms of papers are articles, reviews, and chapter books. Each category of document comprises 571 published articles, accounting for 79.97% of the total. Additionally, there are 51 review papers, making up 7.14% of the total, and 46 book chapters, which represent 6.44% of the total. Additional categories of published publications include conference papers (32 documents or 4.48%), books (6 documents or 0.84%), conference reviews (4 documents or 0.56%), brief surveys (3 documents or 0.42%), and data paper (1 document or 0.14%). Table 1 implies the publication types for the 714 documents pertaining to the research trends of gellan gum applications.

Table 1. Type of Publication (*Jenis Publikasi*).

Type of Publication (*Jenis Publikasi*)	**Total Documents** (*Jumlah Dokumen*)	**Percentage** (*Persentase*) **(%)**
Article	571	79.97
Review	51	7.14
Book Chapter	46	6.44
Conference Paper	32	4.48
Book	6	0.84
Conference Review	4	0.56
Short Survey	3	0.42
Data Paper	1	0.14
Total	**714**	**100**

Annual Publication Trend

Annual publication trends on gellan gum application based on total publication and total citation are shown in Figure 2.

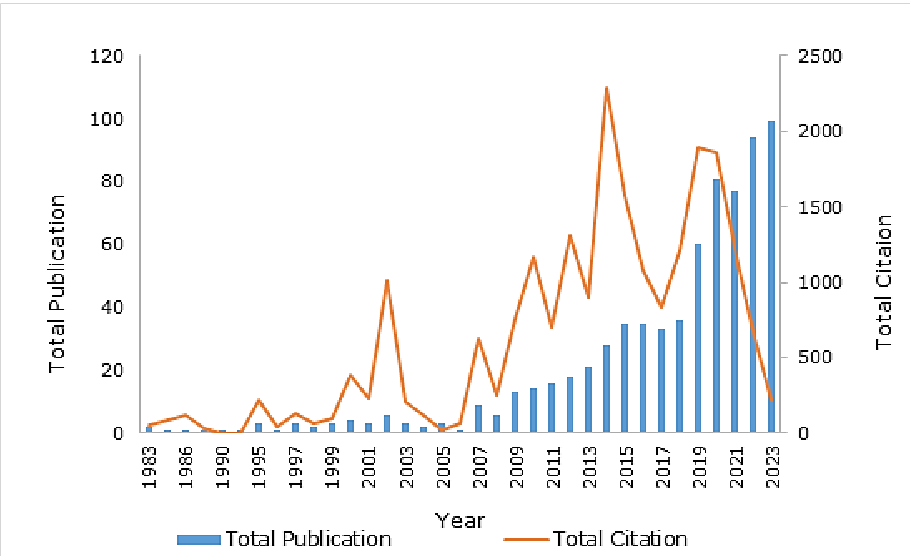

Figure 2. Annual Publication Trends of Gellan Gum Applications (*Tren publikasi penelitian mengenai gellan gum*)

Subject Area and Journal Tittle

The 714 documents are classified into numerous topic categories, with materials science accounting for 16.46% of the total, followed by chemistry (13.81%), biochemistry genetics and molecular biology (12.45%), chemical engineering (11.04%), and engineering (10.97%). Agricultural and biological sciences (8.75%), pharmacology, toxicology, and pharmaceutics (5.36%), immunology and microbiology (3.70%), physics and astronomy (3.51%), and medicine (3.45%) are all among the top ten subject areas. Table 2 contains the whole list of topic categories and table 3 contains top 10 journal title in gellan gum applications.

Table 2. Subject Area (*Topik subjek area*).

Subject Area (*Topik Area*)	**Total Publication** (*Jumlah Publikasi*)	**Percentage** (*Persentase*) **(%)**
Materials Science	267	16,46
Chemistry	224	13,81
Biochemistry, Genetics and Molecular Biology	202	12,45
Chemical Engineering	179	11,04
Engineering	178	10,97
Agricultural and Biological Sciences	142	8,75
Pharmacology, Toxicology and Pharmaceutics	87	5,36
Immunology and Microbiology	60	3,70
Physics and Astronomy	57	3,51
Medicine	56	3,45
Energy	42	2,59
Economics, Econometrics and Finance	32	1,97
Environmental Science	26	1,60
Business, Management and Accounting	13	0,80
Earth and Planetary Sciences	13	0,80
Computer Science	11	0,68
Multidisciplinary	11	0,68
Social Sciences	7	0,43
Health Professions	6	0,37
Arts and Humanities	3	0,18
Nursing	3	0,18
Mathematics	1	0,06
Neuroscience	1	0,06
Veterinary	1	0,06
Total	**1622**	**100**

Table 3. Journal Title (*Nama Jurnal*).

Journal Title (*Nama Jurnal*)	**TC**	**TP**	**h-index**	**g-index**	**PY_start**
International Journal of Biological Macromolecules	2059	51	24	45	2013
Carbohydrate Polymers	1821	35	24	35	1989
Food Hydrocolloids	609	20	11	20	2015
Polymers	124	12	7	11	2019
Materials Science and Engineering C	329	11	8	11	2013
Journal of Tissue Engineering and Regenerative Medicine	565	10	10	10	2009
International Journal of Pharmaceutics	579	10	7	10	2014
Journal of Food Processing and Preservation	46	9	4	6	2019
Journal of Food Science	157	8	7	8	2015
Colloids and Surfaces B: Biointerfaces	354	7	7	7	2003

TC: total citation (jumlah sitasi), TP: total publications (jumlah publikasi), PY_start: start of publication year (tahun dimulainya publikasi)

Citation Analysis

The Scopus database has a substantial impact on the metrics associated with citations. Table 4 shows the top five most cited publications on the research trend regarding gellan gum. The amount of citations is used to identify the most influential articles.

Table 4. Top 5 Cited Publications (*5 Jurnal dengan Sitasi Terbanyak*).

Author (*Penulis*)	**Year** (*Tahun*)	**Title** (*Judul*)	**TC**	**CpY**	**Source Title** (*Nama Jurnal*)
Luo and Wang	2014	Recent development of chitosan-based polyelectrolyte complexes with natural polysaccharides for drug delivery	595	54.09	International Journal of Biological Macromolecules
Janssen *et al*.	2002	Improved Culturability of Soil Bacteria and Isolation in Pure Culture of Novel Members of the Divisions Acidobacteria, Actinobacteria, Proteobacteria, and Verrucomicrobia	558	24.26	Applied and Environmental Microbiology
Gasperini *et al*.	2014	Natural polymers for the microencapsulation of cells	459	41.73	Journal of the Royal Society Interface
Kailasapathy	2002	Microencapsulation of probiotic bacteria: technology and potential applications.	382	16.61	Current issues in intestinal microbiology
Lozano *et al*.	2015	3D printing of layered brain-like structures using peptide modified gellan gum substrates	341	34.10	Biomaterials

TC: total citations (jumlah sitasi), CpY: citations per year (jumlah sitasi per tahun)

Country Contribution Analysis

In addition, we conducted an analysis of the extent to which each country contributes to the application of gellan gum. Pertaining to total document and citation metrics, Table 5 displays the five countries that have contributed the most. A total of 58 countries participated in the research article regarding the applications of gellan gum. China has the biggest number of studies, with 145 documents, followed by India with 110 documents and Portugal with 70 documents. The United States and United Kingdom made immense contributions, with 58 and 49 documents, respectively. China had the greatest total citation count of 2650, prior to India with 2559 citations and the USA with 2022 citations.

Table 5. Top 5 Countries Contribution based on Total Document and Total Citation (*5 Negara teratas berdasarkan jumlah publikasi dan sitasi*).

Country *(Negara)*	**Total Publication** (*Jumlah publikasi)*	**Total Citation** (*Jumlah sitasi*)
China	145	2650
India	110	2559
Portugal	70	1845
USA	58	2022
United Kingdom	49	393

Table 6 conveys the five countries that have the highest link strengths. Link strength is a measure of the extent of collaboration. As the level of connectivity between links improves, the frequency and importance of collaborations also increase. The VOSviewer software provides information on the link strength values. VOSviewer allows for the display of partnerships between authors from different countries, enhancing the understanding of scientific collaboration dynamics among authors from diverse nationalities (Liu & Edgar, 2002).

Table 6. Top 5 Countries Contribution based on Total Document and Total Link Strength (*5 Negara teratas berdasarkan jumlah publikasi dan keterkaitannya).*

Country (*Negara)*	**Total Publication** (*Jumlah publikasi)*	**Total Link Strength** (*Keterkaitan*)
United States	58	37
Portugal	70	37
United Kingdom	49	35
Belgium	14	26
China	145	25

With 58 papers, the United States had the greatest total link strength of 37, demonstrating its prominence in international partnerships with authors from different nations. Portugal also attained a total link strength of 37 across 70 documents, demonstrating its substantial involvement in international joint efforts. Although China has the highest number of papers, with a count of 145, it only ranked fifth in terms of international collaboration, with a total connection strength of 25. The United Kingdom and Belgium were both significant donors to international author collaboration, ranking among the top 5 countries in terms of total link strength. The United Kingdom had 35 contributions, while Belgium had 26.

The authors' international collaborations were represented in Figure 3 by VOSviewer. The United States possesses the greatest node due to its highest total link strength. The grouping of countries is denoted by the hues of both the vertices and the edges in the graph. The visualization revealed a total of eight clusters. The primary cluster, denoted by the color red, comprises seven countries: The United States, China, Saudi Arabia, Egypt, Pakistan, Turkey, and Singapore. The second cluster, indicated by the color green, consists of the United Kingdom, France, Italy, Spain, Romania, and Switzerland. The dark blue cluster comprises Belgium, Australia, Germany, the Netherlands, and Poland. The light green cluster consists of Malaysia, India, Iran, and Taiwan. The subsequent cluster, seen in the hue of purple, comprises Portugal, Brazil, and Canada. Finland and the Russian Federation constitute the orange cluster. Ultimately, the final cluster consists of Japan and Thailand.

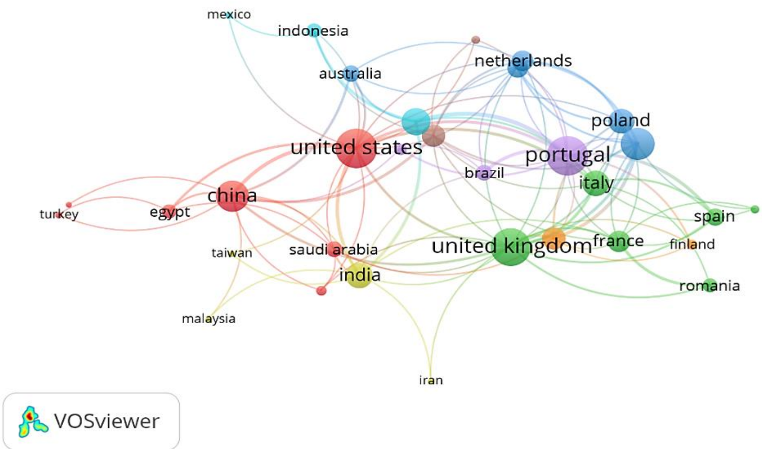

Figure 3. Visualization of Country Co-authorship (*Visualisasi kolaborasi antar negara*).

Keyword Analysis

Table 7 displays the top 20 keywords ranked by their overall link strengths. The term "Gellan gum" appeared 369 times and had a total link strength of 5379, making it the most frequently used keyword. The term "hydrogels" ranked second in terms of frequency, appearing 207 times. The term "Polysaccharides bacterial" ranked third in terms of frequency, appearing 204 times.

Table 7. Top 20 Keywords based on Total Link Strength (*20 Kata Kunci Teratas berdasarkan Kekuatan Tautan Total*).

No	**Keyword** (*Kata Kunci*)	**Occurrences** (*Jumlah*)	**Total Link Strength** (*Keterkaitan*)
1	Gellan Gum	369	5379
2	Polysaccharides, Bacterial	204	5216
3	Bacterial Polysaccharide	183	4712
4	Chemistry	183	4608
5	Hydrogels	207	3925
6	Controlled Study	135	3548
7	Nonhuman	137	3449
8	Human	114	2940
9	Tissue Engineering	121	2906
10	Animal	86	2556
11	Biocompatibility	100	1975
12	Scanning Electron Microscopy	81	1914
13	Drug Delivery System	71	1837
14	Gelation	94	1812
15	In Vitro Study	62	1724
16	Unclassified Drug	63	1621
17	Cell Culture	71	1618
18	Tissue	72	1585
19	Physical Chemistry	56	1556
20	Metabolism	55	1542

Figure 4 shows the four clusters that the keywords can be placed into. The first cluster, highlighted in red, comprises of keywords such as amino acids, animal cell, bioactivity, biocompatibility, biodegradation, biomaterial, bone development, biomedical application, bone regeneration, calcium phosphate, cartilage regeneration, cell adhesion, cell culture, cell death, cell growth, cell proliferation, cell structure, chondrocyte, composite hydrogel, cross-linking, cytology, degradation, drug effect, elastic modulus, endothelial cells, fibroblast, hydrogels, hydroxyapatite, in-vitro, mammals, mechanical properties, mineralization, osteoblast, osteogenesis, particle size analysis, pharmacology, physiology, pore size, porosity, rats, scaffold, tissue engineering, and young modulus. The second cluster, highlighted in green, includes various scientific terms such as adsorption, anthocyanin, antioxidant activity, bacterial polysaccharide, biofilm, chemical composition, chemical reaction, colorimetry, contact angle, elasticity, electrospinning, enzyme activity, Escherichia coli, flow kinetics, food packaging, hydrogen bond, hydrolysis, hydrophilicity, ions, metal nanoparticles, moisture, molecular weight, nanocomposite, nanofabrication, pH, shear rate, scanning electron microscopy, surface properties, synthesis, temperature, tensile strength, thermodynamic stability, ultrastructure, viscoelasticity, water vapor, and x-ray diffraction. The third cluster consists of various components such as agarose, alginate acid, bacteria, biomolecules, biosynthesis, biopolymer, carrageenan, cellulose, chitosan, coatings, controlled release, dextran, drug delivery, drug products, emulsification, encapsulation, enzymes, gellan gum, glucose, glucuronic acid, gur gum, phase separation, polyelectrolytes, polysaccharides, probiotics, proteins, Spingomonas elodea, wound dressing, wound healing, xanthan gum, and yeast. The last cluster is characterized by a light yellow color and encompasses various topics such as adhesives, animal experiments, antibacterial activity, carboxylmethylcelulose, comparative study, controlled drug delivery, diffusion, drug bioavailability, drug carrier, drug efficacy, drug formulation, drug release, ex vivo study, hardness, intranasal drug administration, medicinal chemistry, nanoencapsulation, poloxamer, stability, viscosity, and zeta potential. The Figure 5 overlay representation of the term overyear is displayed.

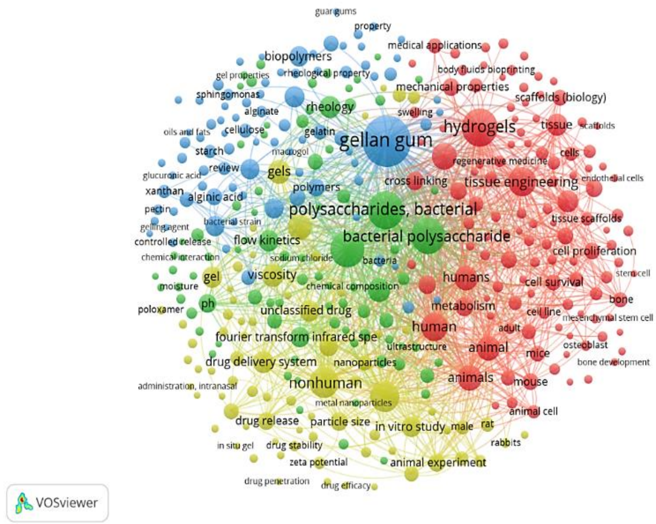

Figure 4. Visualization of Keyword Co-Occurrence (*visualisasi keyword yang sering muncul*).

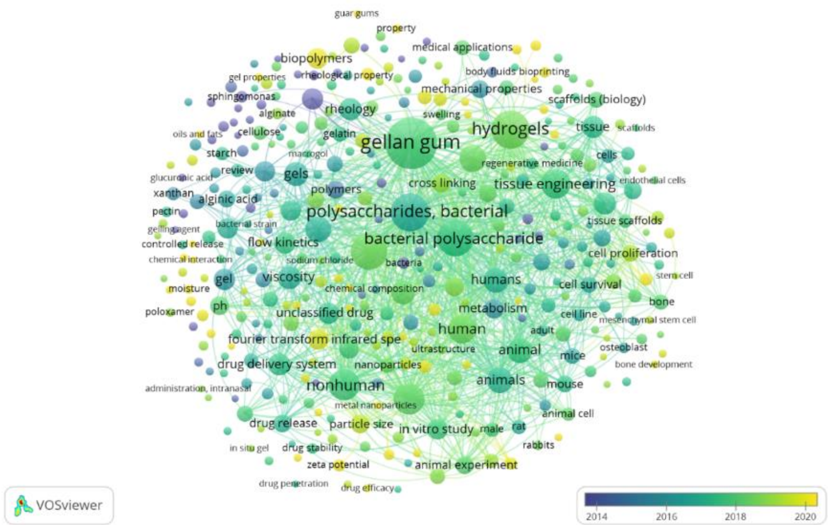

Figure 5. Overlay Visualization Map of Keywords (*Visualisasi keyword berdasarkan waktu*).

DISCUSSION

The annual publication trends of gellan gum are shown in Figure 2. Before 2007, little attention was paid to gellan gum application research since less than ten publications are produced yearly. As the total publication reached its pinnacle in 2023 with 99 documents, an increasing trend is shown starting in 2009. It illustrates a growing desire among academics to learn more about gellan gum.

A total of 150 journal titles were published to examine the current study pattern regarding the utilization of gellan gum. Table 3 depicts the 10 most prominent journal titles. Total Publications (TP) measures the quantity of documents (publications), whereas Total Citation (TC) quantifies the number of citations for each journal title (Lam *et al.*, 2023). The h-index evaluates the impact of journals and writers based on the number of papers they have published and the number of citations those articles have received. In contrast, the g-index evaluates impact by considering the estimated distribution of citations. Thus, the h-index and g-index are important metrics to use when gauging the journal's production (Dominković *et al.*, 2022). The journal "International Journal of Biological

Macromolecules" has the highest number of publications, with 51 articles, and has received 2059 citations. It is closely followed by "Carbohydrate Polymers," which has published 35 articles and received 1821 citations. Notably, "Carbohydrate Polymers" holds the distinction of being the first journal to publish in this topic field since 1989. The journal "Food Hydrocolloids" ranks third in terms of publication frequency, with a total of 20 papers and 609 citations.

The document titled "Recent development of chitosan-based polyelectrolyte complexes with natural polysaccharides for drug delivery" by Luo and Wang in 2014 is the most frequently referenced publication, with a total of 595 citations. The article discussed recent developments in the field of drug delivery utilizing chitosan-based polyelectrolyte complexes (PEC) with natural polysaccharides, such as alginate, hyaluronic acid, pectin, carrageenan, xanthan gum, gellan gum, gum arabic, and carboxymethyl cellulose (Luo and Wang, 2014). The publication titled "Improved Culturability of Soil Bacteria and Isolation in Pure Culture of Novel Members of the Divisions Acidobacteria, Actinobacteria, Proteobacteria, and Verrucomicrobia" by Janssen *et al*. in 2002 is the second most cited document, with a total of 558 citations. The paper pointed out the most potent medium for culturing soil bacteria is dilute nutrient broth (DNB) with the addition of gellan gum (Janssen *et al*., 2002). The work authored by Gasperini *et al*. in 2014, which has been mentioned the most, examines the process of enclosing living human cells within a hydrogel matrix that allows for selective passage of substances (Gasperini *et al*., 2014).

Kailasapathy *et al*. authored a paper entitled "Microencapsulation of probiotic bacteria: technology and potential applications" which garnered 382 citations. For the micro-encapsulation of probiotic bacteria, the authors investigated the use of starch, gellan gum, kappa-carrageenan, and gelatin (Kailasapathy, 2002). Lozano *et al*. received a total of 341 citations for their study titled "3D printing of layered brain-like structures using peptide modified gellan gum substrates". The researcher examined the alteration of peptides in the gellan gum hydrogel, which significantly enhances the growth of primary cells and the creation of brain networks (Lozano *et al*., 2015).

Figure 5 depicts an overlay visualization map that showcases the distribution of keywords, providing insights into the patterns and developments in publications about the application of gellan gum. The keywords highlighted in yellow signify the most recent developments and current areas of focus for scholars. The mentioned terms are anthocyanin, wound dressing, colorimetry, nanofiber, pharmacology, 3D printing, anti-infective drugs, zeta potential, and food packaging. These keywords represent new and creative uses and areas of interest in the field of gellan gum research.

Currently, pharmacology is the main focus of study on gellan gum. This research covers a wide range of inquiries into its pharmacological effects, how drugs are released from it, how it delivers drugs, its ability to heal wounds, and its potential as an anti-infective agent. Gellan gum has attracted considerable interest in drug administration and wound healing applications due to its non-toxic nature, gelation capabilities, and biocompatibility, both when used alone and in combination with synthetic and natural chemicals or polymers (Xu *et al*., 2018). Thorough investigation has shown that it can be used with a wide range of polymers, including both natural and manufactured ones. Nevertheless, the extensive utilization of this substance is impeded by its restricted mechanical robustness when utilized as a framework or in materials for wound healing. Although gellan films have been thoroughly studied for their potential in wound healing, there is still limited research on hydrogel-based systems in this area. Gellan gum (GG) is a popular choice for making wound dressings because it contains a lot of water and is a soluble biopolymer. It has the unique capacity to create films or membranes that can be used for repairing tissue (Ferris *et al*., 2013).

Liu *et al*. undertook a pioneering study to explore the possibility of a composite film made of gellan gum, zinc oxide, and carbon nanotubes for wound healing (Liu *et al*., 2022). Ravi *et al*. (2023) developed a new hydrogel method using gellan gum to provide ascorbic acid topically for wound care management. This work focused on altering the structure of grafted poly (ethylene glycol) methacrylate by attaching it to the renewable biopolymer gellan. This process led to the creation of a graft copolymer (GPMA) that was crosslinked through both covalent and ionic bonds. This novel matrix efficiently administered ascorbic acid to wounds, providing promising therapeutic advantages. In a complementary investigation, Reczyńska-Kolman *et al*. explored composite wound dressings based on gellan gum and alginate, focusing on enhancing antibacterial activity by incorporating the antibacterial peptide nisin (NSN) (Reczyńska-Kolman *et al.*, 2021). Their research provided vital knowledge regarding the advancement of materials used in wound treatment. In addition, Özkahraman *et al.* investigated the creation of a bilayer wound dressing made of gelatin and gellan gum. Their research intended to speed wound healing by inhibiting bacterial infections. The bilayer hydrogels functioned as efficient carriers for releasing antibiotics, demonstrating a promising strategy in the treatment of wounds (Özkahraman *et al.*, 2022).

Gellan gum has shown great potential as a valuable component in packaging films. In recent years, there has been a global focus on the creation and use of active films, namely those that are biodegradable and possess antibacterial and antioxidative capabilities (Gong *et al.*, 2018). Gellan gum has limited water resistance but does have inherent antibacterial and antioxidant properties. As a result, academics have investigated many approaches to improve its effectiveness. These methods involve combining gellan gum with other biopolymers or mixing it with naturally occurring chemicals or inorganic nanoparticles like zinc oxide, TiO2, and montmorillonite clay. The objective of these endeavors is to enhance the film's ability to repel water, its capacity to operate as a barrier (Zhang *et al.*, 2017) and antimicrobial activity (Du *et al.*, 2019).

Innovative polyvinyl alcohol/gellan gum-based bioplastics were developed by Elsaeed *et al.* (2023). This study examined the impact of adding guava leaves and chickpea extracts to improve the tensile properties of polyvinyl alcohol/gellan gum bioplastics (Elsaeed *et al.*, 2023). In a related endeavor Chen *et al.* investigated the possible use of gellan gum in biofilm packing. Their methodology consisted of combining gellan gum with bacterial cellulose and nano-TiO2/CuO in order to extend the duration that fresh-cut pepper remains suitable for consumption. The addition of bacterial cellulose greatly improved the mechanical strength, barrier characteristics, and stability of the films made from gellan gum (Chen *et al.*, 2023). Yue *et al.* (2023) made a significant contribution to this discipline by creating a triple-layer film. The biofilm consisted of a layer of polyvinyl alcohol (PVA) that provided protection, a layer made of a combination of gellan gum (GG) and PVA that incorporated Alhagi sparsifolia flower extract (AFE) to enhance antioxidative properties, and a control layer of GG that released antioxidants slowly. The inclusion of AFE in the films resulted in a decline in the water vapor and oxygen barrier characteristics, as well as a decrease in tensile strength. Nevertheless, it enhanced the light barrier characteristics, elongation at break, and antioxidative capabilities. The study conducted by Yue *et al.* in 2023 found that the three-layer biofilm structure had superior properties in blocking light, water vapor, and oxygen. Additionally, it showed an enhanced ability to slowly release antioxidants (Yue *et al.*, 2023).

CONCLUSION

Recent research on gellan gum (GG) has seen significant growth, predominantly in journal articles. The most cited work by Luo and Wang (2014) has amassed 595 citations since 2014. China leads in GG publications, with 145 documents, and top sources include the "International Journal of Biological Macromolecules." Keyword analysis reveals a strong focus on biomedical and pharmacological applications of GG, particularly in wound dressing. GG research is also expanding into biofilm packaging, blending with other biopolymers, and incorporating active natural compounds or nanoparticles to improve water resistance, barrier properties, and antimicrobial activity. This study, relying solely on the Scopus database, may have minor limitations. However, the overall conclusions and identified trends are robust. This research serves as a foundation for future studies and industrial applications of GG.

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AUTHOR CONTRIBUTIONS

All authors are the main contributions to this paper. FAS: conceptualization of the study, collecting research data, drafting the article; IPM: processing data, visualizing concept and data, drafting the article; FT: define the research method, R: data collection and supervision

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