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A bibliometric analysis of polymer composites reinforced with jute and flax fibers: research trends and scientific mapping

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Abstract. Polymer composites reinforced with natural fibers, such as jute and flax, have emerged as sustainable alternatives to synthetic fiber-reinforced polymers for structural and biomedical applications. This bibliometric and scientometric review aimed to map the scientific production on jute- and/or flax-reinforced epoxy and polyester composites published between 2014 and 2024 using data retrieved from the Scopus database. The study followed a multi-step approach involving quantitative bibliometric analysis, scientific mapping with VOSviewer, and qualitative thematic synthesis. After applying the eligibility criteria, 182 articles were included. The results showed a marked increase in scientific production from 2019 onward, with India standing out as the leading country in publication output and international collaboration. The literature was predominantly focused on mechanical properties, particularly tensile, flexural, and impact performance, with epoxy resins appearing as the most frequent matrix. Emerging topics included curing behavior, glass transition, hybridization, and biocompatibility. Despite the expansion and consolidation of the field, few studies have addressed thermal comfort, long-term durability, dynamic performance, or clinical integration in biomedical applications. These findings indicate that jute- and flax-reinforced polymer composites represent a growing and promising research area, while also highlighting the need for interdisciplinary studies focused on biomedical functionality, sustainability, and long-term performance.
Keywords: Bibliometric analysis, Epoxy resin, Flax fiber, Jute fiber, Mechanical properties, Polymer composites.

Introduction

Historical records indicate that ancient civilizations already used mixtures, such as clay with straw, for the construction of dwellings. However, it was from the mid-20th century onward that composites gained prominence with the manufacture of designed and engineered multiphase composites (Callister, 2019). In recent decades, composite materials have attracted the attention of researchers in the fields of materials science and engineering, and with technological advances, the production of lightweight, strong, and versatile materials with a broad spectrum of applications has increased (Mittal et al., 2016; Hu et al., 2019).

Modern composites are classified, according to the nature of the matrix, into three categories: polymeric, metallic, and ceramic. Polymer-matrix composites have advantages such as a lower volume-to-weight ratio; a higher specific strength-to-weight ratio; the ability to be molded into different shapes and sizes; corrosion resistance; an easy manufacturing process; and lower cost (Mittal et al., 2016; Dahy, 2017).

The growing environmental concern and demand for sustainable practices have continuously driven interest and advances in research in polymeric materials science. Among the most prominent materials, fiber-reinforced polymers (FRPs) have received significant attention due to their exceptional mechanical properties and versatility of application. The combination of the mechanical, chemical, and biological properties of these materials makes them suitable for a variety of biomedical applications, such as tissue engineering, drug delivery, implant design, and prosthetic sockets (Karim et al., 2023; Ortiz et al., 2023; Qureshi, 2022).

Fiber-reinforced polymer (FRP) is a material that has been applied for decades in the maritime, automotive, aerospace, railway, sports (Correia, 2015; Hollaway, 2010), and, more recently, biomedical industries (Sikkema et al., 2020). The combination of the mechanical, chemical, and biological properties of these materials makes them suitable for a variety of biomedical applications, such as tissue engineering, drug delivery, implant design, and prosthetic sockets (Francis, 2021; Hamad et al., 2023).

In general, FRP composites consist of a polymeric matrix, commonly epoxy and polyester, reinforced with synthetic fibers such as carbon, glass, and Kevlar (Karim et al., 2023; Liu et al., 2015; Vara Prasad & Talupula, 2018). The combination of these properties has driven their application in modern engineering and bioengineering projects, consolidating their importance in the development of innovative solutions. These materials have low density, corrosion resistance, and high specific strength and stiffness values (Hollaway, 2010). In addition, they are easy to process and allow customization to meet specific requirements (Tănase et al., 2024).

Traditionally, FRPs are reinforced with synthetic fibers, which, although they provide superior mechanical performance, present environmental limitations, notably non-biodegradability and the high energy consumption required for their production (Sumithra et al., 2023; Rajak et al., 2021; Isik et al., 2024). Greater attention has been given to the use of sustainable, biodegradable, and green composites due to the large amounts of waste generated and the scarcity of fossil fuels (Wang et al., 2019).

Polymeric composites reinforced with natural fibers (PCRNFs) emerge as promising alternatives due to their exceptional attributes, such as cost-effectiveness, light weight, higher specific modulus, abundant availability, and biodegradability, combining the environmental advantages with competitive mechanical properties (Jawaid & Abdul Khalil, 2011; Faruk et al., 2012; Sanjay et al., 2018; Santos et al., 2024).

Among the natural fibers that are widely used as reinforcement, the most common are flax, jute, hemp, banana, sisal, kenaf, and ramie (Holbery & Houston, 2006). The fibers used in PCRNFs, as they come from renewable sources, offer greater environmental friendliness compared to pure polymers or conventional polymer composites (Bhat et al., 2023).

Among the numerous natural fibers, flax fibers are the most widely used, and this popularity is due to their versatility, high tensile strength (Bourmaud et al., 2018), good vibration absorption (Monette et al., 2021; Mathijsen, 2018), and a well-established harvesting method (Richely et al., 2022). Another commonly used fiber is jute, which is biodegradable and the second most employed natural fiber as a reinforcement source for polymer composites, recognized as an excellent alternative in terms of strength, thermal conductivity, and low cost (Islam & Alauddin, 2012).

Natural fibers such as flax and jute represent sustainable alternatives for polymer composites, reducing dependence on non-renewable resources. Bibliometric analysis is a strategic tool for monitoring the evolution of the topic, identifying influential research, prominent authors and institutions, and guiding decisions by researchers and policymakers in this growing field.

Considering the above, the objective of this research was to conduct a scientometric analysis of bibliometric data on jute and flax fibers as reinforcement sources for epoxy or polyester polymer matrices for diverse and biomedical applications.

Contextualization and analysis

Bibliometric approach and methodological procedures

The present article is a bibliometric and scientometric review involving data collection and synthesis on polymer composites made of polyester or epoxy resin reinforced with natural jute and flax fibers, used individually, hybridized with each other, or combined with other natural or synthetic fibers. The study was conducted in three stages: quantitative bibliometric analysis, bibliometric mapping using VOSviewer, and qualitative thematic synthesis based on the mapped results.

General bibliometric approach

Bibliometric analyses have been increasingly used in several research areas, such as geopolymer composites (Yang et al., 2022), metal matrix composites (Sekhar et al., 2021), recycling of fiber-reinforced plastics (Colombo et al., 2022), thermal energy storage in cement composites with phase change materials (Afgan & Bing, 2021), straw/rice husk polymer composites (Deepak et al., 2021), magnesium oxychloride cement-based construction materials (Maier & Manea, 2022), and applications of lignocellulosic fibers in polymer and hybrid composites (Santos et al., 2024). This analytical approach has become particularly prominent in composite materials research, providing critical insights and trends, thus justifying the present study.

Data source and search strategy

Numerous publications have addressed the topic under study, reinforcing the need to choose a reliable database for the retrieval of relevant academic articles. For this reason, the Scopus database, from Elsevier, was selected due to its broad multidisciplinary coverage and strong representation in the areas of health sciences, exact sciences, and engineering. The platform brings together documents from specialized databases such as Medline, Embase, Compendex, World Textile Index, Fluidex, Geobase, and Biobase (Pranckutė, 2021).

The search strategy employed a combination of relevant keywords and Boolean operators to ensure comprehensive and focused retrieval of articles. The search was performed on 8 May 2025. in the TITLE-ABS-KEY field of Scopus. The search string used was: TITLE-ABS-KEY(("jute fiber*" OR "flax fiber*" OR jute OR flax OR linen) AND ("epoxy resin*" OR "polyester resin*" OR epoxy OR polyester) AND (composite* OR laminate*) AND ("mechanical properties" OR tensile OR flexural OR impact OR thermal OR "water absorption")). This strategy aimed to capture articles addressing the use of jute and/or flax fibers as reinforcement sources for polymer matrices, including mechanical, chemical, thermal, and morphological properties, as well as applications in different industries and sectors.

Eligibility criteria

To ensure the relevance and quality of the retrieved articles, the following documents were included: full articles published between 2014 and 2024, in English, related to the reinforcement of epoxy or polyester resin laminates through the application of jute and flax fibers, used individually or hybridized with each other or with other fibers. The exclusion criteria were studies that did not perform mechanical tests on laminated composites; studies that did not test epoxy and polyester resins; and studies that did not analyze jute or flax fibers as reinforcement options for the resins.

Data collection and screening

The data collection process involved a systematic search of the Scopus database using predefined criteria, as previously mentioned. To determine how the articles fit within the context of this research, filters were established (Table 1) following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) methodology: identification, screening, eligibility, and inclusion (Moher et al., 2010).

Table 1. Search limits and filters applied to records retrieved from the Scopus database.

Option	Applied Filter
Range	2014 to 2024
Document type	Article
Language	English
Keyword	Epoxy Resins, Polyester Resins

Data extraction and VOSviewer analysis

Data extraction was conducted independently by two reviewers in order to minimize bias and increase the reliability of the results. In cases of disagreement, a third reviewer was consulted to resolve conflicts and reach consensus, ensuring validation of the collected information and consistency in the bibliometric analyses, which contributed to strengthening the methodological rigor of the review.

The VOSviewer software (version 1.6.20) was used for metadata analysis of the articles. VOSviewer is an open-source software tool available free of charge and is commonly used across a variety of fields.

For this research, articles were extracted through searches of titles, abstracts, and keywords. Publication trends over time were examined to identify growth patterns and research hotspots. Citation networks were constructed to identify influential authors in the domain. Keywords were analyzed to identify common themes and trends. Countries and publication sources were also analyzed.

Table 2. Various options selected, and constraints applied during VOSviewer analysis.

Analysis	Option	Limit Applied
Authors mapping	Analysis type	Bibliographic coupling
	Analysis unit	Authors
	Minimum publications by author	02
Citation mapping	Analysis type	Citation
	Analysis unit	Documents
	Minimum number of citations	04
Countries mapping	Analysis type	Bibliographic coupling
	Analysis unit	Countries
	Minimum publications by country	02
Mapping of publication sources	Analysis type	Bibliographic coupling
	Analysis unit	Sources
	Minimum publications by source	04
Keywords co-occurrence	Analysis type	Co-occurrence
	Analysis unit	All keywords
	Minimum co-occurrence	10

The data analysis considered article titles, abstracts, and keywords, providing a comprehensive overview of the research landscape during the period from 2014 to 2024. The Comma-Separated Values (CSV) file extracted from the database was imported into VOSviewer. The software performed reading and extraction of bibliographic metadata, as well as normalization of author names, countries, institutions, and publication sources. Based on this, mapping networks were generated for authors, citations, countries, publication sources, and keyword co-occurrence, enabling a structured visualization of relationships and trends present in the analyzed scientific literature. The various options selected at each stage and the limits applied in the software analysis are shown in Table 2. The different aspects, their networks, and co-occurrences were illustrated through the creation of maps, while their statistical values were displayed through the construction of tables.

The methodological flow of data analysis began with the selection of the Scopus database, followed by data extraction in CSV format. Subsequently, VOSviewer was used to organize and interpret the metadata. The process culminated in the quantitative bibliometric analysis, scientific mapping, and qualitative thematic synthesis.

Bibliometric mapping and thematic analysis

Initially, 1,043 articles were identified, after which they were subjected to a screening process in which filters were applied, namely: publication period, document type, English language, and keywords, as described in Table 1. After applying these filters, 248 articles remained, which were analyzed through the reading of titles and abstracts for eligibility. Following the application of the exclusion criteria, 182 documents were included in the study. The activities considered in each phase of this quantitative analysis are presented in Figure 1.

Scientific production over time

Figure 2 illustrates the distribution of articles published each year, from 2014 to 2024, within the scope of the review.

It can be observed that in the early years (2014–2018), research in this field remained relatively low, with an average of seven publications per year, considering that in 2014 no studies were identified on the topic under analysis. In 2019, interest in the topic and the number of documents showed significant growth, with 22 studies in the area, remaining stable in 2020; however, a decline was observed in 2021, with 18 publications. In 2022, research on the topic reached its peak, with a total of 38 publications. In 2023, there was another decline, with 16 articles, followed by renewed growth in 2024, with 30 studies.

Between 2015 and 2018, publications on polymer composites reinforced with natural fibers were strongly focused on the mechanical characterization of laminates and their structural performance under different testing conditions. The articles “Fabrication, characterization, and modeling of laminated composites based on woven jute fibers reinforced with epoxy resin” (Abdellaoui et al., 2015) and “Mechanical properties of waste paper/jute fabric reinforced polyester resin matrix hybrid composites” (Das, 2017) point to an almost exclusive emphasis on tensile testing, hydromechanical characterization, and structural damage analysis. The journals that published these studies, such as, “Materials and Design” and “Carbohydrate Polymers”, reinforce the technical and materials-engineering-oriented focus of this research.

On the other hand, studies published in 2024 show a considerable expansion of the thematic scope. In addition to mechanical properties, the emergence of concerns related to environmental sustainability can be observed, demonstrating alignment with the objectives of the UN 2030 Agenda and life cycle assessment, as evidenced by the approach adopted by Cáceres (2024) in their article “Experimental Global Warming Potential-Weighted Specific Stiffness Comparison among Different Natural and Synthetic Fibers in a Composite Component Manufactured by Tailored Fiber Placement.” Other studies incorporate higher levels of experimental complexity, such as the use of nanodiamonds, stacking sequence variations, and low-velocity impact testing, indicating methodological advances in the investigation of material strength and dynamic behavior. Furthermore, the presence of journals such as “Polymers” and “Engineering Research Express” suggests an openness to more interdisciplinary approaches, including potential applications in health and environmental fields.

This comparison highlights an evolution in the research field, which starts from a solid foundation of studies focused on mechanical performance (2015–2018) and advances toward a broader and more technically sophisticated agenda in 2024, incorporating environmental, functional, and sustainable variables aligned with contemporary demands in engineering and ecological materials.

The reduction in the number of publications in 2023 after the peak observed in 2022 may reflect multiple factors. One possible factor relates to the natural cycles of scientific production. The growth observed up to 2022 may reflect momentum associated with strategic investments in research focused on sustainability and materials innovation, especially during and after the COVID-19 pandemic, a period marked by a significant increase in funding for applied research areas such as health, rehabilitation, and biocomposites (Chiari et al., 2022). In addition, external factors such as natural disasters and extreme climate events may have directly impacted the productive capacity of research centers and universities in countries with strong representation in this field, such as India, a country notably affected by floods and severe heat waves in recent years (Albugami et al., 2025). Such events not only compromise institutional infrastructure and logistics but also interfere with the availability of agricultural raw materials widely used in studies on natural composites (Beauvais et al., 2022).

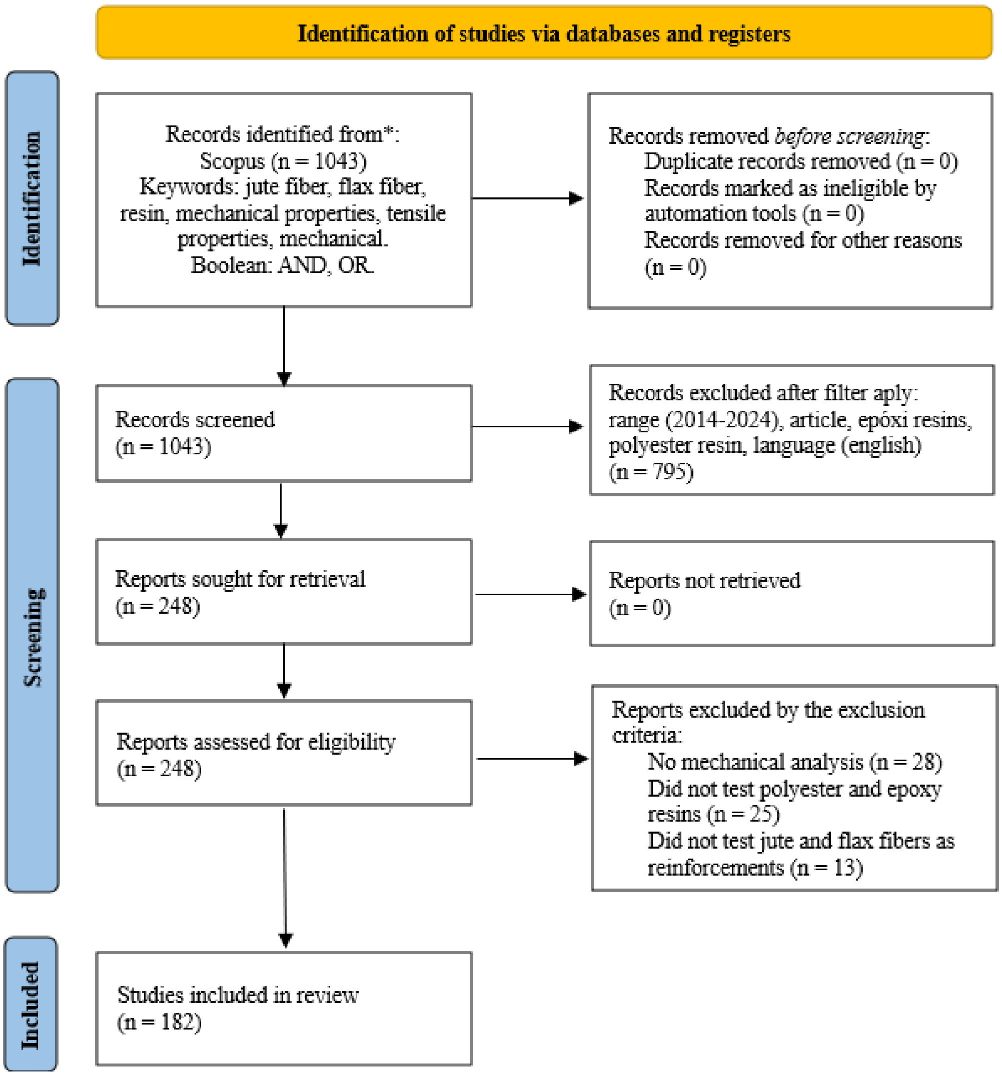

Figure 1. Flowchart of the screening and eligibility phases

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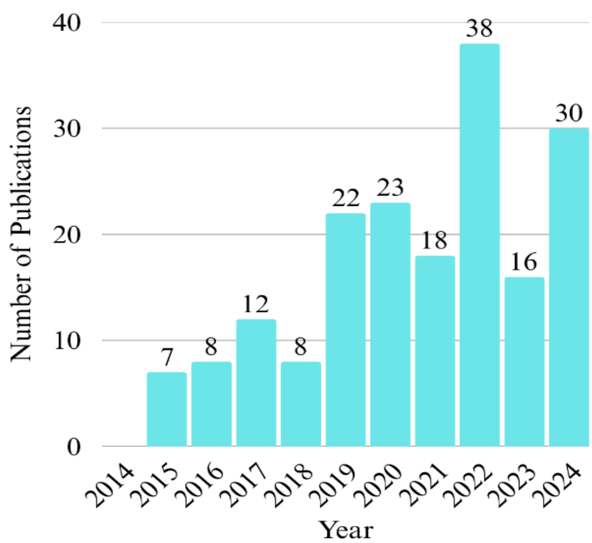

Figure 2. Distribution of articles per publication year.

Nevertheless, despite the factors mentioned, there has been an expansion in scientific output over the past six years, indicating that polymers reinforced with jute and flax fibers have gained significant prominence in research on sustainable fiber-reinforced composites, likely driven by increased awareness of environmental sustainability and advances in materials science, pointing to a peak in research activity. This suggests that the field has reached a high level of maturity and widespread interest among researchers. This growth is consistent with the study conducted by Santos et al. (2024), who analyzed applications of lignocellulosic fibers in polymeric and hybrid composites from 2012 to 2022 and identified a significant increase in the number of studies starting in 2019, with a peak in 2022, the last year included in their analysis. Data collected in the review carried out by Sun et al. (2023) also demonstrate progressive growth in the number of articles examining natural fibers during the first two decades of the 21st century, especially from 2019 onward, corroborating the findings of the present study.

Author mapping

Based on the criteria described in Table 2, an analysis of bibliographic coupling among authors was carried out using VOSviewer. This step aimed to identify the main researchers and collaborative groupings in the literature related to polymer composites reinforced with natural jute and/or flax fibers. Next, Figure 3 presents the generated mapping, highlighting the clusters formed from the similarity of the bibliographic references used by the authors included in the sample.

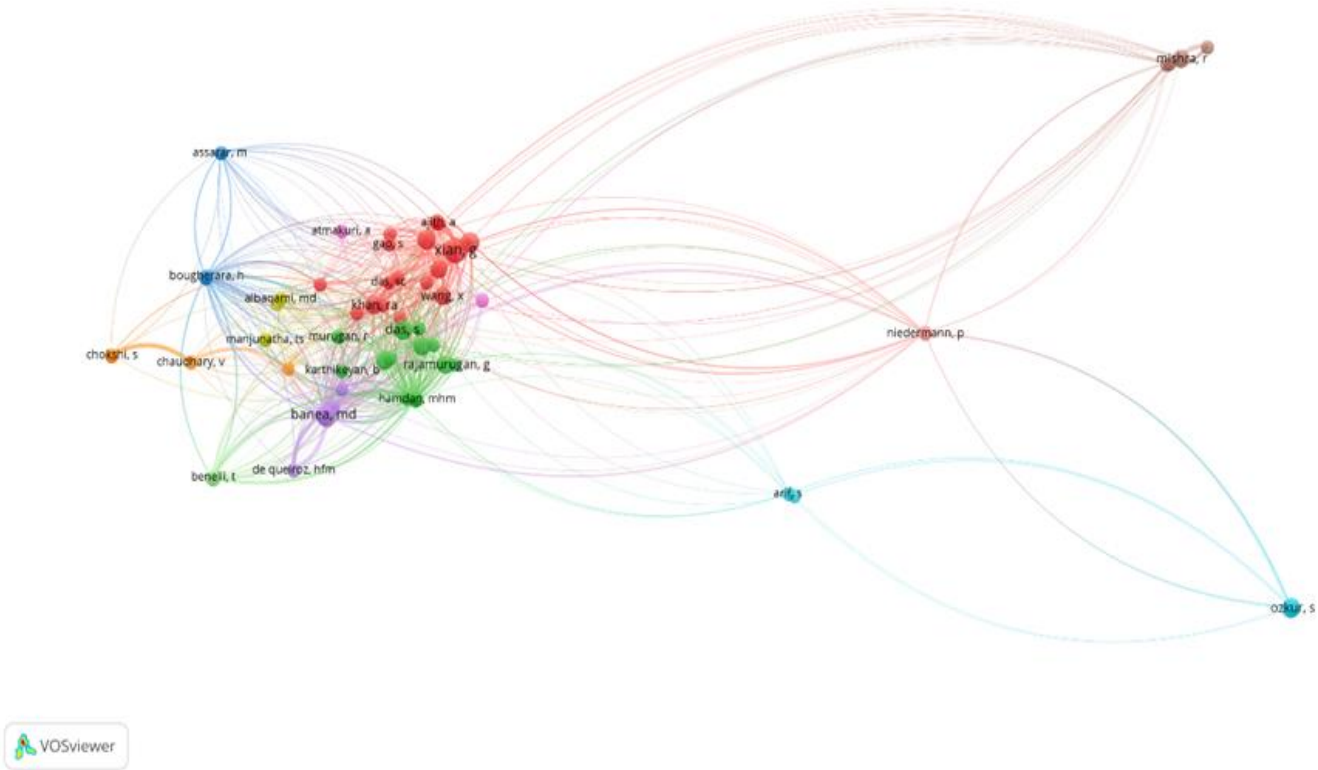

Figure 3. Bibliographic coupling map between authors with at least two publications related to polymer composites reinforced with natural jute and/or flax fibers. The colors represent different clusters of authors with greater similarity in the references used.

In the figure, the thickness of the connections between the nodes indicates the degree of bibliographic similarity, while the size of the nodes reflects the number of publications or the relevance of the author within the analyzed set. Authors with a greater number of connections act as central nodes, influencing the structure and direction of research on natural composites.

The map reveals the presence of six main clusters, represented by different colors, which group authors with greater bibliographic similarity.

The red cluster, central and densely connected, highlights authors such as Xian, G., Wang, X., Das, S.C., and Gao, S. This group represents the most consolidated thematic core of the network, indicating strong overlap in the references used and probable alignment in research lines, with emphasis on composites reinforced with natural fibers (Wang et al., 2015; Das et al., 2021; Yang et al., 2022). Xian G., the author with the highest number of included studies, has investigated the effects of nanoparticles grafted onto fiber surfaces on the mechanical properties of natural fiber composites (Ajith et al., 2016; Sherief et al., 2017; Wang et al., 2019). Another highly relevant theme is the effect of fiber stacking sequence on the mechanical performance of laminates, as addressed by Das et al. (2021).

The green cluster is formed by authors such as Krishnasamy, P., Karthikeyan, B., Hamdan, M.H.M., and Das, S., who exhibit high internal cohesion and reflect an active group with significant output in polymeric materials reinforced with plant fibers, especially in structural applications. Representative studies in this group address dynamic mechanical behavior, nanofiller addition, water absorption, and jute-polyester composite performance (Das, 2017; Hamdan et al., 2019; Krishnasamy et al., 2021; Arun Kumar et al., 2024).

The light blue cluster highlights a sub-network led by Ozkur, S. and Arif, S., with clear connections among group members but less interaction with the central clusters (Ozkur et al., 2020; Shah et al., 2024). This group presents a more specific thematic focus, such as the optimization of epoxy resin through the addition of acrylated epoxidized soybean oil (Ozkur et al., 2021; Ozkur et al., 2022).

The dark blue cluster, whose most representative author is Assarar, M., shows a group with peripheral connections and lower relational density (Chilali et al., 2018; Cheour et al., 2020). The arrangement and thickness of the edges indicate a more restricted collaboration network.

The purple cluster includes authors such as Cavalcanti, D.K.K., Banea, M.D., de Queiroz, H.F.M., Neto, J.S.S., and Lima, R.A.A. This thematically cohesive group suggests institutional proximity and concentrated collaborations, possibly in regional contexts, including Latin American ones. Representative studies in this cluster analyzed natural fiber-reinforced hybrid composites, adhesively bonded joints, jute-sisal hybridization, and curauá fiber applications (Cavalcanti et al., 2019; De Queiroz et al., 2020; Cavalcanti et al., 2021).

The orange cluster, formed by authors such as Chokshi, S. and Chaudhary, V., shows a smaller number of connections with the other clusters, which may reflect an alternative or more recent approach within the field, including mathematical modeling and the use of plant- and animal-waste nanofillers in biofiber-reinforced composites (Chokshi & Gohil, 2022; Chokshi et al., 2022; Radhakrishnan et al., 2024).

The analysis of the 70 authors identified in the database reveals that the researchers Xian, G., Banea, M.D., and Cavalcanti, D.K.K. lead in total number of citations, with 271, 270, and 270 citations, respectively, together representing more than 17% of the total citations accounted for in the dataset. These authors also demonstrate high academic connectivity, with total link strength greater than 680, indicating strong integration in co-authorship networks and similar thematic areas. The calculation of the citation z-score, used to identify statistical outliers, highlights these three researchers with values above 3, evidencing an impact significantly above the average of the analyzed group. In addition, authors such as Neto, J.S.S. and Lima, R.A.A. also showed expressive influence, with 240 and 229 citations, respectively. The data reinforces the relevance of these researchers in consolidating knowledge on polymer composites reinforced with natural fibers, including emerging applications in biomedical and industrial sectors. Data regarding the number of citations and the total link strength of the top 10 authors can be observed in Table 3.

Table 3. Top 10 most cited authors in publications (2014–2024) related to polymer composites reinforced with jute and/or flax fibers. Data includes number of documents, total citations, total link strength, citation share relative to all 70 identified authors (%), and citation z-score.

Authors	Documents	Citations	Link strength	% Citations	Z-score
Xian, G.	6	271	687	5,77	3,04
Banea, M.D.	4	270	683	5,75	3.02
Cavalcanti, D.K.K.	4	270	683	5,75	3.02
Neto, J.S.S.	3	240	583	5,11	2,58
Lima, R.A.A.	2	229	452	4,88	2,41
Li, H.	4	201	464	4,28	2,00
Wang, H.	4	141	273	3,00	1,10
Khan, R.A.	3	141	203	3,00	1,10
Wang, A.	3	136	399	2,90	1,03
Das, S.C.	2	123	157	2,62	0,83

It is also relevant to consider the geographical contribution, noting authors such as Cavalcanti, D.K.K., Lima, R.A.A., and Neto, J.S.S., whose studies indicate a strong participation of Brazil, a country traditionally active in research on natural fibers and polymer composites (Cavalcanti et al., 2019; Cavalcanti et al., 2021; Cavalcanti et al., 2022).

Citation mapping

Figure 4 presents the citation map. This type of visualization makes it possible to observe how the documents in the analyzed set cite each other, highlighting the most influential works within the selected literature.

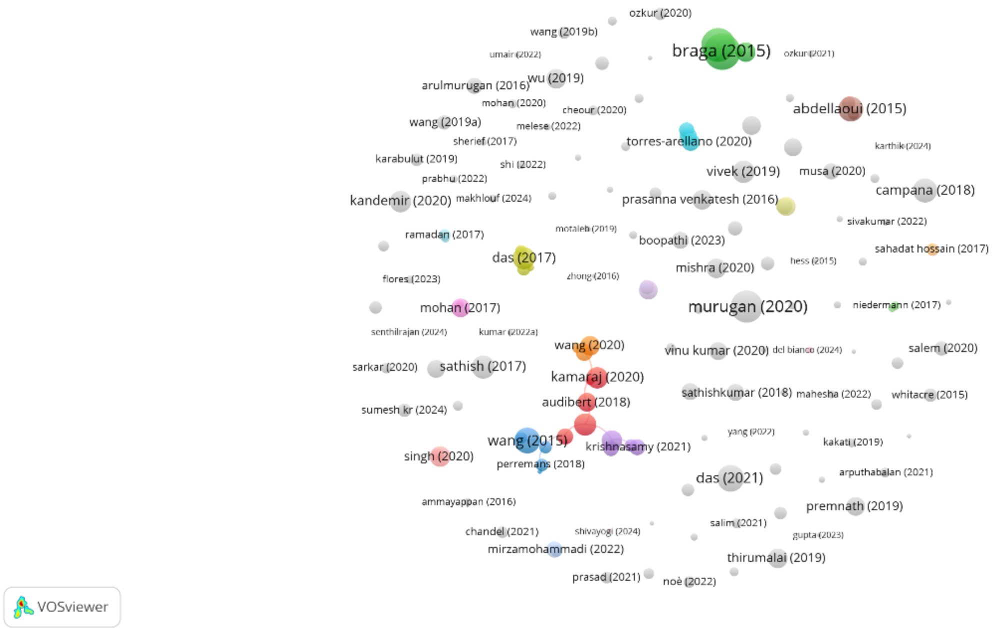

Figure 4. Citation mapping generated using VOSviewer software, with minimum number of citations of 4. Each node represents a document (author and year), and node size is proportional to the number of citations received within the analyzed dataset.

Among the highlights, it is observed that the article by Braga and Magalhaes (2015) is the most cited in the analyzed network. Other prominent documents include Murugan et al. (2020), Cavalcanti et al. (2019), Campana et al. (2018), and Abdellaoui et al. (2015).

The research conducted by Braga and Magalhaes (2015) evaluated hybrid epoxy resin composites reinforced with jute and glass fibers in different proportions. The study demonstrated, through experimental analysis, that increasing the proportion of glass fiber in hybrid composites significantly improves tensile strength, impact resistance, and thermal stability, while a higher presence of jute fiber results in lower density and greater water absorption. Flexural strength varied little among the formulations. Thus, glass fiber contributes more to mechanical and thermal performance, while jute offers advantages in lightness and sustainability, although with functional limitations.

Jute fiber was also the subject of analysis in the research by Cavalcanti et al. (2019) and Abdellaoui et al. (2015). On the other hand, the studies by Murugan et al. (2020) and Campana et al. (2018) investigated flax fiber as a source of reinforcement for polymer matrices.

The green cluster, led by Braga and Magalhaes (2015), brings together central and pioneering studies on the topic. The red cluster, with emphasis on Kamaraj et al. (2020) and Audibert et al. (2018), represents a more alternative research strand, as they analyze the effects of graphene addition and hybridization with less commonly used synthetic fibers such as Kevlar, respectively. The blue cluster, with documents such as Wang et al. (2015), points to the area of applied science and manufacturing.

The proximity between the nodes suggests that the documents are frequently cited together. This indicates that they share thematic similarity or are used as complementary references. The central density of the map reflects the existence of a core of highly interconnected publications, which likely constitutes the most consolidated theoretical body of the field.

Documents located at the edges of the map, with smaller and less connected nodes, for example, Flores et al. (2023) and Senthilrajan et al. (2024) indicate less cited or more recent publications that have not yet established robust citation links with the rest of the analyzed literature.

Table 4 presents the ten most cited works within the set of analyzed documents based on data exported from VOSviewer. The number of citations refers to direct citations among documents in the database, reflecting the influence of each work on the theoretical body of the field.

The most cited article is by Braga and Magalhaes (2015), with 201 citations, representing 4.63% of the total citations. This work also stands out due to its high Z-score (5.42), indicating several citations well above the average. This is followed by the studies by Cavalcanti et al. (2019) and Murugan et al. (2020), which also present high citation counts and statistical significance.

Table 4. Top 10 most cited documents based on citation analysis using VOSviewer. The "Citations" column indicates the number of times each document was cited within the dataset. "Percentual (%)" refers to the proportion of total citations each document represents. "Z-score" expresses how far each citation count deviates from the dataset mean, highlighting statistically significant outliers.

Rank	Documents	Citations	Percentual (%)	Z-score
1	Braga RA (2015)	201	4.63%	5.42
2	Cavalcanti DKK (2019)	175	4.03%	4.60
3	Murugan MA (2020)	152	3.50%	3.87
4	Das SC (2021)	111	2.56%	2.57
5	Wang H (2015)	105	2.42%	2.38
6	Abdellaoui H (2015)	96	2.21%	2.09
7	Campana C (2018)	86	1.98%	1.78
8	Sathish S (2017)	82	1.89%	1.65
9	Vivek S (2019)	79	1.82%	1.56
10	Kumar S (2020b)	75	1.73%	1.43

Country distribution and international collaboration

The map generated by VOSviewer (Figure 5) presents the bibliographic coupling among countries based on a minimum of two documents per country. This visualization makes it possible to identify the geographical distribution and the intensity of scientific collaborations in the analyzed thematic area.

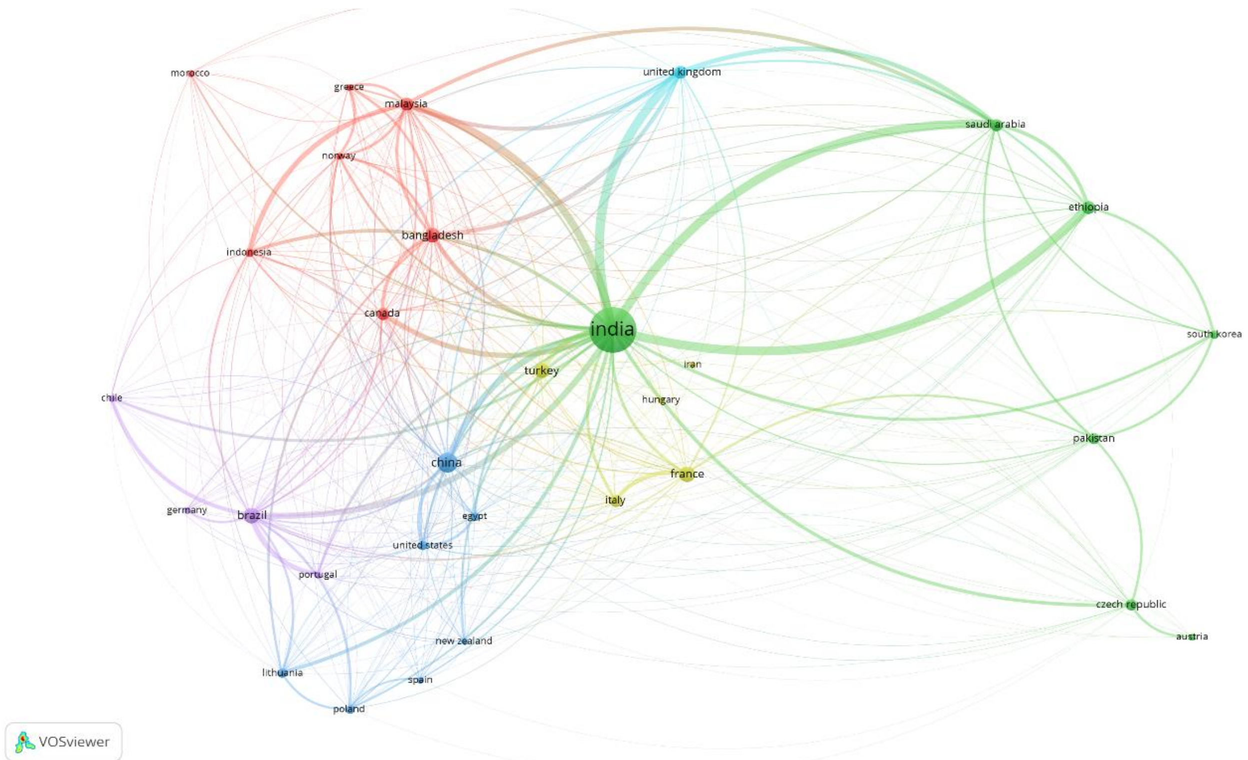

Figure 5. Countries mapping, with minimum publications by country of 2. Node size represents the number of publications; the thickness of the links indicates the strength of bibliographic coupling. Seven clusters were identified, with India as the most central and influential country in the network.

India stands out as the most prominent node in the network, reflecting its central position and the highest number of publications that met the inclusion criteria. The strong bibliographic connection between India and countries such as Saudi Arabia, Ethiopia, Pakistan, South Korea, and Iran highlights intense scientific cooperation, especially among Asian countries and some African nations. The thickness of the lines connecting the countries represents the strength of these links, indicating recurrent and well-established collaborations.

The nodes were organized into seven distinct clusters, representing collaborative communities with thematic, regional, or institutional affinities. The green cluster, led by India, predominantly brings together Eastern countries such as Pakistan, Iran, Saudi Arabia, Turkey, and South Korea, as well as African countries such as Ethiopia, suggesting significant transcontinental collaboration among South Asia, the Middle East, and Africa. The dark blue cluster includes countries with high scientific output and international connectivity, such as China, the United States, Egypt, Portugal, Poland, and New Zealand, indicating well-established transnational networks. The purple cluster groups countries such as Brazil, Germany, Chile, and Lithuania, highlighting interregional cooperation between South America and Europe.

Other groupings also reveal relevant associations. The red cluster, composed of Malaysia, Indonesia, Bangladesh, Canada, and Greece, points to collaborative links focused on technological development in polymer composites. The yellow cluster, formed by France, Italy, and Hungary, indicates a predominantly European research axis. The light blue cluster, centered on the United Kingdom, and the pink cluster, with countries such as Norway and Morocco, represent active scientific communities with smaller-scale intercontinental collaborations.

This mapping provides a comprehensive view of the geopolitical distribution of scientific production, highlighting the centrality of India and the role of emerging and consolidated countries in advancing research on polymer composites reinforced with natural fibers.

Among the most cited articles produced by Indian researchers, two high-impact publications stand out. The study by Kumar et al. (2020) entitled "Investigation of Mechanical and Viscoelastic Properties of Flax- and Ramie-Reinforced Green Composites for Orthopedic Implants," explores the mechanical and viscoelastic properties of green composites for biomedical applications, such as orthopedic implants, demonstrating the feasibility of natural fibers for clinical use. This work represents an important interface between materials engineering and biomedical engineering, indicating the potential application of natural composites in biomedical solutions.

Another highlight is the study of Murugan et al. (2020) entitled "Low Velocity Impact and Mechanical Behaviour of Shot Blasted SiC Wire-Mesh and Silane-Treated Aloevera/Hemp/Flax-Reinforced SiC Whisker Modified Epoxy Resin Composites," which addresses improvements in mechanical properties and impact performance of hybrid composites through the incorporation of treated fibers and modifications to the epoxy matrix. The research demonstrates the technical complexity and sophistication achieved in Indian studies, reflecting advanced trends in composite material design for structural applications.

Table 5 presents the ten countries with the highest number of publications on polymer composites reinforced with natural jute and/or flax fibers in the period from 2014 to 2024. India stands out prominently, with 81 publications, representing 35.84% of the total and presenting a high z-score of 5.32, which positions it substantially above the global average. This result highlights the consolidation of India as a reference hub in research on natural fibers applied to polymer composites, which can be attributed to the availability of raw materials, consolidated academic infrastructure, and policies encouraging research in sustainable materials.

Table 5. Top 10 most productive countries in publications (2014–2024) on polymer composites reinforced with jute and/or flax fibers. Shown are the number of documents, citations, total link strength, share of total documents (%) across 31 countries, and document count z-scores.

Rank	Country	Documents	Citations	Link Strength	Documents (%)	Z-score
1	India	81	1681	2420	35.84%	5.32
2	China	16	426	468	7.08%	0.63
3	Brazil	10	496	715	4.42%	0.20
4	France	10	296	366	4.42%	0.20
5	Turkey	9	114	284	3.98%	0.12
6	Bangladesh	9	272	544	3.98%	0.12
7	United Kingdom	7	190	734	3.10%	-0.02
8	Ethiopia	7	69	495	3.10%	-0.02
9	Malaysia	7	263	760	3.10%	-0.02
10	Italy	6	39	249	2.65%	-0.09

Other countries with significant participation include China, Brazil, France, Turkey, and Bangladesh, which contribute substantially to the advancement of knowledge in the field, as indicated by both the number of publications and the citation indicators and link strength within collaboration networks. A heterogeneous geographical distribution of scientific production is observed, with representation from countries in Asia, South America, and Europe, reflecting the growing internationalization of research on lignocellulosic fiber-based composite materials.

Although this review included 182 scientific articles after rigorous screening and application of eligibility criteria, the country distribution analysis performed with VOSviewer revealed a total of 226 documents attributed to 31 different countries. This numerical discrepancy arises from the counting methodology adopted by VOSviewer, which considers each international co-authorship institutional link as an individual occurrence. Thus, a single article with co-authors affiliated with different countries is counted multiple times, reflecting the participation of each country involved in the scientific output.

Publication sources and journal mapping

Figure 6 presents the bibliographic coupling map of the most relevant publication sources in the literature on polymer composites reinforced with natural jute and/or flax fibers. The visualization was generated based on the analysis of shared references among journals, highlighting groupings of journals with similar thematic alignment.

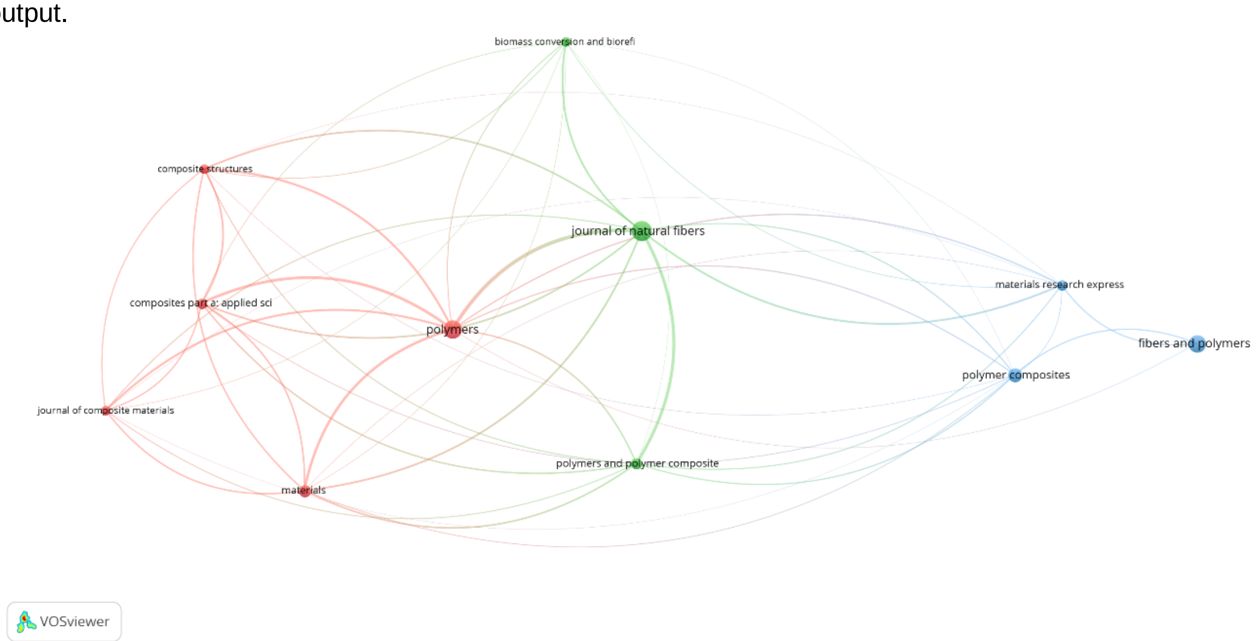

Figure 6. Bibliographic coupling map of publication sources related to polymer composites reinforced with jute and/or flax fibers. The map shows clusters of journals with similar citation patterns, based on shared references. Node size indicates publication volume, and link thickness represents the strength of bibliographic coupling.

In Figure 7, three distinct clusters are observed, each represented by a different color, indicating cores of journals with shared citation patterns. The journal Polymers stands out in the red cluster as one of the main nodes in the network, with high connectivity both with journals focused on materials science (Materials, Composite Structures, Composites Part A: Applied Science and Manufacturing) and with journals specialized in natural fibers and biomaterials, such as the Journal of Natural Fibers. The latter forms a strongly interconnected subgroup with journals such as Polymers and Polymer Composites and Biomass Conversion and Biorefinery, evidencing the relevance of sustainable approaches and the valorization of lignocellulosic materials in the field.

The green cluster groups journals such as Fibers and Polymers, Polymer Composites, and Materials Research Express, reflecting an editorial core focused on the properties and performance of advanced polymeric materials. The analysis suggests that scientific production on jute and flax fibers as reinforcement in epoxy or polyester matrices is distributed between multidisciplinary materials science journals and journals specialized in polymers and composites, reinforcing the interdisciplinary nature of the topic.

Finally, the blue cluster brings together journals such as Polymer Composites, Fibers and Polymers, and Materials Research Express. This group is representative of publications focused on the physicochemical and mechanical characterization of polymeric materials, with emphasis on performance and industrial applications. The presence of this cluster suggests a more applied and experimental strand of the literature, focused on materials engineering, especially in the context of replacing synthetic reinforcements with natural fibers with competitive performance.

Table 6 presents the 11 journals with the highest number of publications related to the use of natural jute and/or flax fibers as reinforcement in polymer composites. The Journal of Natural Fibers leads in publication volume, representing 19.32% of the total analyzed, followed by Polymers (15.91%) and Fibers and Polymers (14.77%). These three journals also stand out due to their positive z-scores, indicating performance above the dataset average in terms of number of articles.

Among the articles published in the Journal of Natural Fibers, special attention should be given to the recent study by Flores et al. (2023), which investigated the mechanical and hygroscopic properties of unidirectional hybrid jute laminates combined with synthetic glass and carbon fibers.

The results demonstrated that hybridization promotes a significant improvement in structural properties and a reduction in moisture absorption compared to exclusively natural composites. This approach reinforces the potential of natural–synthetic hybrids for moderate structural applications, balancing mechanical performance and sustainability.

Table 6. Scientific publication sources on polymer composites reinforced with jute and/or flax fibers. Listed are the number of documents, citations, total link strength, percentage of documents, and z-scores for publication volume. Values are based on the 88 documents published in sources that met the minimum threshold of four publications in VOSviewer.

Rank	Source	Documents	Citations	Link Strength	Documents (%)	Z-score
1	Journal of Natural Fibers	17	256	155	19.32	2.04
2	Polymers	14	257	162	15.91	1.36
3	Fibers and Polymers	13	188	16	14.77	1.13
4	Polymer Composites	9	139	43	10.23	0.23
5	Materials	7	133	94	7.95	-0.23
6	Polymers and Polymer Composites	6	230	88	6.82	-0.45
7	Composites Part A: Applied Science and Manufacturing	5	309	94	5.68	-0.68
8	Materials Research Express	5	148	46	5.68	-0.68
9	Biomass Conversion and Biorefinery	4	59	36	4.55	-0.91
10	Composite Structures	4	204	78	4.55	-0.91
11	Journal of Composite Materials	4	127	60	4.55	-0.91

In the study conducted by Cáceres et al. (2024), published in Polymers, the authors proposed an innovative analysis by comparing the structural and environmental efficiency of composites manufactured by Tailored Fiber Placement, considering both natural and synthetic fibers. The introduction of the criterion of specific stiffness weighted by global warming potential highlights an emerging trend in the field: the integration of functional performance and environmental impact, promoting the development of materials with a lower carbon footprint for structural applications.

Wang et al. (2023), in their article published in Fibers and Polymers, carried out an orthogonal analysis of the mechanical and fatigue properties of flax–glass hybrid composites. The results evidenced the predominant influence of fiber orientation on strength and fatigue durability, indicating pathways for optimizing hybrid structural composites. The application of rigorous experimental design and in-depth fractographic analysis reinforces the growing sophistication of research methodologies in polymer composites reinforced with natural fibers.

Although some journals present a lower volume of publications, such as Composites Part A and Composite Structures, these venues accumulate high citation counts, reflecting their high relevance and impact factor. Journals such as Polymers and Polymer Composites and Materials, in turn, demonstrate strong thematic integration, with high total link strength, suggesting a central role in citation networks and thematic similarity.

This diversity of sources highlights the interdisciplinary nature of research on natural composites, encompassing fields ranging from materials science and mechanical engineering to sustainability and bioeconomy. The analysis also indicates a balance between journals specialized in polymers and broader journals focused on materials engineering and structural composites.

Keyword co-occurrence and thematic trends

Figure 7 presents the keyword co-occurrence map extracted from the titles, abstracts, and keywords of the 182 documents included in the sample. The analysis was conducted based on a minimum threshold of 10 occurrences per term, using VOSviewer, and resulted in the identification of four main clusters, each represented by a distinct color.

The software used an algorithm to group keywords with strong co-occurrence links, displaying them in different colors to denote thematic groups. The layout was generated automatically by the software, which spatially links the nodes based on the strength of their connections. The proximity and links between the nodes indicate how closely related certain concepts are within the dataset.

The red cluster, located on the left, is centered on terms such as “jute fibers,” “polyester resins,” “tensile strength,” “bending strength,” and “biodegradability.” This grouping represents a thematic axis focused on the mechanical properties of jute-reinforced composites, with emphasis on unsaturated polymers and structural strength aspects. The presence of terms such as “impact strength,” “water absorption,” and “biocomposite” indicates an approach oriented toward sustainability and mechanical performance.

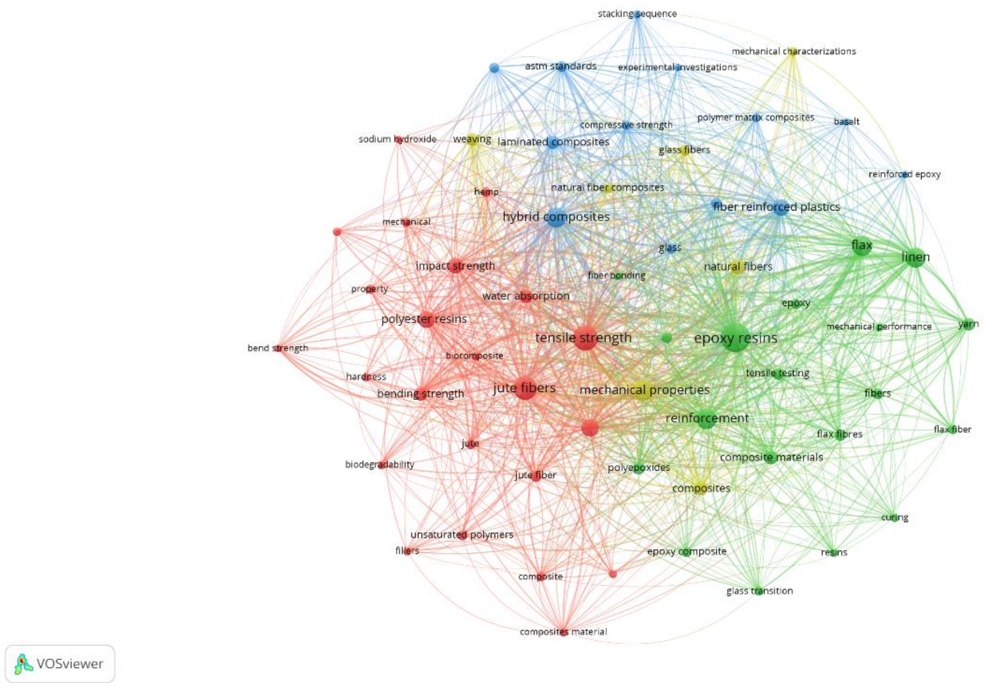

Figure 7. Co-occurrence network of author keywords extracted from 182 documents on polymer composites reinforced with jute and/or flax fibers, analyzed using VOSviewer 1.6.20. A minimum occurrence threshold of 10 was applied. The size of the nodes reflects the frequency of each keyword; the link strength corresponds to the degree of co-occurrence.

The green cluster, on the right, is centered on terms such as “epoxy resins,” “linen,” “flax,” “mechanical performance,” “curing,” and “reinforcement.” It represents the core of research on flax-reinforced composites, including studies on thermal behavior, glass transition, and mechanical performance. The high density of connections in this region points to a cohesive and well-established field of study.

The blue cluster, located at the top, groups terms such as “hybrid composites,” “natural fiber composites,” “glass fibers,” “compressive strength,” “stacking sequence,” and “ASTM standards.” This group reflects experimental investigations focused on standardized characterization and comparison between different types of fibers, including hybrid reinforcements (natural and synthetic).

The yellow cluster, smaller and more diffuse, connects themes that orbit among the others, such as “polymer matrix composites,” “mechanical characterizations,” and “experimental investigations,” functioning as a bridge between the clusters.

The central and most recurrent term, “mechanical properties,” acts as a semantic link among all groups, evidencing that the predominant focus of the literature is the evaluation of the mechanical properties of jute- and/or flax-based composites. The density and thickness of the connections indicate the degree of semantic association and the frequency with which the terms appear together, revealing consolidated thematic relationships.

Table 7 summarizes the ten most recurrent keywords identified among the 62 analyzed in the Scopus database, based on a total of 1,707 occurrences. In addition, the percentage contribution of each keyword to the overall discussion was calculated based on the total number of occurrences, showing not only how frequently a theme is mentioned but also its importance to the overall study.

The most prominent keyword was “epoxy resins,” with 141 occurrences (8.26% of the total), also presenting the highest positive deviation from the overall mean frequency (Z-score = 2.36), which highlights its central role in studies on natural composites. Subsequently, “tensile strength” (5.74%) and “jute fibers” (5.21%) reaffirm the research focus on the evaluation of mechanical properties, particularly tensile strength, of composites reinforced with lignocellulosic fibers. The presence of “mechanical properties,” “reinforcement,” and “hybrid composites” evidences a systematic approach to the development and structural characterization of these materials.

Flax fibers also show significant relevance, represented by the terms “flax” and “linen,” each contributing close to 4%. Notably, “scanning electron microscopy” indicates the recurrent use of morphological analyses to support material characterization. The statistical data confirms that, although some keywords are concentrated above the mean, there is a well-defined thematic core that articulates materials, characterization techniques, and mechanical properties, supporting the validity and coherence of the scope of this review.

The keyword density analysis, illustrated in Figure 8, revealed the main thematic focuses of research that use jute and flax fibers as reinforcement for polymer composites based on epoxy or polyester resins.

Table 7. Top 10 most frequent keywords identified in the bibliometric analysis of publications on polymer composites reinforced with jute and/or flax fibers (2014–2024). The table presents the absolute frequency, percentage contribution (based on a total of 62 keywords), and standardized Z-score values for each keyword.

Keywords	Occurrences	Total Link Strength	Contribution (%)	Z-score
epoxy resins	141	1178	8.26	2.36
tensile strength	98	917	5.74	0.78
jute fibers	89	837	5.21	0.45
mechanical properties	73	684	4.27	-0.13
reinforcement	68	597	3.98	-0.32
hybrid composites	67	662	3.92	-0.35
flax	67	570	3.92	-0.35
linen	65	551	3.81	-0.43
scanning electron microscopy	51	510	2.99	-0.94
fiber reinforced plastics	47	439	2.75	-1.09

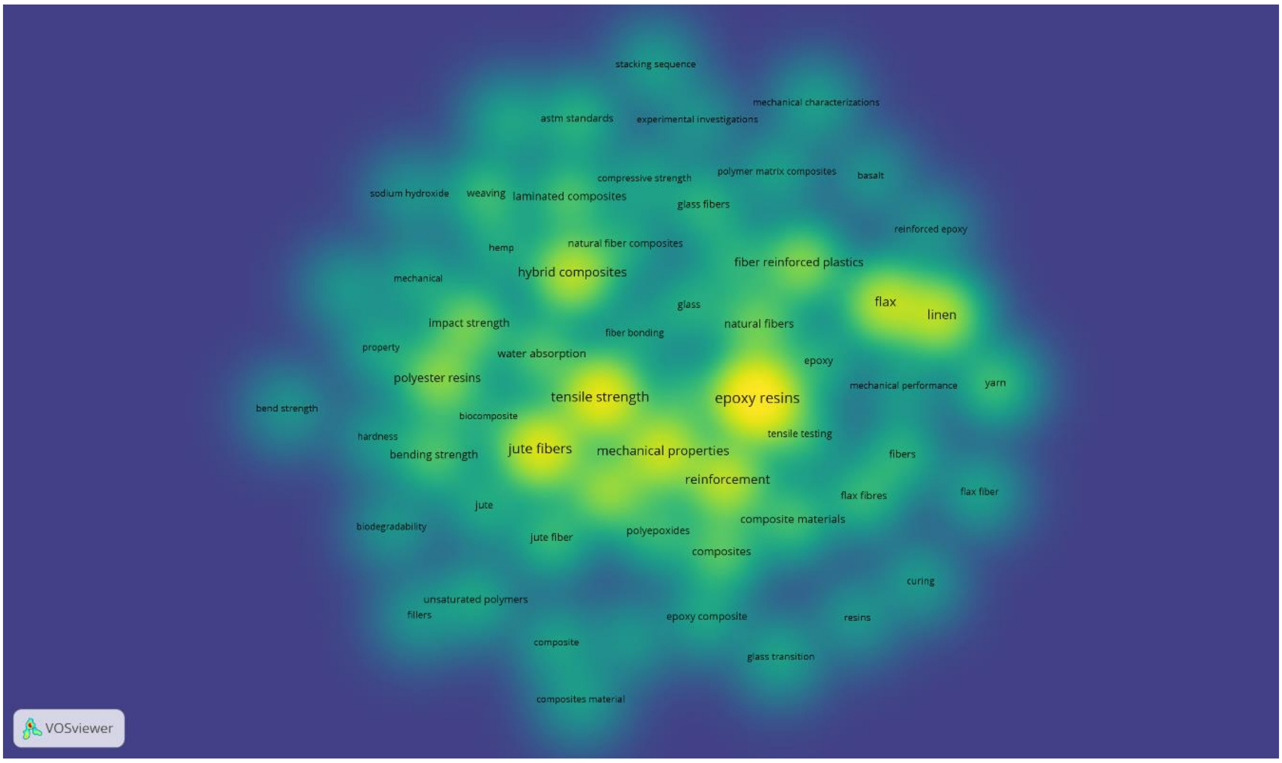

Figure 8. Density visualization of author keywords from publications on polymer composites reinforced with jute and/or flax fibers, generated using VOSviewer 1.6.20. The color gradient (from blue to yellow) indicates the frequency of keyword occurrences, with yellow representing the most frequently used terms. Central themes include "epoxy resins", "tensile strength", "jute fibers", and "mechanical properties", reflecting core topics in literature.

The terms with the highest density, located in the brightest regions of the map, are “epoxy resins,” “tensile strength,” “jute fibers,” “mechanical properties,” and “reinforcement.” This concentration shows that the predominant focus of the research revolves around the mechanical characterization of composites reinforced with natural fibers—especially jute—in epoxy matrices. In addition, the relevant presence of terms such as “polyester resins,” “biodegradability,” and “bending strength” complements the discussion on mechanical performance and material sustainability.

The absence of extensive dark areas on the map indicates a reasonably broad thematic dispersion, with several terms presenting moderate frequency levels. This suggests that although the field is centered on mechanical properties, there are diverse subthemes contributing to the consolidation of knowledge, such as thermal evaluation, durability, biodegradability, and industrial applications.

Studies from the most recent year included in the review demonstrate methodological evolution, as observed through keywords such as stacking sequence, sodium hydroxide, fillers, biodegradability, and sustainability. This evolution is confirmed by research that conducted experimental analyses on fiber stacking sequence (B H S et al., 2024; Aranha et al., 2024), natural fiber treatments (Flores et al., 2023), the addition of fillers aimed at improving the mechanical properties of polymer composites reinforced with jute and flax fibers (Arun Kumar et al., 2024; Radhakrishnan et al., 2024; Ganesan et al., 2024; Doineau et al., 2024; Li et al., 2025; Venkatesh et al., 2024), and growing concern for the environment and sustainability, showing increasing interest in alignment with the goals of the 2030 Agenda (Cáceres et al., 2024; Ciardiello et al., 2024).

These results, obtained through qualitative analysis using VOSviewer, confirm the relevance of the bibliometric grouping and co-occurrence extraction methodology, while also supporting the objective of this review to map trends and guide future research on the use of lignocellulosic fibers in polymer matrices.

Research gaps and future perspectives

Although the results of the bibliometric analysis indicate extensive scientific production focused on evaluating the mechanical properties of composites reinforced with jute and flax fibers, relevant gaps are observed. The scarcity of terms related to thermal comfort, dynamic behavior in use, or clinical application—fundamental aspects for the development of orthopedic components such as prosthetic sockets—highlights the lack of interdisciplinary approaches integrating materials engineering and biotechnology. Furthermore, although terms such as “water absorption” and “biodegradability” are present, their low density suggests that durability factors, hydrothermal aging, and the environmental impact of laminates remain underexplored, especially in long-term use contexts. These gaps open space for future investigations that consider not only the structural properties of biocomposites, but also their functional and physiological suitability for biomedical applications, promoting advances more closely aligned with clinical, industrial, and sustainability needs.

Conclusion

This bibliometric review demonstrated that research on polymer composites reinforced with jute and flax fibers has expanded substantially over the last decade, particularly from 2019 onward. The field is mainly centered on epoxy-based composites and on the evaluation of mechanical properties, including tensile, flexural, and impact performance. India emerged as the leading country in scientific production and international collaboration, while journals focused on natural fibers, polymers, and composite materials represented the main publication sources.

The keyword and network analyses confirmed that the literature is consolidated around structural performance and material characterization. However, topics related to thermal comfort, dynamic performance, long-term durability, hydrothermal aging, and clinical integration remain underexplored. Therefore, future investigations should move beyond mechanical characterization and incorporate interdisciplinary approaches that connect materials engineering, sustainability, and biomedical functionality.

By integrating bibliometric mapping and thematic analysis, this review provides a structured overview of the scientific evolution of jute- and flax-reinforced polymer composites and identifies research directions with potential relevance for sustainable materials and biomedical applications.

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