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GLOBAL RESEARCH TRENDS ON OIL PALM WASTE-BASED AS SOUND ABSORPTION MATERIAL: A BIBLIOMETRIC ANALYSIS

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Abstract:

The increasing demand for sustainable acoustic materials has accelerated research into renewable biomass resources as environmentally friendly alternatives to conventional synthetic absorbers. Among these resources, oil palm waste has received increasing attention due to its abundance, renewability and the potential suitability for sound absorption applications. However, despite the growing literature, comprehensive bibliometric evidence describing publication trends, collaboration networks, thematic evolution and emerging research directions remains limited. Therefore, this study attempts to perform a bibliometric analysis to assess global research trends on oil palm waste-based sound absorption material. Bibliometric data were extracted from the Scopus database and analysed using VOSviewer, Scopus Analyzer and Scopus AI to identify publication trends, highly cited publications, co-occurrence patterns of keywords,

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leading contributing countries and international collaboration networks. The results showed a significant increase in publications after 2010, indicating growing scientific interests in the utilisation of oil palm biomass for sustainable acoustic applications. Furthermore, citation analysis also demonstrated that the most cited studies were mostly related to composite materials, thermal performance and sustainable engineering applications. The keyword co-occurrence analysis identified acoustic performance, material characterisation and multifunctional engineering material, whereby the leading research themes placed Malaysia as the main contributor and the collaborator hub. Notably, the strong interconnection between mechanical properties, sound absorption, thermal conductivity, density, natural fibres and oil palm biomass suggests that research trends increasingly emphasise integrated performance optimisations rather than isolated acoustic assessment. Thus, this field has evolved from agricultural waste utilisation towards multifunctional material development involving acoustic, physical, thermal and mechanical optimisation. The findings contribute to SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action) by supporting sustainable material innovation and biomass valorisation strategies.

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Keyword:

Bibliometric Analysis, Sound Absorption, Acoustic Material, Oil Palm, Bio-Based Material

Introduction

Rapid industrialisation, urbanisation, transportation activities and infrastructure expansion have made noise pollution a critical environmental and public health problem. Long-term exposure to high levels of noise has been linked to a number of negative health impacts and psychological effects including hearing impairment, sleep disturbance, reduced work productivity, stress and cardiovascular complications (Kanu et al., 2025; World Health Organisation [WHO], 2018). Hence, the demand for efficient sound absorption materials has been growing rapidly in the fields of building acoustics, transportation systems, hospitals, industrial plants and environmental noise-control applications. Conventional synthetic sound absorbers such as fibreglass, mineral wool and polyurethane foam have been extensively utilised due to their good acoustic properties. However, these materials have been proven to exhibit several environmental and health-related limitations, including poor biodegradability, disposal challenges, caused high energy consumption during manufacturing and potential respiratory irritation during handling and installation (Hemmati et al., 2024; Mohammad Alizadeh et al., 2024).

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Consequently, the growing concern of environmental problems and the initiatives for sustainable development have caused research efforts to move towards the development of environmentally friendly acoustic materials from renewable biomass resources. Acoustic materials from natural fibres have demonstrated promising potential due to their biodegradability, low density, renewability, porous cellular structures and comparatively low cost of production (Hassan et al., 2021; Rao et al., 2025). Moreover, the use of agricultural waste materials is also contributing to waste minimisation, biomass valorisation and implementation of rigorous circular economy. Thus, the use of sustainable biomass resources for acoustic engineering applications has become an important research direction in the green material technology and sustainable manufacturing industries.

Among the various agricultural biomass resources, oil palm waste has attracted increasing research interest owing to its abundant availability and potential for sustainable material development. This is due to the large quantity of biomass generated by the palm oil industry, particularly in major palm oil-producing countries such as Malaysia and Indonesia. Large quantities of residues, including empty fruit bunches (EFB), oil palm trunk (OPT), oil palm fronds (OPF), mesocarp fibres, and palm kernel shells, are generated during palm oil processing and plantation replanting, creating significant waste management challenges if not effectively utilised (Ilyas et al., 2022; Pulingam et al., 2022). Despite the increasing research interest, a comprehensive understanding of the overall research landscape remains limited.

To address this gap, this study provides a comprehensive bibliometric analysis of global research on oil palm waste-based sound absorption materials. The study examines publication trends, keyword co-occurrence, country contributions, and international collaboration to provide strategic insights for future research and sustainable acoustic material development.

Conceptual Research Map

Figure 1 presents the conceptual research map generated using Scopus AI to demonstrate the main research directions related to oil palm-based sound absorption materials. The concept map shows that current research development is mainly concentrated around three interrelated domains namely on acoustic performance, material properties and engineering applications. The interrelationship of these research domains suggests that oil palm biomass research has gradually progressed from simple agricultural waste utilisation to the development of multifunctional bio-based materials for acoustic engineering applications.

It was found that the acoustic performance cluster was closely related to the sound absorption coefficient, noise reduction coefficient and acoustic impedance. This suggests that impedance tube measurements remain among the leading approaches for evaluating acoustic behaviour in natural fibre-based materials.

The applications cluster also indicates an increasing research interest in the use of oil palm biomass for the production of particleboard and sound insulating materials. The use of oil palm fibres in particleboard and composite panel systems has been discussed in several previous studies due to their lightweight structure, fibrous morphology and potential acoustic functionality (Aisyah et al., 2024; Prasetiyo et al., 2023; Sekar et al., 2021). These studies also reflect the increasing industrial interest in environmentally friendly alternatives for building acoustics and interior engineering applications.

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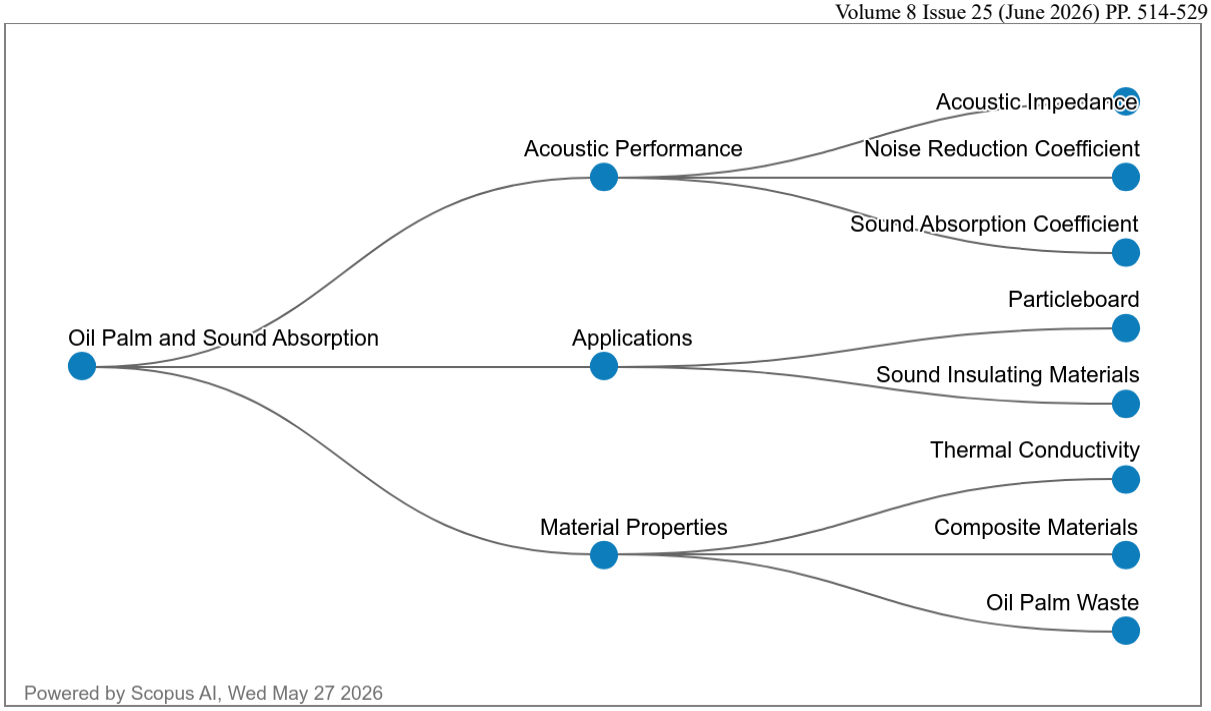

Figure 1: Concept Map of Major Research Directions for Oil Palm as Sound Absorption Material

Source: (Scopus AI, Fri May 27 2026)

In addition, studies also showed that the material properties cluster demonstrated strong thematic relationship involving thermal conductivity, composite materials and oil palm waste. Nonetheless, this current research focuses on multifunctional material behaviour rather than exclusively on sound absorption performance. As a result, this study reveals that the bibliometric structure reflects increasing multidisciplinary integration between the acoustic engineering, sustainable materials science, biomass composite technology and the thermal engineering applications.

Hence, the novelty of this study lies in providing a comprehensive bibliometric analysis of oil palm waste-based sound absorption materials, which is a field with limited bibliometric evidence. Unlike previous experimental and review studies that mainly focused on material performance, this study adopts a bibliometric approach to systematically investigate the research landscape. By integrating publication trends, influential publications, collaboration networks, thematic evolution and research hotspots, the study provides a structured understanding of the research landscape while identifying emerging research opportunities.

Research Questions

This study aims to assess the global development of research on sound absorption materials derived from oil palm waste using a bibliometric approach to offer a thorough comprehension of the existing research environment. Its analysis focuses on identifying the growth of publications, influential studies, dominant themes of research, leading contributing countries and the patterns of international collaboration in the field. The following research questions are developed to guide the bibliometric analysis:

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RQ1: What are the trends in publication based on annual distribution?

RQ2: What are the ten most frequently cited articles in this research field?

RQ3: What are the most frequently occurring keywords linked to this research field?

RQ4: Which top 10 countries are the leading contributors based on publication count?

RQ5: What are the international collaboration patterns based on country-level co-authorship?

Methodology

Bibliometric analysis is a quantitative research methodology used to evaluate, organise and visualise scientific publications through the analysis of bibliographic data (Ghazali et al., 2026; Al-khoury et al., 2022). This approach enables researchers to identify publication trends, influential studies, research collaborations and thematic developments within the field of study (Wu & Wu, 2017). Furthermore, bibliometric techniques facilitate the exploration of intellectual structures and emerging research directions through citation-based and keyword-based analyses (Chen et al., 2020). In this study, bibliometric analysis was adopted to provide an overview of research developments related to oil palm waste-based sound absorption materials.

The bibliometric workflow consisted of five stages. First is the database selection, followed by search query development. Next, data were retrieved, screened and cleaned. Bibliometric analysis and data visualisation was conducted using VOSviewer version 1.6.20, Scopus Analyzer, Scopus AI and mapchart.net. Finally, interpretation of the research trends and thematic structures were demonstrated. This workflow enabled a systematic evaluation of publication growth, influential studies, research hotspots and collaboration patterns within the field of oil palm waste-based acoustic materials.

Data Source and Search Strategy

To ensure the quality and relevance of the literature analysed, a structured search strategy was employed using the Scopus database. This is widely used due to its comprehensive coverage of peer-reviewed research. The search was conducted on 27 May 2026, which covered publications from 1998 to 2026 and retrieved 244 English-language journal articles and conference papers from the Scopus database after applying the predefined inclusion and exclusion criteria. The search used advanced search query shown in Table 1: TITLE-ABS-KEY ("oil palm") AND (acoustic OR "sound absorption" OR noise) AND (particleboard OR panel OR composite OR fibreboard) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")). The query was designed to find highly relevant documents by requiring all eight keywords: *oil palm, acoustic, sound absorption, noise, particleboard, panel, composite, fibreboard*.

Based on predetermined inclusion and exclusion criteria which are outlined in Table 2 below, a methodical screening procedure was carried out. To maintain linguistic coherence and prevent translation constraints, only English-language publications were included. By restricting the relevant literature type to journal articles and conference papers only, the study's consistency

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was guaranteed. Books, reviews, conference reviews, and non-English literature were therefore not included. Only publications in the final stage were chosen, whereas pieces that were still marked as "in press" were not included. This thorough search and screening procedure produced 244 journal articles in total. The collected dataset provided a strong basis for further bibliometric analysis, guaranteeing that the conclusions were grounded in excellent, relevant and thematically cohesive research results.

Table 1: The Search String

Scopus	**TITLE-ABS-KEY (“oil palm") AND (acoustic OR "sound absorption" OR noise) AND (particleboard OR panel OR composite OR fibreboard) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp"))**
Access date:	Wed May 27 2026

Table 2: The Selection Criterion in Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Literature type	Journal (Article), Conference Paper	Book, Review, Conference Review
Publication Stage	Final	In Press

Data Analysis and Visualisation

The bibliographic records retrieved were exported from Scopus in a CSV format including citation information, bibliographical data, abstracts, author keywords and references. Then, data cleaning was performed with OpenRefine to remove redundancy of keywords. The dataset was further analysed using VOSviewer version 1.6.20, a bibliometric visualisation software widely used in the mapping of scientific data and research networks (Van Eck & Waltman, 2010).

Several bibliometric indicators were examined, including annual publication trends, citation performance, country contributions, keyword co-occurrence networks and international collaboration patterns. Keyword co-occurrence analysis was performed to identify dominant research themes and thematic relationships within the field. Additionally, co-authorship analysis was conducted to evaluate collaborative relationships among contributing countries.

Furthermore, Scopus AI was utilised to generate a conceptual research map that provided the thematic overview of the major research themes associated with oil palm-based sound absorption materials. The Concept Map (Figure 1) was subsequently interpreted alongside the bibliometric findings to enhance understanding of the thematic evolution of the research field.

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Results and Discussion

RQ1: What Are the Publication Trends Based on Annual Publication Distribution?

Figure 2 presents the annual trend in the number of publications of relevant research from 1998 to 2026. The results clearly indicate that there is an upward trend in the number of publications which indicates the growing interest of scholars in the use of oil palm biomass for acoustic and engineering applications. The first development phase (1998-2009) was presented by a relatively low level of publication activity, with fewer than five documents per year. This pattern suggests that the field was still in its exploratory phase where research mainly focused on exploring the basic properties of natural plant fibres and agricultural biomass materials for potential engineering applications.

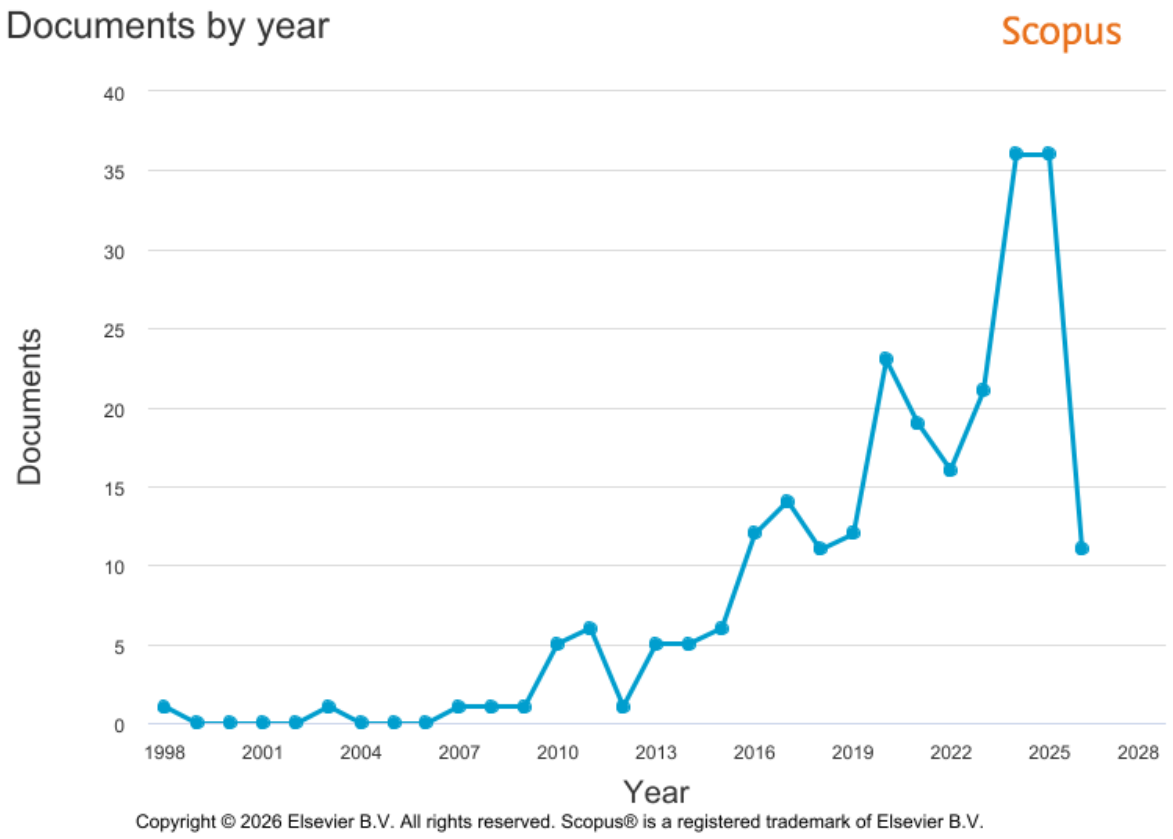

Figure 2: Number of Documents Based on Year of Publication

Source: (Scopus, Wed May 27 2026)

However, from 2010 onwards a gradual increase in the publication output was observed. The annual production between 2010 and 2015 ranged from about five to six documents, indicating the beginning of a continuous interest in the research area. This growth can be attributed to the growing awareness about the sustainable material development, biomass valorisation and environmentally friendly alternatives instead of the conventional synthetic acoustic absorbers. Furthermore, the increased awareness of waste management and the application of circular economy principles have encouraged researchers to investigate agricultural residues and their added values as good engineering resources.

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The growth was more pronounced after 2016, with the number of publications increasing from 12 in 2016 to more than 20 in 2021. This trend demonstrates a change from exploratory investigations to broader research diversification in terms of acoustic performance, material characterisation and sustainable engineering applications. Interestingly, as the frequency of publications increases, oil palm biomass materials are no longer seen as agricultural waste alone but are now increasingly seen as multifunctional materials that offer acoustic and multifunctional properties benefits. The most significant growth phase occurred between 2023 and 2025, with more than 35 documents per year, signifying a growing research momentum and a higher level of multidisciplinary integration in the areas of acoustic engineering, materials science, composite technology and sustainability-related research.

Nevertheless, the seemingly lower publication count for 2026 can be attributed to only a partial-year record as the dataset was collected on 27 May 2026. Thus, the decreased observation is rather related to the ongoing publishing and indexing processes in the Scopus database and not so much to the decrease of research activity. Overall, the trend in publications shows a growth of the research field, advancing from exploratory studies to multidisciplinary research on sustainability, biomass valorisation and the development of multifunctional materials.

RQ2: What Are the Top 10 Most Cited Articles in This Research Field?

The 10 most cited publications directly related to the scope of the study are shown in Table 3. Citation analysis is a common method for identifying influential articles that have significantly contributed to the growth and distribution of knowledge in a study field.

Table 3: Most Cited Articles

No.	Author	Title	Year	Source Title	Cited By
1	Or et al.	Oil palm empty fruit bunch fibres as sustainable acoustic absorber	2017	Applied Acoustics	129
2	Khankhaje et al.	Properties of quiet pervious concrete containing oil palm kernel shell and cockleshell	2017	Applied Acoustics	73
3	Mawardi et al.	An investigation of thermal conductivity and sound absorption from binderless panels made of oil palm wood as bio-insulation materials	2022	Results in Engineering	72
4	Zulkifli et al.	Comparison of acoustic properties between coir fibre and oil palm fibre	2009	European Journal of Scientific Research	42
5	Tomyangkul et al.	Enhancing sound absorption properties of open-cell natural rubber foams with treated bagasse and oil palm fibers	2016	Journal of Reinforced Plastics and Composites	40
6	Rasat et al.	Properties of composite boards from oil palm frond agricultural waste	2011	BioResources	37
7	Jayamani et al.	Acoustical, thermal and morphological properties of zein	2016	Journal of Applied Polymer	36

No.	Author	Title	Year	Source Title	Cited By
		reinforced oil palm empty fruit bunch fiber bio-composites		Science	
8	Yahya et al.	A Review on the Potential of Natural Fibre for Sound Absorption Application	2017	IOP Conference Series: Materials Science and Engineering	36
9	AlRahman et al.	Comparison of acoustic characteristics of date palm fibre and oil palm fibre	2014	Research Journal of Applied Sciences, Engineering and Technology	30
10	Bakri et al.	Reinforced Oil Palm Fiber Epoxy Composites: An Investigation on Chemical Treatment of Fibers on Acoustical, Morphological, Mechanical and Spectral Properties	2015	Materials Today: Proceedings	20

Source: (Scopus, Wed May 27 2026)

The results indicate that the most influential publication in the field was reported by Or et al. (2017), entitled Oil Palm Empty Fruit Bunch Fibres as Sustainable Acoustic Absorber, which accumulated 129 citations. The study represents one of the earliest investigations demonstrating the potential of oil palm empty fruit bunch (EFB) fibres as environmentally friendly sound absorbing materials. The high citation impact of this article indicates that sustainable acoustic absorber development has established a foundation research theme that has influenced further studies on multifunctional oil palm biomass materials.

The second and third most cited publications were reported by Khankhaje et al. (2017) and Mawardi et al. (2022), receiving 73 and 72 citations respectively. These studies extended the application of oil palm biomass beyond conventional fibre-based absorbers by investigating quite pervious concrete and binderless bio-insulation panels. The presence of these studies among the most cited publications indicates growing research interest in multifunctional acoustic materials capable of simultaneously providing acoustic, structural and thermal performance benefits.

It's interesting to note that the rapid publication growth phase seen in Figure 2 closely aligns with the majority of papers produced between 2014 and 2022. These key studies have greatly influenced the direction of following research. The citation analysis demonstrates that oil palm waste-based sound absorption material research is primarily centred on sustainable sound absorption materials and acoustic characterisation as reported by Zulkifli et al. (2009) and Yahya & Vui (2017). More importantly, the recurring appearance of studies integrating acoustic performance with thermal, physical and morphological evaluation provides further evidence that future research is likely to focus on multifunctional holistic material optimisation rather than acoustic performance evaluation alone.

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RQ3: What Are the Most Frequently Occurring Keywords Associated with This Research Field?

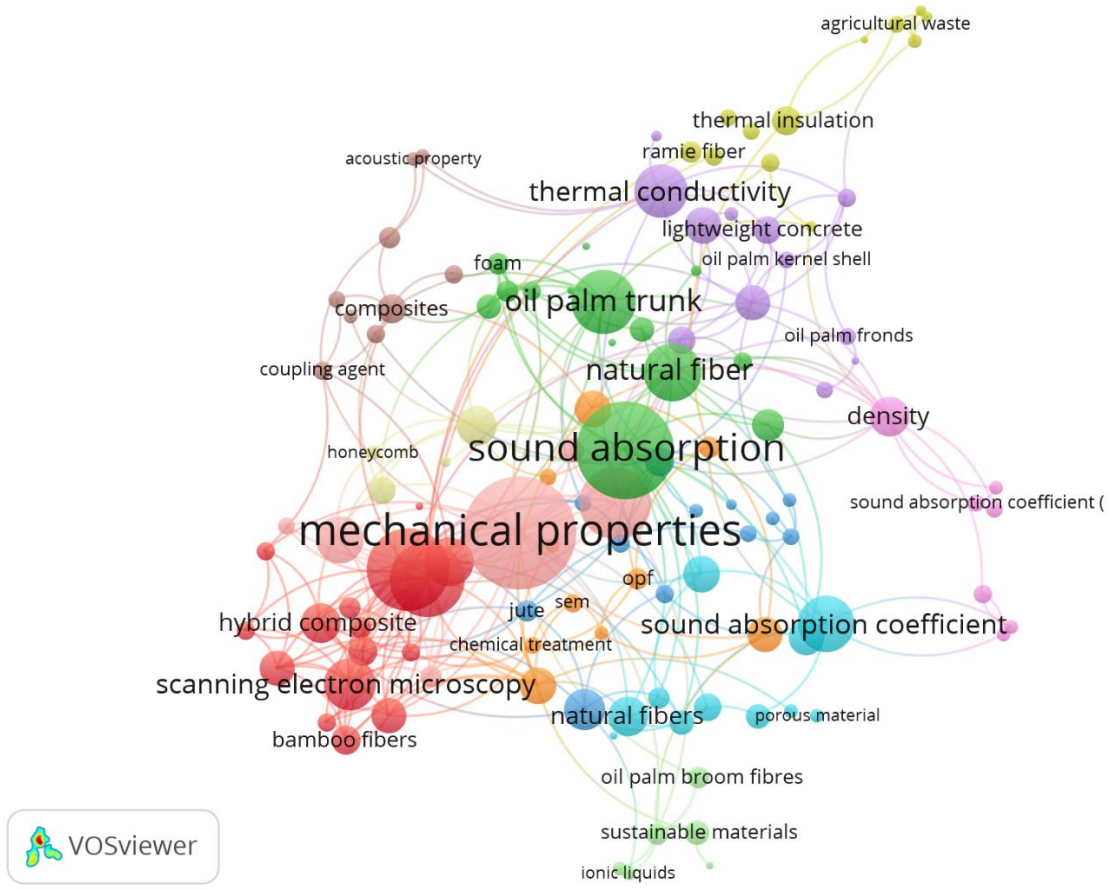

Figure 3: Network Visualisation Map of Keywords' Co-Occurrence
Source: (Scopus, Wed May 27 2026)

Figure 3 presents the co-occurrence network of the keywords generated by VOSviewer based on author keywords extracted from the retrieved publications. The network is composed of several interconnected clusters that correspond to the major research themes in the field of study. The size of each node is the frequency of the keyword, and the connecting lines are the thematic relationships among research topics.

Results indicate that the most dominant keywords are mechanical properties and sound absorption. This suggests that the current research is mainly driven by these dual objectives of effective acoustic performance and retention of material functionality and structural integrity. This observation points to the fact that oil palm biomass is being explored more as not only a good sound absorb but also as multifunctional engineering material to meet the practical application requirement.

The strong relationship of sound absorption, sound absorption coefficient, natural fibre and oil palm trunk proves that the evaluation of acoustic performance is still a major research focus in the field. Interestingly, these keywords are highly linked to mechanical properties, hybrid composites, scanning electron microscopy and composites, showing that acoustic behaviour is often studied along with the structural and microstructural characterisation. Scanning electron

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microscopy is prominent, thus further highlighting the increasing importance of understanding structure property relationships, especially the influence of fibre morphology, pore structure and material composition on overall performance. This pattern reflects greater emphasis on establishing structure-property relationships capable of supporting the development of more durable and efficient acoustic materials.

Another interesting finding is the presence of keywords like thermal conductivity, density, thermal insulation and sustainable materials which are strongly connected with the main acoustic and material-performance clusters. The vast interconnections among these themes demonstrate that the field has now grown towards multidisciplinary research integrating acoustic performance, thermal insulation, mechanical strength and material characterisation.

To summarise, the findings clearly indicate a transition from agricultural waste utilisation to the development of multifunctional oil palm-based materials integrating acoustic, thermal, microstructural, physical and mechanical performance. The strong thematic relationships among these research areas further highlights the need for a holistic characterisation approach in future studies.

RQ4: Which Top 10 Countries Are the Leading Contributors Based on The Number of Publications?

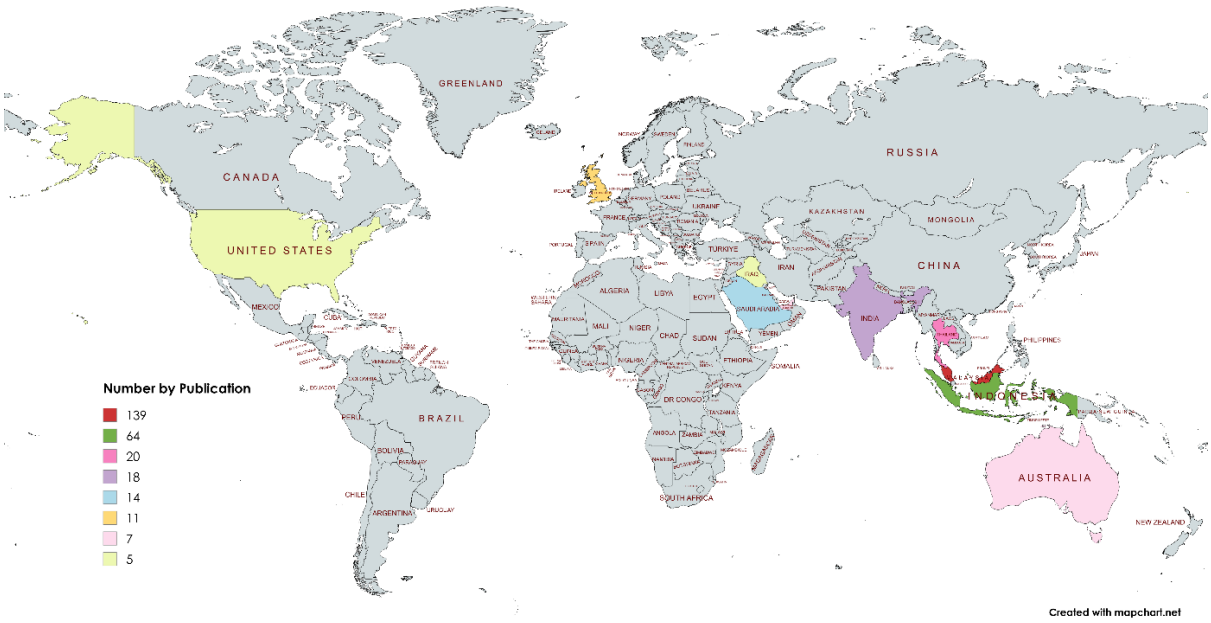

Figure 4: Country Mapping Based on The Number of Published Documents
Source: (Scopus, Wed May 27 2026)

The distribution of the geographic locations based on the number of published documents is shown in Figure 4. The leading country is Malaysia with 139 publications, followed by Indonesia with 64 publications. Next is Thailand (20 publications), India (18 publications) and Saudi Arabia (14 publications). The United Kingdom, Australia, the United Arab Emirates, Iraq, and the United States completed the list of the ten leading contributors. The considerable difference between Malaysia and the remaining countries highlights the central role of Malaysia in driving research development related to oil palm biomass utilisation and acoustic material innovation.

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The strong dominance of Malaysia and Indonesia is not surprising since both countries are among the largest producers of palm oil in the world and produce substantial quantities of oil palm biomass residues through plantation and processing activities (*National Biomass Action Plan 2023-2030*, 2023). The abundance of oil palm waste resources provides a practical basis for research and development activities towards conversion of agricultural residues into value-added engineering materials. Indeed, the availability of raw materials is a major factor affecting research productivity in this field. This strong research capacity has also enabled Malaysia to establish broad international collaborations and maintain its leadership in advancing oil palm biomass research for sustainable acoustic applications.

The presence of countries such as the United Kingdom, Australia and the United States among the leading contributors shows that the interest in oil palm biomass research is not limited to palm oil producing countries only. This finding indicates that oil palm waste is increasingly being recognised not only as an agricultural residue but also as a potential sustainable material resource with diverse engineering applications. The contribution of researchers from developed countries also reflects the growing international interest in renewable materials, circular economy initiatives and environmentally sustainable acoustic technologies. All in all, the participation of developing and developed countries reflects the growing global awareness of oil palm biomass as a promising resource for sustainable material innovation. The continuous international involvement may further increase the diversity and technological advancement of research in this field.

RQ5: What Are the International Collaboration Patterns Based on Country-Level Co-Authorship?

Figure 5 presents the country-level co-authorship network generated using VOSviewer, illustrating the international research collaboration patterns. In the network, node size represents the relative contribution of a country, whereas connecting lines indicate collaborative relationships established through co-authored publications. Countries positioned closer together generally exhibit stronger collaborative interactions.

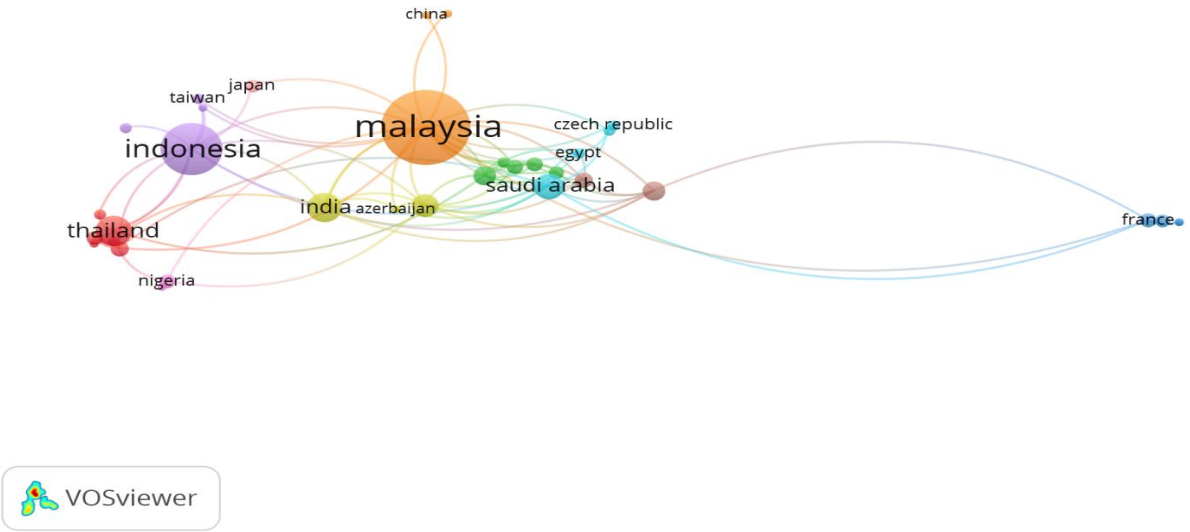

Figure 5: Network Visualisation Map of Co-Authorship by Countries' Collaboration
Source: (Scopus, Wed May 27 2026)

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The results highlights that Malaysia occupies the most central position within the collaboration network and demonstrates the largest node size among all participating countries. This finding is consistent with the publication analysis presented in Figure 4, where Malaysia was the country with the highest contribution in terms of research output. Malaysia's central position in the network suggests that the country functions not only as the primary knowledge producer, but also a major collaboration hub connecting several international research partners.

Indonesia is the second most important collaboration node in the network. Since Indonesia is also among the largest contributors to publication output, the collaboration pattern observed indicates that Malaysia and Indonesia together act as one of the main drivers of research development in the field. The strong connectivity between these countries further indicates the existence of an established regional knowledge network centred around oil palm biomass utilisation and sustainable engineering applications.

Another interesting finding is the presence of smaller collaboration clusters involving countries such as Saudi Arabia, Egypt, the Czech Republic, Azerbaijan and India. Although these countries contribute fewer publications compared to Malaysia and Indonesia, the involvement of countries with diverse geographical and industrial backgrounds suggests that research on oil palm biomass has received interest outside the traditional palm oil producing regions.

In general, the co-authorship network indicates that the international collaboration in the research of oil palm waste-based sound absorption material is mainly driven by a few high-productivity countries, with Malaysia serving as the central hub of collaboration. The network also shows growing international involvement and multidisciplinary participation, suggesting that future research development may benefit from broader international collaboration with expertise in acoustics, materials science, sustainable manufacturing and environmental engineering. Such collaboration could accelerate innovation and facilitate the translation of oil palm biomass research into practical industrial applications.

Conclusion

This study provides a comprehensive bibliometric assessment of global research on oil palm waste-based sound absorption materials based on the analysis of publication trends, most influential publications, contributions by countries, keyword co-occurrence and international collaboration networks. The findings demonstrate a steady growth and maturity of research with Malaysia as the leading contributor and collaboration hub which reflects the key role of palm oil producing countries in driving this research field. Keyword co-occurrence analysis further reveals a transition from studies related to acoustic performance towards multidisciplinary research integrating acoustic, thermal, physical and mechanical properties, focusing on structure-property-performance relationships. These findings highlight the evolution of oil palm biomass from an agricultural waste resource to a multifunctional bio-based material with significant potential for sustainable acoustic engineering applications. Furthermore, the study provides a strategic knowledge base to guide future research, strengthen international collaboration, and advance biomass valorisation, sustainable material innovation and circular economy practices that support SDGs 9 (Industry, Innovation and Infrastructure), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production) and 13 (Climate Action). Future research should prioritise the development of multifunctional oil palm waste-based acoustic materials with optimised acoustic, thermal, physical, and

mechanical performance while promoting interdisciplinary collaboration to accelerate technology translation and commercialisation.

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