ISSN: 2621-4709 E-ISSN: 2621-2528
Journal of Applied Agricultural Science and Technology
Vol. 10 No. 3 (2026): 652-671

A Bibliometric Analysis of Indonesian Scientific Literature on Nutmeg (*Myristica fragrans* Houtt)

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Abstract. *Nutmeg (Myristica fragrans* Houtt*) is one of Indonesia's indigenous plants with high economic value and has long been a leading global commodity. Despite the abundance of literature on nutmeg, no bibliometric study has provided a more comprehensive and objective quantitative mapping of research trends. This study aims to obtain bibliometric information of Indonesian scientific literature on nutmeg (Myristica fragrans* Houtt*) and its development trends using the Scopus database. The analysis identified that Lesmana R. as the most relevant author, Padjadjaran University as the most relevant affiliated institution, "Potential natural dual agonist PPARα/γ-induced antidiabetic and antidyslipidemic properties of safrole-free nutmeg seed (Myristica fragrans* Houtt*) extract" as the most highly cited document, the IOP Conference Series: Earth and Environmental Science as the source with the most articles on nutmeg, and Malaysia as the most relevant collaborating country for Indonesian scientific literature on this topic. Recent keywords include "toxicity", "chemometrics", "broiler chicken", "morphology", "weight gain", "gene expression", "FTIR spectrophotometry", "agricultural robot", and "forestry". It is recommended for future study to do microbiological evaluation in nutmeg trade and/or evaluation of nutmeg antioxidant activity through in vivo studies, including its relationship with glycemic status, to complement the Indonesian scientific literature on nutmeg (Myristica fragrans* Houtt*).*
Keywords: *Bibliometrix; keyword analysis; myristica fragrans; nutmeg; Scopus; VOSviewer.*

Type of the Paper: Regular Article.

1. Introduction

Nutmeg is one of Indonesia's indigenous plants with high economic value and has long been a leading global commodity [1,2]. This plant, belonging to genus *Myristica*, consists of 72 species [2]. *Myristica fragrans* Houtt. is one of the nutmeg species with high economic value, and Indonesia is the world's largest producer and exporter for this species [1,2]. Seeds and mace are two main and popular commodities derived from nutmeg [3,4].

Besides its household use as a spice and cooking ingredient, nutmeg has also been used in various traditional medicines [5,6]. Its pharmacological benefits include: hepatoprotective activity, antioxidant activity, memory enhancing activity, anticancer activity, aphrodisiac activity, antidiabetic activity, anti-depressant activity, hypolipidemic and hypocholesterolemic effect, antimicrobial activity, antibacterial, anti-inflammatory, and anti-carcinogenic, antihyperglycemic [3,7–9]. To date, nutmeg has remained an important ingredient in the food and beverage,

https://doi.org/10.55043/jaast.v10i3.510
Received October 13, 2025; Received in revised form May 20, 2026; Accepted July 2, 2026; Published August 31, 2026
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pharmaceutical, and cosmetics industries [4].

Although many documents on nutmeg (*Myristica fragrans* Houtt) are available in the Scopus database, none of them are bibliometric studies. In fact, bibliometric studies provide a more comprehensive and objective quantitative mapping of research trends, enabling researchers, research institutions, or governments to develop more targeted and relevant research and policy maps. Therefore, given Indonesia's status as the country of origin and the world's largest producer and exporter of nutmeg, this study aims to obtain bibliometric information of Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt) and its development trends. Several relevant software/applications were used to identify the most relevant authors, affiliated institutions, documents, sources, and collaborating countries. Meanwhile, keyword analysis was conducted to obtain information on literature development trends.

2. Materials and Methods

2.1. Data Collection

Data were collected using the Scopus database with the keywords nutmeg OR "myristica fragrans" (search within article title), with the search limited to final documents (in publication stage), Indonesia (country/territory), and English (language). Data were collected on August 16, 2024; any changes made after that date were not considered in this study. A total of 172 documents obtained at this stage were exported in CSV format, and data cleaning was conducted using OpenRefine and Microsoft Excel software. Two documents were identified as duplicates and manually removed, leaving 170 documents for analysis.

2.2. Tools and Types of Analysis

The tools used in this study were OpenRefine, Microsoft Excel, RStudio (Bibliometrix), and VOSviewer. OpenRefine and Microsoft Excel were used for data refinement. For bibliometric analysis, RStudio and Bibliometrix were used. Bibliometrix is a unique open-source tool, designed to perform comprehensive science mapping analysis, as it is very useful in a constantly changing science such as bibliometrics [10]. The main information, the most relevant of authors, affiliations, documents, sources, and collaboration countries on this topic was obtained with Bibliometrix. Keyword analysis along with its network visualization and overlay, was performed using VOSviewer, a software tool for creating, visualizing, and exploring maps based on network data [11].

3. Results and Discussion

2.3. Main Information

Fig. 1 displays the main information from data collected from the Scopus database related to Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt). The earliest literature

indexed in the Scopus database is a note entitled “In vitro mutagenicity tests on capsicum pepper, shallot, and nutmeg oleoresins” [12], published in Agricultural and Biological Chemistry. Fig. 2 shows the annual distribution of 170 documents published between 1985 and August 2024. In the Scopus database, the literature on this topic has only shown an increasing trend in the last decade, with the number of documents > 10 per year after 2018. With a publication growth rate of 8.6% per year, nutmeg (*Myristica fragrans* Houtt) remains an interesting topic despite a decrease in the number of published documents in 2022.

Fig. 1. Main information from the Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt).

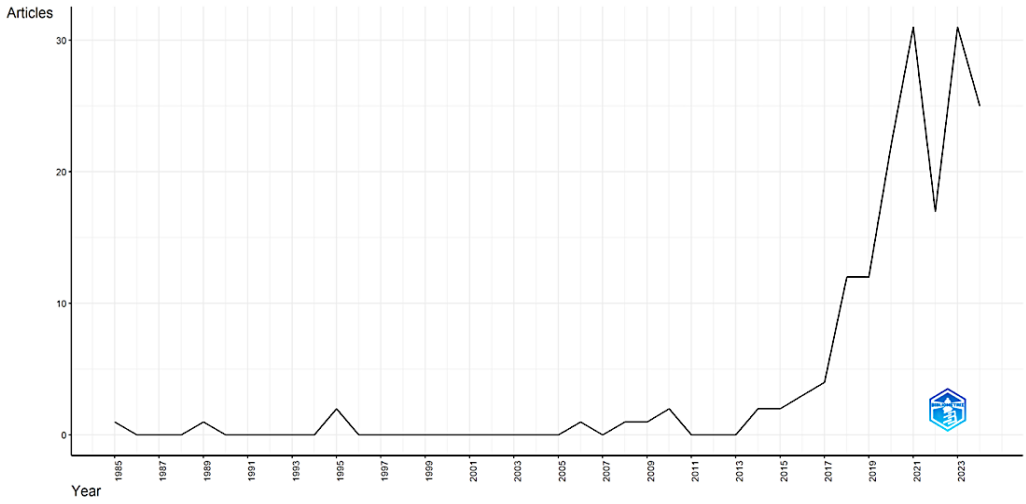

Fig. 2. Annual production of Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt).

2.4. Most Relevant Authors

The growth of literature in a particular field can be attributed to the author's scientific community, affiliations, and sources [13]. Fig. 3 shows the most relevant authors on this topic based on the number of documents published in the Scopus database. Lesmana R is the most productive author, with a total of 9 documents, followed by Pratiwi YS and Supratman U, with each having 7 documents. Dharmaputra OS, Goenawan H, and Sapsuha Y each have 6 documents, while Lestari K, Sylviana N, and Tarawan VM each have 5 documents. The authors' publication consistency and citation performance are presented in Fig. 4. Lesmana R has consistently produced

documents on this topic from 2018 to 2022. The same thing was also conducted by Sapsuha Y, who from 2021 to 2024 continued to produce documents on nutmeg (*Myristica fragrans* Houtt).

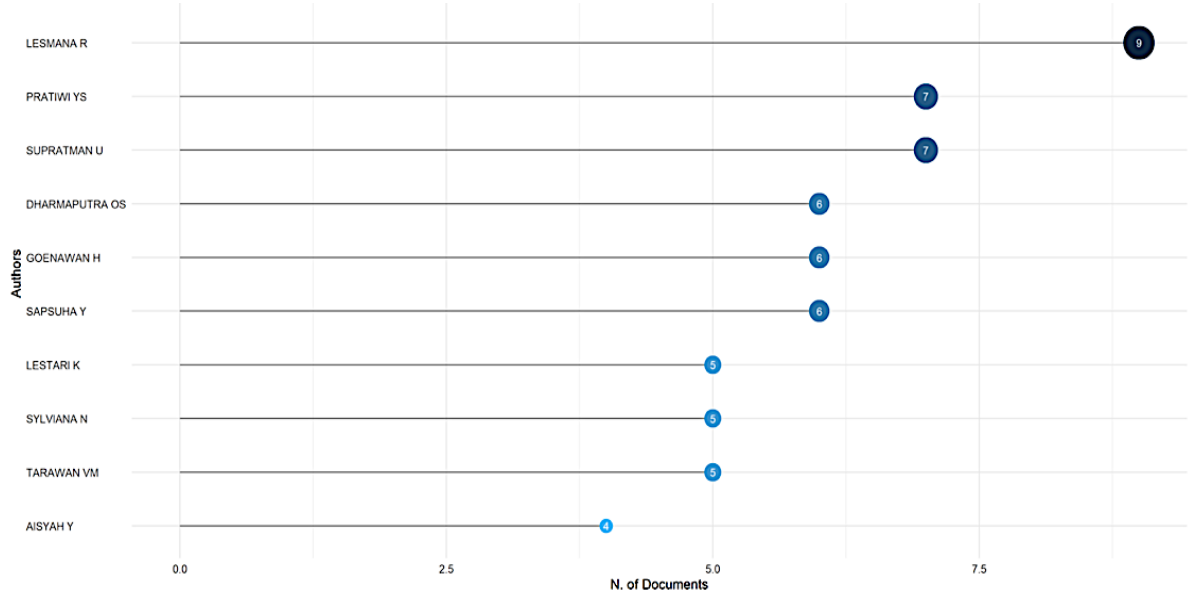

Fig. 3. Most relevant authors of Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt).

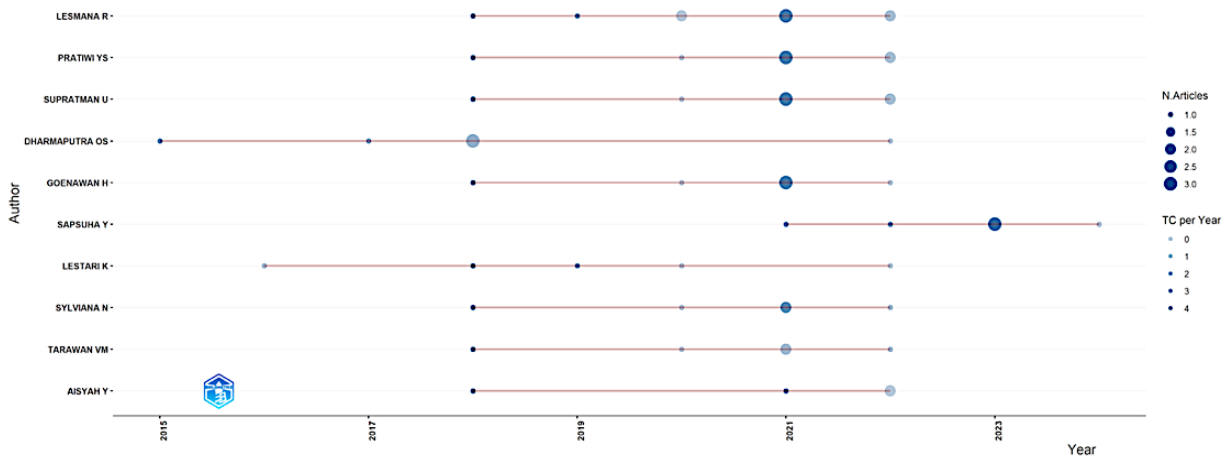

Fig. 4. Author's production over time.

2.5. Most Relevant Affiliated Institutions

Fig. 5 presents the top ten affiliated institutions in this topic. Padjadjaran University ranks first, followed by Syiah Kuala University and IPB University. The inclusion of Pattimura University and Khairun University among the top ten affiliated institutions in this topic is expected, as both are located in the nutmeg production centers in Indonesia, Maluku and North Maluku [14]. Surprisingly, Yonsei University, based in South Korea, also ranks among the top ten affiliated institutions on this topic. A closer examination shows that several publications led by Indonesian first authors include co-authors affiliated with Yonsei University.

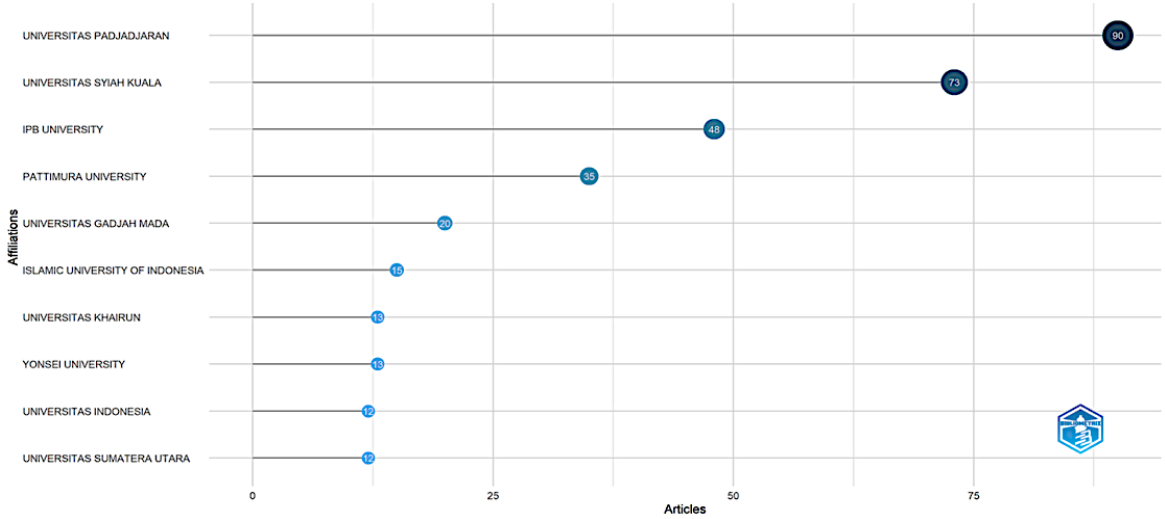

Fig. 5. Most relevant affiliated institutions for Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt).

2.6. Most Relevant Documents

Table 1 displays the documents with the highest citation scores. The choice between local citation and global citation scores depends on the intended scope of the analysis and the need to construct the most representative and efficient dataset. In other words, the optimal data set will be the smallest in size and have the highest relevance [15]. Therefore, documents with high local citation scores can be considered as key documents in the focus area of the research [16]. In this study, local citations local citation scores were used to identify the key publications that have contributed most significantly to the development of Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt). The three most influential documents are presented below in descending order.

Table 1. Top documents by citation score (limited to local citation score ≥ 1).

Rank	Document	Year	LC	GC (Rank)	Ratio
1	Lestari et al. (2019) - Nat Prod J [17]	2019	7	12 (20)	58.33
2	Dharmaputra et al. (2015) - Biotropia [18]	2015	6	19 (13)	31.58
3	Sapsuha et al. (2021) - Livest Res Rural Dev [19]	2021	4	9 (25)	44.44
4	Warsito (2021) - Indones J Pharm [20]	2021	3	8 (29)	37.50
5	Assa et al. (2014) - Int J Chemtech Res [21]	2014	3	33 (8)	9.09
6	Sudradjat et al. (2018) - 2018, J Young Pharm [22]	2018	2	7 (31)	28.57
7	Susanna et al. (2020) - Walailak J Sci Technol [23]	2020	2	6 (37)	33.33
8	Marks & Pomeroy (1995) - Bull Indones Econ Stud [24]	1995	2	6 (38)	33.33
9	Machmudah et al. (2006) - J Supercritical Fluids [25]	2006	1	85 (2)	1.18
10	Tallei & Kolondam (2015) - Hayati J Biosciences [26]	2015	1	36 (6)	2.78
11	Riyanto et al. (2021) - Ind J Nat Prod Resour [27]	2021	1	2 (66)	50.00
12	Yunita et al. (2022) - Biodiversitas [28]	2022	1	4 (47)	25.00
13	Muchtaridi et al. (2016) - J Appl Pharm Sci [29]	2016	1	2 (69)	50.00
14	Kusuma et al. (2020) - Mol Biol Rep [30]	2020	1	4 (48)	25.00
15	Muchtaridi et al. (2010) - Int J Mol Sci [31]	2010	1	94 (1)	1.06
16	Horison et al. (2019) - Food Res [32]	2019	1	23 (11)	4.35
17	Lesmana et al. (2021) - Vet Med Sci [33]	2021	1	2 (75)	50.00
18	Dharmaputra et al. (2018) - Int Food Res J [34]	2018	1	4 (51)	25.00
19	Sapsuha et al. (2022) - Agron Res [35]	2022	1	5 (45)	20.00

GC = global citation; LC = local citation; Ratio = (LC/GC) x 100.

First, "Potential natural dual agonist PPARα/γ-induced antidiabetic and antidyslipidemic properties of safrole-free nutmeg seed (*Myristica fragrans* Houtt) extract" [17]. As indicated by the title, this study reports in vivo studies of the antidiabetic and antidyslipidemic properties of safrole-free nutmeg seed extract samples. This study found the potential antidiabetic and antidyslipidemic activity of safrole-free nutmeg extract administered to a rat model of type 2 diabetes mellitus. Safrole-free nutmeg extract also has the potential to increase PPARα and PPARγ levels, which are thought to contribute to its antidiabetic and antidyslipidemic properties. Based on our review of the articles citing this article, we found it to be particularly important because it provides in vivo evidence of the antidiabetic and antidyslipidemic activities of nutmeg extract.

Second, "Fungal infection and aflatoxin contamination in stored nutmeg (*Myristica fragrans*) kernels at various stages of the delivery chain in North Sulawesi Province" [18]. This paper reports on post-harvest handling of nutmeg seeds, the presence of fungi (including *A. flavus*) and aflatoxin contamination in stored nutmeg seeds, as well as the moisture content and percentage of damage to nutmeg seeds in North Sulawesi province. The results of non-parametric statistical analysis showed that the influence of the delivery chain did not provide a significant difference in water content, percentage of damaged nutmeg seeds, number of fungal populations, and total amount of aflatoxin. This study also recommends improving post-harvest handling methods for nutmeg seeds at the farmer, collector, and exporter levels in North Sulawesi Province to minimize aflatoxin B1 contamination and the total amount of aflatoxin. This article has been frequently cited because it provides comprehensive empirical mapping information regarding critical control points of microbiological contamination along the nutmeg commodity supply chain. In addition, this article also presents quantitative data on shifts in the dominance of fungal species (such as *Aspergillus niger, Endomyces fibuliger, and Eurotium repens*) and the accumulation of aflatoxin levels from the farmer, collector, to exporter levels. Other findings, including the relationship between traditional drying methods, high physical damage to nutmeg seeds, and the water content threshold are often cited as the basis for arguments or comparative data in studies on food security, mycology, and barriers to Indonesian nutmeg exports in the international market.

Third, "The effect of nutmeg flesh (*Myristica fragrans* Houtt) extract on growth performance, internal organs and carcass of broiler chickens raised at high stocking density" [19]. This paper reports that feed supplemented with nutmeg extract improves the performance of broiler chickens raised at high stocking densities. In the bibliometric landscape, this article plays a significant role as a primary reference in the search for alternative phytogenic products to replace Antibiotic Growth Promoters (AGP) in the poultry industry. It is consistently cited for its contribution in exploring the utilization of nutmeg (*Myristica fragrans* Houtt) pulp waste as a feed additive that supports sustainability aspects. Furthermore, its focus on mitigating stress in chickens

due to high stocking density makes it a crucial reference. Their empirical findings, which prove that the inclusion of nutmeg pulp extract improves growth performance and feed conversion ratio (FCR) without causing negative side effects on carcass and internal organ characteristics, are often adopted as a theoretical basis and comparative benchmark for subsequent studies on herbal- and synbiotic-based feed.

According to Batista-canino et al. [16], global citation scores can be considered to identify potential seeds for new research topics beyond the primary focus of a study. Global citation is the total number of citations a document receives from all publications indexed in a database (Scopus, in this study). As shown in Table 1, several documents provide insights into potential research directions that extend beyond Indonesian scientific literature only focusing on nutmeg (*Myristica fragrans* Houtt). In addition, papers with high global citation scores also show a large scientific impact across research topics beyond nutmeg (*Myristica fragrans* Houtt). In this context, the studies by Assa et al. [21], Siti Machmudah et al.[25], and Tallei & Kolondam [26] -which rank among top-10 in local citation and also top-10 in global citation- need to be highlighted. The study by Muchtaridi et al. [31], which has the most global citations, also needs to be mentioned in this context. These papers are briefly explained below.

"Antioxidant potential of flesh, seed and mace of nutmeg (*Myristica fragrans* Houtt)" [21] ranked 5th in local citation and 8th in global citation (local citation score: 3; global citation score: 33). This paper evaluated the antioxidant potential of methanol extracts of nutmeg flesh, seeds, and mace using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) method, ferric reducing antioxidant power (FRAP), ferric ion chelation activity, and antioxidant activity test in a linoleic acid system with a ferrous thiocyanate (FTC) reagent. Total phenolics and phytochemicals of the extract were also evaluated. The study reported that seed extract has the strongest free radical scavenging ability based on DPPH and FRAP tests, total phenols correlated with DPPH and FRAP, and nutmeg's ability to inhibit linoleic peroxidation well. In addition, tannins, flavonoids, and terpenoids were detected in seed and mace extracts, while the fruit flesh extract contains flavonoids and terpenoids.

"Supercritical CO_2 extraction of nutmeg oil: experiments and modeling" [25] ranked 9th in local citation and 2nd in global citation (local citation score: 1; global citation score: 85). This paper investigated the extraction process of nutmeg oil from nutmeg seeds with supercritical CO_2 (pressure 15–20 MPa and temperature 313–323 K) and observes the effect of separation parameters such as temperature, pressure, CO_2 flow rate, and particle size on the extraction rate of nutmeg oil. Broken and intact cells (BIC) model combined with discontinuous phase equilibrium between fluid and solid phases and a shrinking core model were selected to describe the extraction process. This paper concludes that the shrinking core model accurately describes the experimental

data for all extraction conditions, while the BIC model only accurately describes the data at lower extraction yields.

"DNA barcoding of Sangihe nutmeg (*Myristica fragrans*) using *mat*K gene" [26] ranked 10th in local citation and 6th in global citation (local citation score: 1; global citation score: 36). This paper discusses the development of DNA barcodes for nutmeg (*Myristica fragrans*) using the recommended standard *mat*K gene (maturase K) fragment. Based on a BLAST search of the NCBI website, Sangihe nutmeg demonstrated 100% sequence with *Myristica fatua*, *M. maingayi*, and *M. globosa*. Sangihe nutmeg also has 3 nucleotide differences with *Rivola sebifera* (99.58% identity) and 4 nucleotide differences with *Knema laurina* (99.43% identity). The paper concludes that the single locus of the *mat*K gene cannot distinguish species in *Myristica* and can only distinguish genus levels in the *Myristicaceae* family.

"Identification of compounds in the essential oil of nutmeg seeds (*Myristica fragrans* Houtt.) that inhibit locomotor activity in mice" [31] has a local citation score of 1 but has the highest global citation score (94) among the 170 documents in this study. This paper reports an evaluation of the inhibitory effect of nutmeg essential oil (*Myristica fragrans* Houtt.) on the locomotor activity of rats in a wheel cage. The results indicate that higher dose and longer administration time of nutmeg essential oil leads to greater locomotor inhibitory effect. Furthermore, the concentration of essential oil compounds in blood plasma was relatively low. Therefore, the author suggested that volatile compounds of nutmeg essential oil identified in blood plasma may be associated with its locomotor inhibitory effects following inhalation.

2.7. Most Relevant Sources/Journals

The 170 documents included in this study were published in 82 journals. Table 2 presents the leading publication sources/journals for Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt) (in this table, limited to journals with ≥ 2 documents). In addition, h-index, g-index, m-index and total citations are also displayed in this table. The 'Hirsch index' (h-index) is a leading author-level research metric, and its value indicates the number of papers with at least a citation score of 'h'. The g-index refers to the largest number for which the top 'g' articles receive at least g^2 citations together [36]. Meanwhile, the m-index is an additional metric also introduced by Hirsch that measures the slope or rate of increase of the h-index over time, obtained by dividing the h-index by the number of years since first publication [37].

The results of the analysis show that the Conference Series remains the primary choice for publishing Indonesian scientific literature from Indonesia on nutmeg (*Myristica fragrans* Houtt). This is evident from the top 5 sources, all of which are Conference Series, IOP Conference Series: Earth and Environmental Science ranking first and accounting for 28.82% of the total publications on this topic. Biodiversitas is a non-conference series journal that publishes the most documents

for this topic (2.35%), followed by Open Agriculture and Journal of Applied Pharmaceutical Science (each 1.76%). Meanwhile, the International Journal of Chemtech Research, Food Science and Biotechnology, Biotropia, and Livestock Research for Rural Development each contributed 1.18% to publishing Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt). These indicate that Indonesian scientific publications on nutmeg should be encouraged to target scientific journals rather than conference proceedings. Despite their academic merit, scientific articles published in conference proceedings generally contain information from preliminary research. In contrast, scientific journals accommodate mature research results that have undergone a thorough evaluation and in-depth peer-review process. Thus, articles published in scientific journals will receive broader academic recognition.

Table 2. Top sources/journals based on the number of published documents (limited to documents ≥ 2).

Rank	Source	NP	h-index	g-index	m-index	TC	PY-start
1	IOP Conference Series: Earth and Environmental Science	46	4	6	0.44	58	2016
2	AIP Conference Proceedings	12	1	1	0.33	1	2022
3	E3S Web of Conferences	8	2	3	0.29	14	2018
4	IOP Conference Series: Materials Science and Engineering	7	3	6	0.38	46	2017
5	Journal of Physics: Conference Series	7	3	3	0.43	12	2018
6	Biodiversitas	4	2	3	0.40	9	2020
7	Open Agriculture	3	1	3	0.25	9	2021
8	Journal of Applied Pharmaceutical Science	3	1	1	0.11	3	2016
9	International Journal of Chemtech Research	2	2	2	0.18	35	2014
10	Food Science and Biotechnology	2	2	2	0.13	21	2009
11	Biotropia	2	1	2	0.10	19	2015
12	Livestock Research for Rural Development	2	2	2	0.50	11	2021

NP = number of publications; PY-start = year the document was first published; TC = total citation.

Referring to the categorization made by Hirsch et al. [37], only two journals (Analytical Letters and Carbon Trends) have above-average scientific impact based on the m-index (see Suplementary Material). Meanwhile, the potential for scientific impact of other journals (including all journals in Table 2) is categorized as average. However, 50% of the sources in this table rank among the top 20 in terms of highest citation score (see Supplementary Material). In fact, ≥ 75% of the journals in this list rank among the top 10 for both h-index and g-index (see Supplementary Material). In addition, Biotropia, Livestock Research for Rural Development, and International Journal of Chemtech Research published the papers with the highest local citation scores.

2.8. Country Collaboration Network

In addition to collaborating with co-authors from Indonesia, the first authors have also collaborated with co-authors from 17 countries in producing scientific literature on nutmeg

(*Myristica fragrans* Houtt). Fig. 6 displays the country collaboration map and the number of jointly published documents. Malaysia, Indonesia's closest neighbor, was the most frequent international collaborator in producing nutmeg (*Myristica fragrans* Houtt) literature (6 documents), followed by Japan (5 documents), South Korea (5 documents), France (3 documents), India (2 documents), and Thailand (2 documents). Meanwhile, the other 11 countries collaborated on 1 document each.

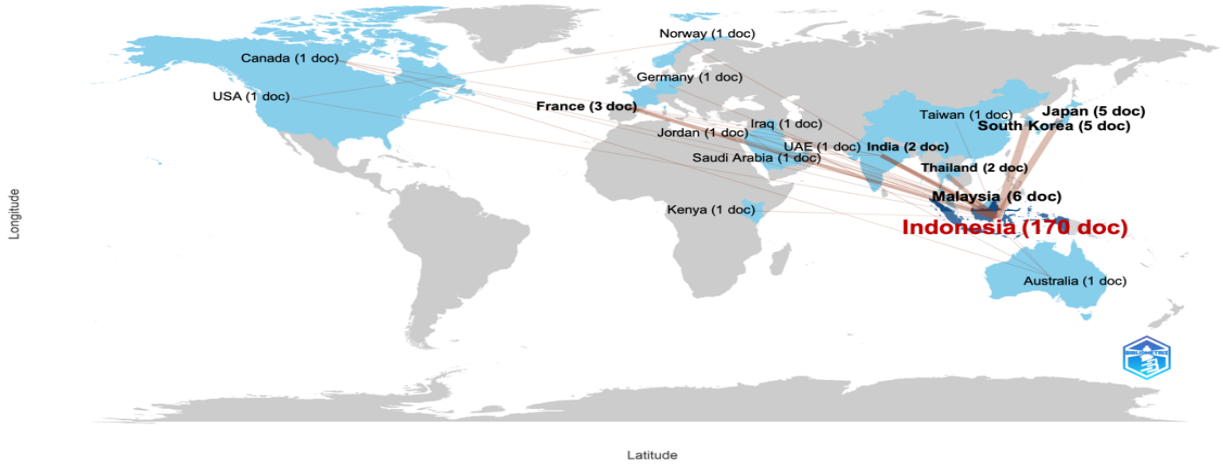

Fig. 6. Country collaboration map. The line thickness is equivalent to the number of collaborative documents.

2.9. Keyword Analysis

Bibliometric analysis based on the Scopus database has become an increasingly popular method for visualizing the structure of scientific fields. A search of the Scopus database using the keywords bibliometric* OR bibliograph* AND Scopus (accessed in August 2024) retrieved 15,159 documents. In bibliographic research, keywords are generally used in the unit of analysis, with author keywords and index keywords serving this purpose. Author keywords are provided by the original authors, whereas index keywords are extracted from the titles of references cited by Thomson Reuters. Index keywords, generated by an automated computer algorithm, are words or phrases that frequently appear in the titles of reference articles and not necessarily in the article title or as author keywords [38]. This study also conducted keyword analysis using author keywords and index keywords and compared the resulting keyword networks.

Table 3. Distributions of the keywords.

Frequency	Authors keywords		Index keywords		All keywords	
	NT	NT (%)	NT	NT (%)	NT	NT (%)
≥ 10	2	0.58	6	0.60	10	0.80
≥ 8	3	0.86	8	0.80	13	1.04
≥ 6	5	1.44	15	1.50	19	1.52
≥ 4	10	2.88	38	3.80	49	3.92
≥ 2	51	14.70	180	18.02	231	18.47
≥ 1	347	100.00	999	100.00	1251	100.00

Frequency = the number of occurrences of a keyword; NT = number of terms; NT (%) = (number of terms/total terms) x 100.

From 1985 to August 2024, 170 publications on nutmeg (*Myrisitica fragrans* Houtt) from Indonesia were indexed in the Scopus database. Table 3 shows the distribution of author keywords and index keywords from all documents used in this study. A total of 347 author keywords and 999 index keywords (ratio 1:2.88) were identified with the help of VOSviewer software. A total of 1,251 unique terms representing the combined set of author and index keywords were also identified. Of these, 95 terms (7.59%) are the same as those used by both types of keywords (author keywords and index keywords). Overall, author keywords were fewer in number than index keywords. In addition, author keywords are more specific, whereas index keywords were broader and reflected more general concepts. This aligns with the findings of Zhang et al. [38], who compared these two types of keywords for a patient adherence research case study.

Table 4. Top 20 most frequently used keywords terms.

Rank	Authors keywords	Frequency	Index keywords	Frequency	All keywords	Frequency
1	nutmeg	25	nutmeg	19	nutmeg	37
2	myristica fragrans	12	nonhuman	18	myristica fragrans	18
3	nutmeg oil	9	article	17	nonhuman	18
4	essential oil	7	controlled study	14	article	17
5	antioxidant	6	agriculture	13	controlled study	14
6	broiler	5	plant extract	12	agriculture	13
7	fungi	4	unclassified drug	9	nutmeg oil	13
8	myristica	4	animal experiment	8	plant extract	12
9	nutmeg seed	4	essential oils	7	essential oil	10
10	performance	4	indonesia	7	myristica	10
11	activated carbon	3	male	7	unclassified drug	9
12	agroforestry	3	myristica	7	animal experiment	8
13	anticancer	3	myristica fragrans	7	indonesia	8
14	diabetes mellitus	3	nutmeg oil	6	essential oils	7
15	gamma irradiation	3	rat	6	male	7
16	macelignan	3	agricultural robots	5	antioxidant	6
17	myristica fragrans houtt	3	animal model	5	broiler	6
18	myristicin	3	antioxidant activity	5	myristicin	6
19	oleoresin	3	economic values	5	rat	6
20	synbiotic	3	plant extracts	5	agricultural robots	5

Frequency = the number of occurrences of a keyword.

Table 4 displays the 20 terms with the highest frequency of author keywords, index keywords, and all keywords. A number of identical terms such as “nutmeg”, “myristica fragrans”, “nutmeg oil”, “essential oil”, “antioxidant”, and “myristica” appear in the author keywords and index keywords. By excluding these identical terms, it can be clearly seen that more specific terms are found in the author keywords, whereas index keywords terms are more general. For instance,

in the index keywords, the terms “unclassified drugs” and “plant extract” are found, while in the author keywords, author found terms such as “nutmeg seed”, “anticancer”, “diabetes mellitus”, “mace lignan”, “myristicin”, “oleoresin”, “symbiotic”. Other examples of general terms in the index keywords are “nonhuman”, “article”, “controlled study”, “agriculture”, “animal experiment”, “indonesia”, “male”, “agricultural robots”, “animal model”, “economic values”. While other specific terms found in the author keywords include “broiler”, “fungi”, “activated carbon”, and “gamma irradiation”.

The literature map of a field of science structure is identified through keyword analysis. Fig. 7 shows a map of Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt) built from author keywords. To highlight the most significant relationships, terms with a frequency of less than 2 were excluded, resulting in 51 terms included in this network mapping. By default, VOSviewer also groups network nodes into clusters. A group of interconnected nodes is called a cluster. In a network, every node is connected to a single cluster. A resolution parameter controls the number of clusters. The number of clusters increases with the value of this parameter [39].

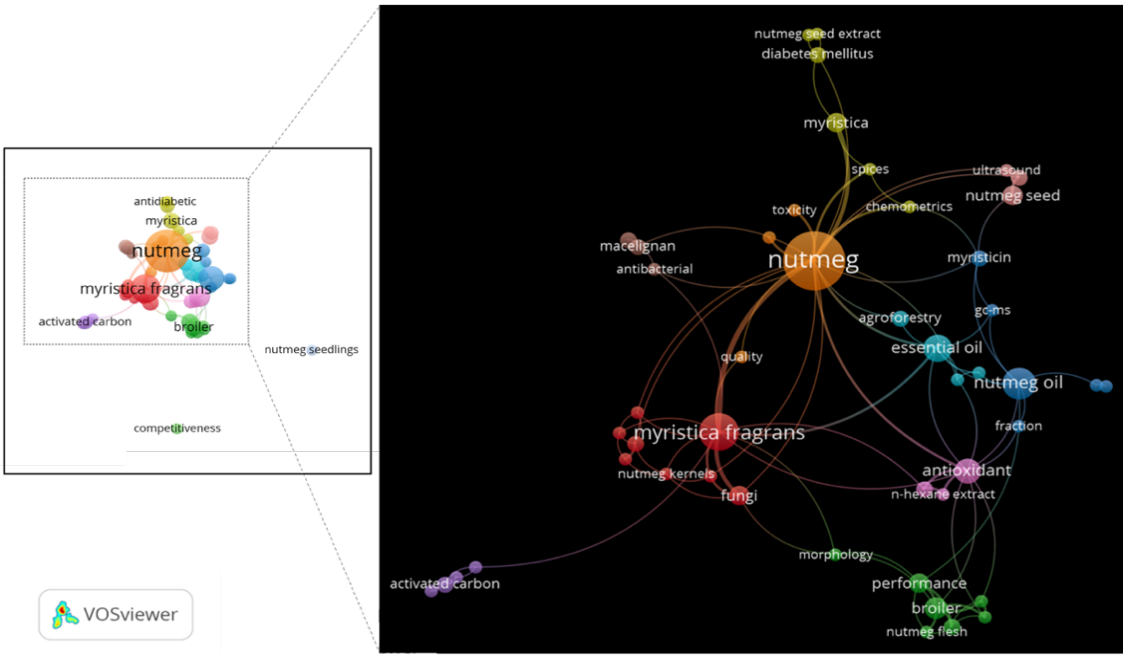

Fig. 7. Knowledge structure of Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt) with author keywords (frequency ≥ 2 times). The size of the nodes indicates the keywords frequency, and the thickness of the lines indicates the co-occurrence frequency of keyword pairs.

Author keywords form 12 clusters, each marked with a different color. Cluster 1 is marked with red color consisting of 8 items: aflatoxin, aflatoxin b1, aspergillus flavus, fungi, gamma irradiation, myristica fragrans, nutmeg kernels, and toxigenic. Cluster 2 is marked with green color consisting of 7 items: broiler, intestinal bacterial population, intestinal morphology, morphology, nutmeg flesh, performance, and synbiotic. Cluster 3 is marked with aqua blue color consisting of 6 items: distillation, fraction, fuzzy logic control, gc-ms, myristicin, and nutmeg oil. Cluster 4 is marked with yellow color consisting of 6 items: antidiabetic, chemometrics, diabetes mellitus,

myristica, nutmeg seed extract, and spices. Cluster 5 is marked with purple color consisting of 4 items: activated carbon, methylene blue, myristica fragrans shell, and nutmeg shell. Cluster 6 is marked with ice blue color consisting of 4 items: agroforestry, edible coating, essential oil, and nanoemulsion. Cluster 7 is marked with an orange color consisting of 4 items: browning, nutmeg, quality, and toxicity. Cluster 8 is marked with brown color consisting of 3 items: antibacterial, macelignan, and myristica fragrans houtt. Cluster 9 is marked with lavender color consisting of 3 items: anticancer, antioxidant, and n-hexane extract. Cluster 10 is marked with salmon red color consisting of 3 items: nutmeg seed, oleoresin, and ultrasound. Cluster 11 is marked with a honeydew color consisting of 2 items: competitiveness and Maluku. Cluster 12 is marked with misty blue color consisting of only 1 item, namely nutmeg seedlings.

The term “nutmeg” indeed becomes the center of the literature on this topic. “myrsitica fragrans”, “nutmeg oil”, “essential oil”, “antioxidant”, and “broiler” which have larger node sizes in their respective clusters are the main subnetworks in the Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt). In addition, thicker connecting lines between the terms “myrsitica fragrans”-“nutmeg”-“myristica” indicate a high frequency of co-occurrence of these terms in a document. This is acceptable, considering that these three terms actually refer to the similar subject. It should be highlighted that in the visualization of keyword analysis, no connecting line was found between the terms "diabetes mellitus" and "antioxidants". In fact, consuming foods rich in antioxidants is highly recommended to inhibit the development of diabetes mellitus [40].

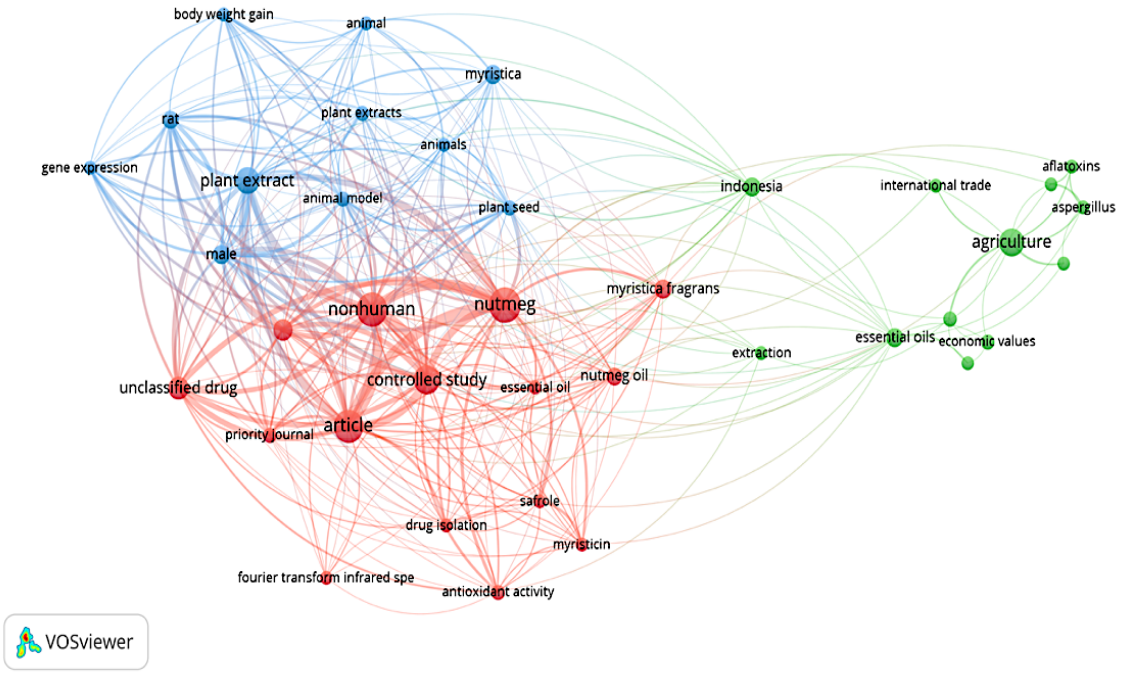

Fig. 8. Knowledge structure of Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt) with index keywords (frequency ≥ 4 times). The size of the nodes indicates the keywords frequency, and the thickness of the lines indicates the co-occurrence frequency of keyword pairs.

To highlight the most significant relationships, terms with a frequency ≥ 2 of the index keywords were included in the network mapping (Fig. 8). The 51 selected terms form 3 clusters (each cluster is marked with a different color). The first cluster in red is dominated by several general terms such as "nutmeg", "nonhuman", "article", "controlled study", and "agriculture", while the specific terms in this cluster tend to be associated with the bioactive compounds of nutmeg (*Myristica fragrans* Houtt). The second cluster in blue focuses on the term "plant extract" with many other subnetworks related to in-vivo study themes. Meanwhile, cluster 3 in green summarizes terms related to economic and trade issues, including microbiology issues. However, this network map shows no direct connecting line between the terms "international trade" and "aflatoxin" and "aspergillus", indicating limited literature discussing the relationship between these two terms. Another notable finding is that the term "antioxidant activity" included in cluster 1 has no connecting line at all with specific terms from the second cluster such as, "animal", "animal model", "rat", "gene expression", and "body weight". This indicates that the Indonesian scientific literature containing the results of antioxidant activity evaluation through in vivo experiments using experimental animals remains very limited or even non-existent.

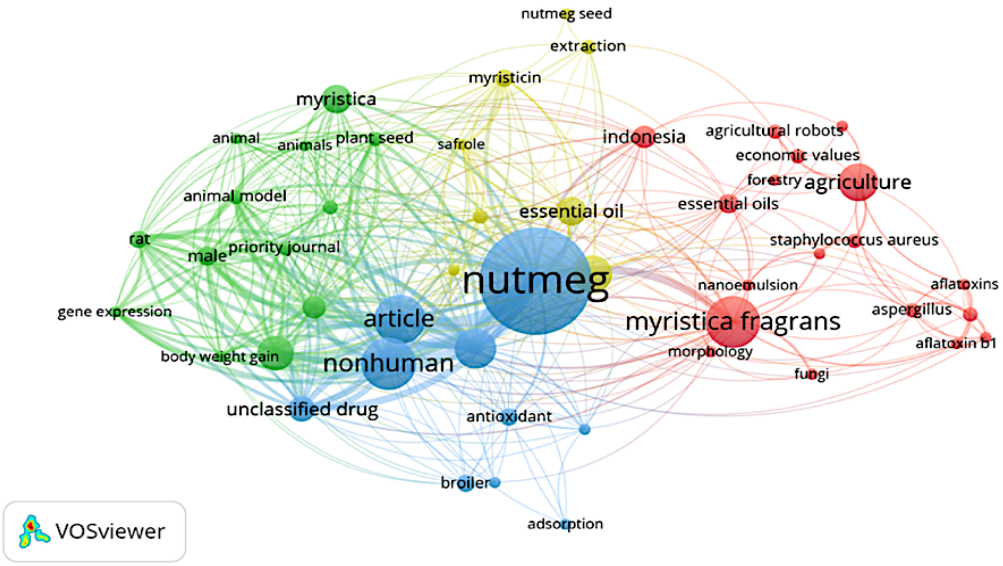

Fig. 9. Knowledge structure of Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt) with all keywords (frequency ≥ 4 times). The size of the nodes indicates the keywords' frequency, and the thickness of the lines indicates the co-occurrence frequency of keyword pairs.

In addition to author keywords and index keywords, this study also displays a literature map based on terms from all keywords by limiting only terms with frequencies above 4 (Fig. 9). As a result, 49 terms were included in the mapping and formed 4 clusters, each represented by a different color. The clustering of these terms is not significantly different from that of author keywords and index keywords. The term "nutmeg" has the largest node size and occupies a central position, and is related to many other large and small subnetworks.

Fig. 10 shows the period of keyword occurrence in Indonesian scientific literature on nutmeg (*Myrstica fragrans* Houtt). Terms in light colors (yellow) are terms that appear in the latest published documents. Conversely, those in dark colors (blue) indicate that the terms appear as keywords in documents published earlier. Fig. 10 shows that the latest keywords in Indonesian scientific literature on nutmeg (*Myrstica fragrans* Houtt) include "toxicity", "chemometrics", "broiler", "morphology", "body weight gain", "gene expression", "FTIR-spectrophotometry", "agricultural robot", and "forestry".

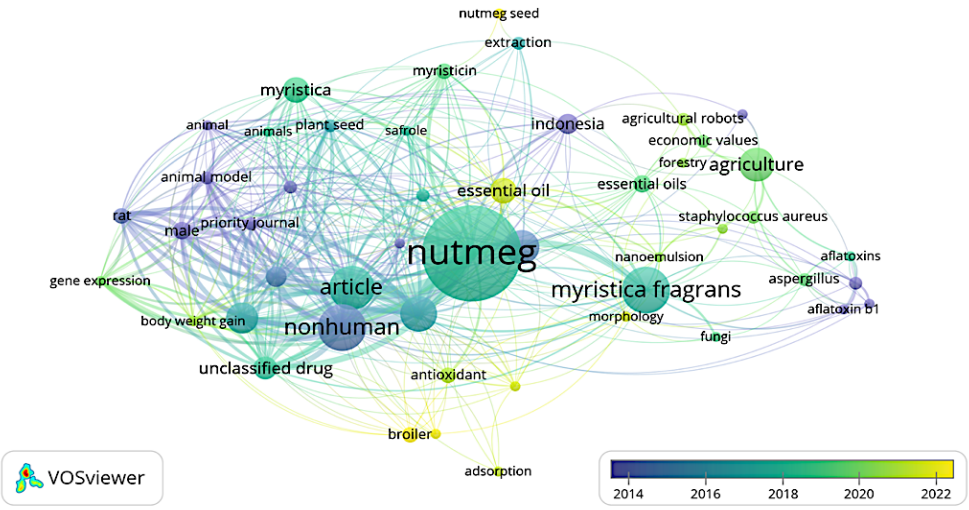

Fig. 10. Overlay visualization of author keywords (A), index keywords (B), and all keywords (C) of Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt).

4. Conclusions

Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt) comprised 170 documents, representing 17.28% of the total documents in the Scopus database. This places Indonesia second after India, contributing 21.14% of the literature on this topic. This finding aligns with Indonesia's status as the country of origin and the world's largest producer and exporter of nutmeg (*Myristica fragrans* Houtt) for centuries. The average number of documents published is 3.98 per year, calculated from 1985 to 2024. However, considering the publication trend and productivity and consistency of authors in the last decade, the number of publications is likely to continue increasing in the coming years.

Lesmana R is identified as the most relevant author, Padjadjaran University as the most relevant affiliation, "Potential natural dual agonist PPARα/γ-induced antidiabetic and antidyslipidemic properties of safrole-free nutmeg seed (*Myristica fragrans* Houtt) extract" as the most relevant document, IOP Conference Series: Earth and Environmental Science as the most relevant sources and Malaysia as the most relevant collaborating country. This study also found the latest terms used as keywords: "toxicity", "chemometrics", "broiler chicken", "morphology", "weight gain", "gene expression", "FTIR spectrophotometry", "agricultural robot", and "forestry".

Limited literature on a particular topic is a gap that needs to be filled. Microbiological evaluation in nutmeg trade and/or evaluation of nutmeg antioxidant activity through in vivo studies, including its relationship to glycemic status, are themes that are currently not available in the Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt), thus becoming an option and an opportunity for future study.

This bibliometric study utilizes only one database source, Scopus. Therefore, publications on nutmeg (*Myristica fragrans* Houtt) indexed exclusively in other databases were not included in the analysis. However, Scopus is one of the largest and most trusted scientific literature databases and can therefore be considered sufficiently representative. Therefore, this paper is expected to provide a clear picture of the development trends of Indonesian scientific literature on nutmeg (*Myristica fragrans* Houtt), including gaps and research opportunities in this topic.

Abbreviations

BIC	Broken and Intact Cells
BLAST	Basic Local Alignment Search Tool
CO_2	Carbon Dioxide
CSV	Comma-Separated Values
DNA	Deoxyribonucleic Acid
DPPH	1,1-Diphenyl-2-Picrylhydrazyl
FRAP	Ferric Reducing Antioxidant Power
FTIR	Fourier Transform Infrared
FTC	Ferrous Thiocyanate
GC	Global Citation
K	Kelvin
LBD	Ligand Binding Domain
LC	Local Citation
*mat*K	Maturase K
MPa	Megapascal
NCBI	National Center for Biotechnology Information
NP	Number of Publications
NT	Number of Terms
PPAR	Peroxisome Proliferator-Activated Receptor
PY-start	Year the document was first published
SNI	Standar Nasional Indonesia
TC	Total Citation

Data availability statement

The data generated in this study are presented in the manuscript. Further inquiries can be directed to the corresponding author.

CRediT authorship contribution statement

Hasbullah: Conceptualization, Formal analysis, Methodology, Resources, Software, Visualization, Data curation, Writing–original draft. **Sri Soenarsih**: Conceptualization, Methodology, Resources, Validation, Data curation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Use of AI in the Writing Process

Nothing to disclose

Acknowledgement

This study was supported by Competitive Research Program of Excellence for Higher Education (PUPKT) Assigned at Faculty of Agriculture - Khairun University 436/UN44.CP/PP.01/2025 (Grant Number: 023.17.2.677532/2025).

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