

The Peruvian Herb with Global Reach: A bibliometric Analysis of *Lepidium meyenii* (maca) Research from 2013 to 2024

Hidayatul Radziah Ismawi^{1*}, Najwa Hanim Othman¹, Maizura Mohd Zainudin¹, Azliana Abd Fuaat²
and Nour El Huda¹

¹Department of Basic Medical sciences, Kulliyah of Medicine, International Islamic University Malaysia

²Department of Pathology and Laboratory Medicine, Kulliyah of Medicine, International Islamic University Malaysia

*Corresponding author: hidayatulradziah@iium.edu.my

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Abstract

This analysis explored the global research trends of *Lepidium meyenii* (maca) from 2013 to 2024, using bibliometric methods, and explore international collaborations, the evolution of active topics and emerging trends. We utilised various methodologies on the SCOPUS database such as keyword co-occurrence and co-authorship analysis to identify the most influential authors, institutions, and countries, along with the most cited publications in this field. We used Bibliomagika 2.2 and Bibliomagika 1.5 Split for frequency analysis, as well as VOSviewer for data visualization. We also delved into the co-occurrence of different terms connected to *Lepidium meyenii* (maca) and author keywords within the specified time period. A total of 313 publications were identified, with the most published in 2022, revealing an upward trend in the past decade. China (223 publications) emerged as the leading country in maca research, and the preeminent journal in this field was identified as *Andrologia* (15 publications). The analysis of keyword co-occurrence highlighted key thematic clusters, with "*Lepidium meyenii* (maca)," "herbal medicine," "macamides," "antioxidant," and "medicinal plants" as the most prevalent author keywords. Our findings suggest the global reach of *Lepidium meyenii* (maca) and offer insights into research patterns, the contributions of different countries, influential authors, and active journals. This data serves as a tool for researchers to identify future directions of research in this field.

Keywords:

Lepidium meyenii; maca; Bibliometrics; biblioMagika; VOSviewer

Introduction

For centuries, the Andean people of Peru have cultivated and used *Lepidium meyenii* (maca) both as a dietary staple and for its medicinal properties. Traditionally, maca has served as a tonic and fertility enhancer for humans and livestock and has been employed in treating various ailments such as rheumatism, respiratory issues, and anaemia^{1,2}.

In 1598, Vasquez de Espinoza journeyed to Peru and meticulously recorded descriptions of this plant widely utilised in the region, along with its various uses, in his work *Compendio y descripción de las Indias Occidentales*. Similarly, Bernabé Cobo, a Spanish Jesuit missionary and author who visited Peru from 1603 to 1629, also referenced this plant in his *Historia del Nuevo Mundo*, asserting that "it thrives in the most remote and coldest regions of the Sierra, where no other cultivated plant provides sustenance to humans. Thus, God bestowed upon the indigenous people of this province this root, ensuring they would not lack a natural food source in their homeland."^{3,4}.

Over the past two decades, maca has garnered worldwide recognition, often marketed online as the "Peruvian Ginseng" for its claimed efficacy in enhancing libido and fertility. This surge in popularity has prompted a transition from traditional cultivation practices to mass production methods, and has led to its cultivation expanding beyond the Andean region to areas such as the Yunnan province in China.¹

We did not find previous bibliometric analysis regarding *Lepidium meyenii* (maca) research specifically, but those closely related to the topic were on medicinal plants found in Peru and Latin America. A notable publication in 2020 by Angulo-Bazán studied scientific output on medicinal plants published between 2000 and 2019 with at least one author with Peruvian affiliation. A summary of these previous studies are listed in Table 1.

This review plans to provide valuable insights into the publication trends, research themes, collaboration dynamics, and future research directions within the field of *Lepidium meyenii* (maca) research.

The methodology of bibliometric analysis necessitates well-defined and concise research questions. This study addresses the following research questions to investigate various trends related to research productivity, collaboration, and knowledge dissemination concerning *Lepidium meyenii* (maca) research:

1. What are the publication trends in *Lepidium meyenii* (maca) research?
2. Who are the most prolific authors in *Lepidium meyenii* (maca) research, and what are the key themes and topics in their research?
3. What are the most influential institutions in the field of *Lepidium meyenii* (maca) research?
4. What are the most active countries in the field of *Lepidium meyenii* (maca) research?
5. What are the most highly cited documents in the field of *Lepidium meyenii* (maca) research, and what are the key themes and topics that they address?
6. What are the most common keywords and themes in the literature on *Lepidium meyenii* (maca) research?
7. What are the patterns of co-authorship in *Lepidium meyenii* (maca) research?
8. What are the key themes and topics that emerge from co-occurrence analyses of author keywords and title/abstract terms in the literature on *Lepidium meyenii* (maca) research?

Methodology

Search Strategy

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart (Figure 1) to conduct our analysis. On 28th October 2023, we gathered data from the Scopus database publications from 2013 to 2024. Our study included “articles” and “reviews” we limited our search to “English” Language publications.

We conducted our search by utilising specific keywords in the article titles. This method assumed that all the retrieved articles are relevant to the topic of our study. Since titles are typically viewed in the initial encounter with the content of an article the title-only search strategy helps ensure that the publications we found are directly related to our subject of interest. The keyword search strings used were as follows: TITLE-ABS-KEY (maca OR lepidium AND meyenii) AND PUBYEAR > 2013 AND PUBYEAR < 2024 AND (EXCLUDE (SUBJAREA , "EART") OR EXCLUDE (SUBJAREA , "VETE") OR EXCLUDE (SUBJAREA , "SOCI") OR EXCLUDE (SUBJAREA , "ENER") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "COMP") OR EXCLUDE (SUBJAREA , "MATE") OR EXCLUDE (SUBJAREA , "ECON") OR EXCLUDE (SUBJAREA , "BUSI") OR EXCLUDE (SUBJAREA , "PSYC") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "MATH")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English"))

A total of 313 journal publications related to *Lepidium meyenii* (maca) research were retrieved from the Scopus database.

Data Screening

In order to ensure the reliability of our bibliometric analysis, only peer-reviewed journal articles were included in this study. This selection criterion was implemented to ensure the relevance and adherence to scholarly standards, as well as transparency for readers.¹⁰ Papers from conference proceedings, books, book chapters, and other non-journal publications were excluded from our analysis. Duplicate documents were identified and removed, and any irrelevant publications were also excluded. Following these criteria, a total of 313 scientific journal articles were chosen for the bibliometric analysis. These selected articles provide a comprehensive overview of the literature on *Lepidium meyenii* (maca) research spanning from 2013 to 2023. Publication-related data were exported in comma-separated values (.csv) format for further analysis.

Data Cleaning and Harmonisation

In bibliometric analysis, data cleaning and harmonization are crucial steps to ensure the precision and dependability of the findings, owing to redundancies present in the raw Scopus data obtained.¹¹ For instance, we utilised various techniques and functions within OpenRefine clustering tools and biblioMagika® Microsoft Excel filters to identify and modify keywords, authors' names, and affiliations. These software tools were instrumental in standardizing and refining unstructured data and fundamental bibliographic details. biblioMagika®, developed by Ahmi¹², was particularly employed for conducting comprehensive bibliometric assessments, encompassing metrics such as total publications (TP), number of contributing authors (NCA), number of cited publications (NCP), total citations (TC), citations per paper (C/P), citations per cited paper (C/CP), citations per author (C/A), citable year, and h-index. The h-index, alongside the g-index, serves as a measure of a researcher's publication productivity and impact. The h-index represents the highest number, h, where at least h publications in the list have been cited h times each.¹³ Additionally, using biblioMagika®, we identified missing data, which was subsequently rectified manually in the database. Following initial data cleaning, we meticulously verified the screened and modified keywords for accuracy using OpenRefine. Cells containing multiple values were consolidated, and

original separators used during the splitting process were re-entered to maintain data uniformity. The cleaned and harmonised data was then exported to its original format for further analysis. These methods substantially enhanced the validity and reliability of the data analyses.

Data Analysis

In our analysis, bibliometric indicators such as citation counts, and co-citation frequencies were utilised. We employed a variety of tools to conduct a comprehensive bibliometric examination. Specifically, we utilised Bibliometrix, an R-based package designed for quantitative bibliometric analysis and accessed the web interface Biblioshiny to analyse the .csv file. Additionally, we made use of the freely available VOSviewer software to create graphical visualisations of the data.¹⁴ By integrating these tools and methodologies, we were able to conduct a thorough and reliable investigation into studies on *Lepidium meyenii* (maca).

Results

Publication profiles and trends

We retrieved a total of 249 original articles and 64 reviews. All were journal articles written in English. These articles were published in 194 different journals. Based on the dataset, 1600 authors contributed to the study of *Lepidium meyenii* (maca), with a total of 1854 author appearances in the articles. There were 11 authors with single-authored papers and an average of 5 co-authors per article.

Regarding the areas of knowledge, most of the publications covered biochemistry, genetics and molecular biology (51.76%), medicine (41.85%), as well as pharmacology, toxicology and pharmaceuticals (30.03%).

Overall, the number of publications per year has increased over time with a slight temporary decrease in 2017. However, the number of citations per year has been varied with a peak of 832 in 2016. The number of articles published has also constantly exceeded 30 per year since 2016 showing steady interest in the subject matter. The highest number of publications was in 2022 with 44 articles published that year. The peak total citation was in 2016 with 832 total citations from 32 number of cited publications with 25.21 average citation per cited publication (Table 2).

Publications by Authors and Institutions

In total, 1600 authors contributed to this field. The top 15 most productive authors included 3 from University of Naples Federico II, 2 from Universidad Peruana Cayetano Heredia, Chinese Academy of Sciences, Yunnan Minzu University, Huazhong University of Science and Technology, and Kyung Hee University respectively. The leading author in this research area was Gustavo F. Gonzales from Peru with 10 articles and 166 citations. He obtained 16.6 citations per paper and 16.6 citations per cited paper, with a h-index of 7. The second most productive author were Qiu Minghua and Peng Xing-Rong from China with 9 publications, 107 total citations with 11.89 citations per paper and 13.38 citations per cited paper.

Overall, the top 5 most productive institutions were Chinese Academy of Sciences, Universidad Peruana Cayetano Heredia, Universidad Nacional Mayor de San Marcos, Yunnan Minzu University, and Yunnan Agricultural University. The Chinese Academy of Sciences had a total publication of 20 with total citation of 434 and a h-index of 9. This was followed closely by Universidad Peruana Cayetano Heredia with 14 total publications, 204 total citations and a h-index of 8.

Publications by Countries

China had the highest number of publications (223) with a h-index of 32, which suggests the significant impact and quality of the research contributions, followed by the United States (67) and Peru (54). China

was also the most cited country with 3447 citations suggesting its strong influence on the global scientific community. It should be noted that the top 20 most productive countries also span 5 different continents namely Asia, North America, South America, Europe and Africa as seen in Table 2.

Publications by Source Titles

Andrologia and International Journal of Biological Macromolecules published 15 and 14 articles respectively and are the most active source titles. This suggests that they are becoming the primary publication platform for research distribution in this field. It is interesting to note that although Andrologia (cite score 4.2) has the higher number of total publications, International Journal of Biological Macromolecules (cite score 14.5) has more than 2.5 times higher total citation score. Rounding up the top 5 active publications are Molecules (9 publications, cite score 6.7), Phytochemistry Letters (9 publications, cite score 3.5) and Journal of Ethnopharmacology (7 publications, cite score 8.6). It is interesting to note that Phytotherapy Research (5 publications, cite score 11.4) and Phytomedicine (3 publications, cite score of 10.4) had good cite scores despite not being in the top 5 most active journals, this may be due to the more specialized nature of the publications.

Citation metrics

The total number of cited papers was 269 out of 313 papers with a total of 4513 citations from 2014 to 2023. There were 501.44 citations per year with 14.42 citations per paper. In average, there were 5.92 authors per paper with 2.43 citations per author with a h-index of 35. The highest cited article was written by Williamson E.M. et al. (2020) with 164 total citations and 32.80 citations per year.¹⁵ The article authored by Cameron M. and Chrubasik S. (2014) had the second highest citation count with 110 total citations.¹⁶

Co-occurrence analysis of author's keywords

We conducted a comprehensive analysis of author keywords utilising co-occurrence patterns. Employing a threshold of at least five occurrences, we identified 39 significant keywords out of a pool of 826. The network depiction of these keywords is visualised in Figure 3, as well as their relationships, with circle sizes corresponding to occurrence frequencies. Notably, the keyword "*Lepidium meyenii* (maca)" stands out with the largest circle, indicative of its frequent appearance. This visualisation reveals the presence of 8 distinct clusters, each centred around a primary keyword that denotes high occurrence rates within the publications. These clusters highlight the interconnectedness and prominence of certain topics within the dataset and were grouped according to themes; reproductive health and fertility (green cluster), alternative and natural approaches to health (red cluster), health maintenance and improvement (blue cluster), natural compounds (olive green), and *Lepidium meyenii* (purple cluster). "*Lepidium meyenii* (maca)" dominated in the purple cluster, followed by "herbal medicine" in the red cluster and "macamides" in the olive-green cluster. The most common keywords were "*Lepidium meyenii* (maca)" (129 occurrences), followed by "herbal medicine" (26 occurrences) and "macamides" (22 occurrences).

Discussion

Based on these findings, it is evident that interest in *Lepidium meyenii* (maca) coincides with the increased interest in medicinal plants as a whole as noted by Yeung AWK et al. (2018).⁵ Alarcon-Ruiz et al. (2023) also noted an increasing trend of research publication on medicinal plants from Latin America and the Caribbean region, while Angulo-Bazán (2020) specifically noted an increase in Peruvian scientific output on medicinal plants.^{7,9}

With a substantial presence in 11 out of the top 20 most active institutions publishing on *Lepidium meyenii* (maca), China is the current dominant force in the research landscape of this Peruvian plant. This trend is

in line with China's longstanding leadership in publications concerning medicinal plants, a position it has maintained for the past three decades as well as the active cultivation of this plant in the Yunnan province of China.^{1,17,18}

Lepidium meyenii (maca) has garnered global attention for its medicinal potential, particularly in enhancing male fertility. Despite a mix of positive findings and inconclusive results in studies examining maca's impact on seminal parameters, aphrodisiac properties, and sexual dysfunction regulation, research on this Peruvian plant thrives.^{19,20} Since the *Andrologia* journal serves as a prominent platform for original research and review articles delving into the current clinical, morphological, biochemical, and experimental aspects of male infertility and sexual disorders, it is not surprising that it is the main source of publications with 15 articles. Following closely behind is the *International Journal of Biological Macromolecules* with 14 publications. This trend reflects the focus of many studies to identify the active compounds or macromolecules responsible for the medicinal properties of *Lepidium meyenii* (maca).^{2,21}

The scope of research on *Lepidium meyenii* (maca) extends far beyond its traditional focus on male fertility. Publications on this Peruvian plant delve into diverse subject areas and explore its potential effects on conditions such as cardiovascular diseases, infectious diseases, dementia, chronic pain relief, immune disorders, and more.^{20, 21, 22} This broad spectrum of study highlights the versatility of maca and its active ingredients, paving the way for numerous opportunities for future research into its beneficial effects.

While our bibliometric analysis provided valuable insights, it is important to acknowledge its limitations. One significant constraint was the inability to incorporate publications in the native languages of the top two countries contributing to research on *Lepidium meyenii* (maca): Mandarin for China and Spanish for Peru. Indeed, we are in agreement with Ramírez-Castañeda V. (2020) that this represents a drawback of the dominance of the English language, as it perpetuates the disparity in global scientific advancement. While a shared language is crucial for scientific communication, it is important to foster multilingual options to enhance diversity while maintaining scientific communications.²³ However, it was noted that the majority of the publications available are in English and therefore the impact of excluding non-English articles may not be profound. Additionally, to ensure relevance, our analysis focused solely on the past decade. Consequently, we were unable to capture trends in this field prior to that period.

Conclusion

This bibliometric analysis highlights the growing trend of research on *Lepidium meyenii* (maca) over the past decade, underscoring the global interest in this Peruvian medicinal plant, particularly from researchers in China. With publications spanning various fields of interest, we anticipate a surge in research output centred on isolating key compounds in maca for medicinal purposes and as value-added ingredients in food products. By providing a comprehensive overview, this study identifies knowledge gaps and lays the groundwork for future investigations, serving as a catalyst for future innovative research in this domain.

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Tables and figures

Table 1: Summary of previous studies

Author	Objective of study	Data Source & Scope	TDE	Bibliometric Attributes Examined
Yeung AWK, Heinrich M, & Atanasov AG (2018) ⁵	To identify and analyze the 100 most-cited ethnopharmacology articles	Scopus	100	<ul style="list-style-type: none"> - publication year - journal title - journal impact factor at the time of publication - SCImago Journal Rank at the time of publication - total citation count - adjusted citation count - field-weighted citation impact - authorship - article type
Salmerón-Manzano E, Garrido-Cardenas JA, & Manzano-Agugliaro, F (2020) ⁶	To study what types of scientific advances are being developed around medicinal plants, what research trends are being carried out, and by which countries and research institutions	Scopus	100,000	<ul style="list-style-type: none"> - publication year - publication source - subject area - institutions - keywords - authors
Angulo-Bazán, Y. (2020) ⁷	To describe the scientific output on medicinal plants published between 2000 and 2019 with at least one author with Peruvian affiliation.	Scopus	300	<ul style="list-style-type: none"> - Year of publication - Language of publication - Areas of knowledge according to the Scopus classification - Peruvian institutions that participated in the research - Research designs
Seo Y, Park HS, Kim H et al. (2022) ⁸	To analyse published papers on the use of herbal medicine in obesity research over the past 20 years using bibliometric methods and present an overview of global research trends	Web of Science Core Collection database	463	<ul style="list-style-type: none"> - publication year - country of publication - journal, research area - author - affiliated institution - keywords
Alarcon Ruiz CA, Maguiña, JL, Apolaya Segura M et al. (2023) ⁹	To describe the scientific production of medicinal plants in LAC, using bibliometric and co-words analysis for original articles from three databases published from 1970 to 2020.	Web of Science Core Collection, LILACS, Scielo Citation Index via Web of Science	15,792	<ul style="list-style-type: none"> - total annual scientific production - absolute and relative frequency of the main scientific journals - highest number of citations - Co-word analysis

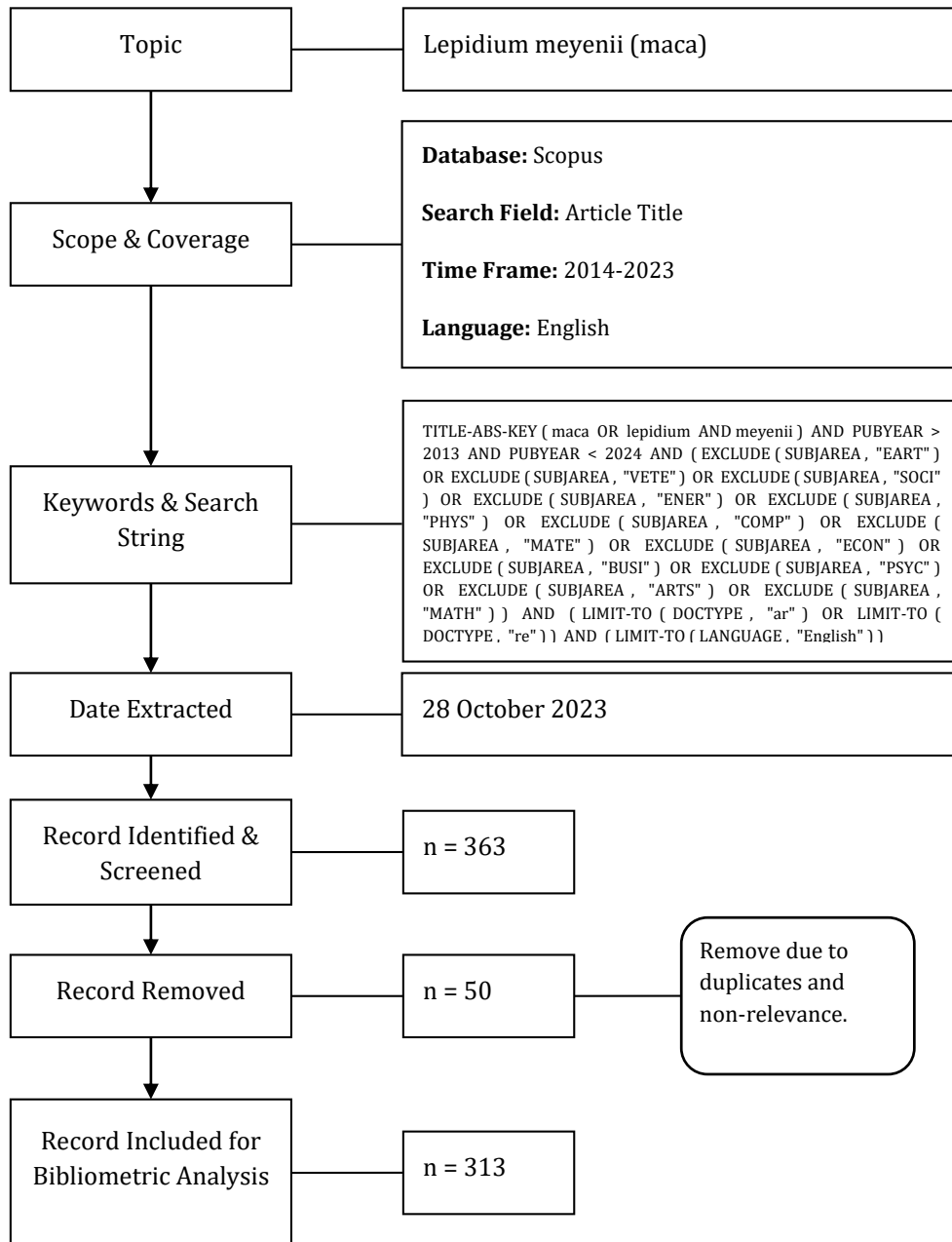


Figure 1: Flow diagram of the search strategy.

Table 2: Year of Publication

Year	TP	NCP	TC	C/P	C/CP	<i>h</i>	<i>g</i>
2014	19	19	666	35.05	35.05	14	19
2015	19	19	434	22.84	22.84	13	19
2016	33	32	832	25.21	26.00	18	28
2017	28	27	567	20.25	21.00	13	23
2018	32	32	741	23.16	23.16	17	26
2019	36	33	427	11.86	12.94	13	19
2020	32	29	461	14.41	15.90	11	21
2021	40	35	249	6.23	7.11	10	13
2022	44	34	117	2.66	3.44	6	7
2023	30	9	19	0.63	2.11	2	3
Total	371						

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; *h*=*h*-index; and *g*=*g*-index.

Table 3: Top 20 Countries contributed to the publications

Country	TP	NCP	TC	C/P	C/CP	<i>h</i>	<i>g</i>
China	223	194	3447	15.46	17.77	32	11
United States	67	60	878	13.10	14.63	16	5
Peru	54	52	815	15.09	15.67	19	4
Italy	39	37	863	22.13	23.32	18	2
India	30	20	265	8.83	13.25	9	3
Brazil	24	15	117	4.88	7.80	6	4
Japan	24	23	340	14.17	14.78	10	3
South Korea	22	15	213	9.68	14.20	7	3
Iran	19	15	165	8.68	11.00	8	3
United Kingdom	13	11	479	36.85	43.55	10	1
Australia	12	9	243	20.25	27.00	8	1
Poland	12	12	128	10.67	10.67	8	0
Spain	10	10	156	15.60	15.60	6	1
Mexico	24	9	48	5.33	5.33	5	1
Taiwan	21	8	161	20.13	20.13	5	0
Portugal	21	4	47	7.83	11.75	3	1
Nigeria	19	5	79	13.17	15.80	4	1
Chile	18	6	23	3.83	3.83	3	1
Switzerland	18	6	174	29.00	29.00	4	1
Germany	15	6	191	31.83	31.83	4	1

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; *h*=*h*-index; and *g*=*g*-index.

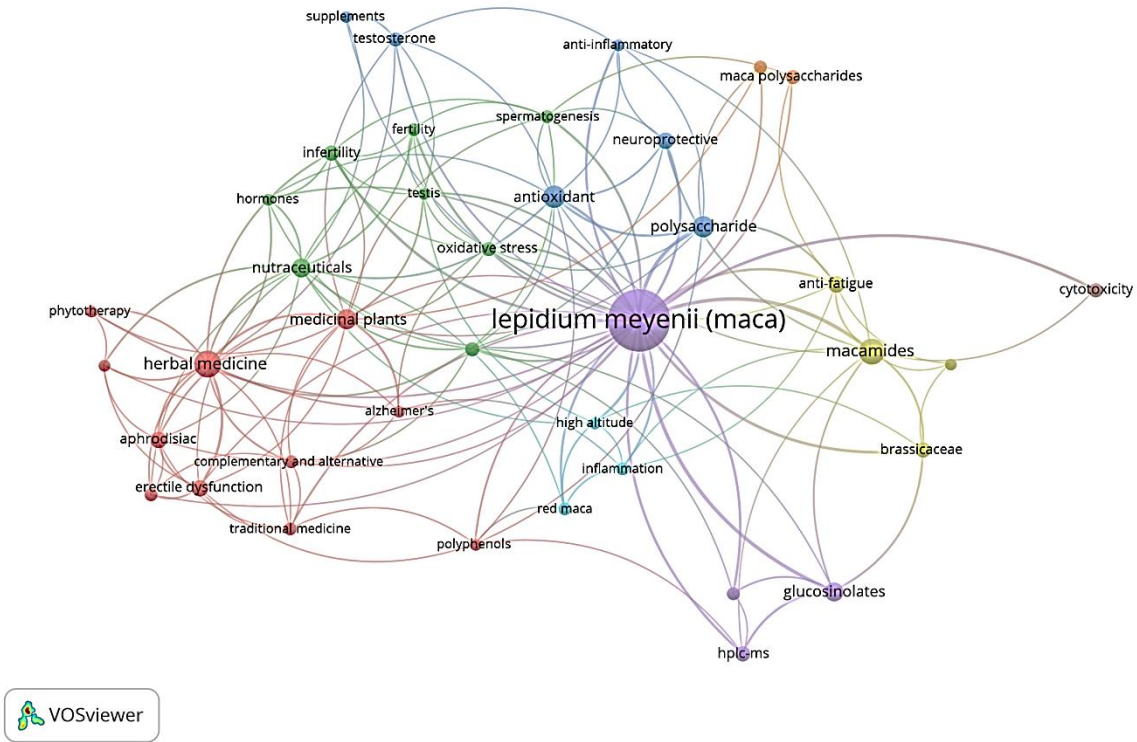


Figure 2: Network visualisation of the author's keywords