Bibliometric Analysis of *Basella* ssp. as an Antioxidant

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Abstract. The last ten years have seen the discovery of free radicals and their damaging impacts. Increasing exogenous antioxidant intake could reduce the damage caused by oxidative stress. Several plants have been shown to have antioxidant activity, and one such plant is *BasellaI.* It is high in phytochemicals which can act as antioxidants, and its consumption may help fight free radicals generated by the body. In particular, this plant is essential for stimulating normal wound healing response. To the best of our knowledge, no bibliometric analysis of published data on Basella as an antioxidant has been done. The goal of this study is to conduct a bibliometric analysis of the research on *Basella*'s antioxidant properties in the Scopus database using the VOSviewer and RStudio tools. There were 56 articles on Basella as an antioxidant according to the bibliometric analysis. The countries with the highest research output was India (27 documents), and the most productive institution was Chiang Mai University (15 documents). The most productive source was the International Journal of Pharmacy and Pharmaceutical Sciences. P. Giridhar had significant significant impact on papers on Basella as an antioxidant (H-index of 5). The most common keywords were "antioxidant" (859 occurrences with 1,340 total link strength) and "Basella alba" (606 occurrences with 1,048 total link strength). Findings from this data suggest the novelties of Basella as an antioxidant.

Keywords : *Basella, antioxidant, bibliometric, VOSviewer, RStudio*

1 Introduction

The last ten years have seen the discovery of free radicals and their damaging impacts. These are toxic substances that the body produces during its normal metabolic process, along with poisons and wastes [1]. By neutralizing free radicals and damaging by-products of normal cell metabolism, antioxidants have protective effects. By contrast, disrupting this balance in humans might result in serious medical conditions. Normally, the body's antioxidant system can remove free radicals, maintaining the proper balance between oxidation and antioxidation [2]. However, excessive creation of free radicals could hinder the procedure from being done successfully, and its effectiveness also decreases with advancing age. Increasing antioxidant intake can minimize health issues and prevent diseases. Therefore, increasing exogenous antioxidant intake could reduce the damage caused by oxidative stress [2]. The majority of exogenous antioxidants come from foods and medicinal plants, such as *Basella*, native to tropical Southern Asia and likely to came from Indonesia or India [3].

Basella (*alba* and *rubra*) is a perennial vine of the Basellaceae family that can withstand intense heat and is also known as Malabar spinach, Indian spinach, Ceylon spinach, and Vine spinach [4]. The antioxidant capabilities of *Basella* are enhanced by its richness in phenols and other secondary metabolites. They can act as organic defenses against free radicals that their metabolisms release [5]. The mechanism of action of preventative antioxidants that decrease the rate of oxidation by a variety of means.Chain-breaking antioxidants *scavenge free radicals, inhibit the initiation stage or stop the propagation step of lipid oxidation [6]. Members of the *Basella* genus are high in phytochemicals, and their consumption may help provide antioxidants that fight free radicals generated by the body [5]. Free radicals are strong oxidizing agents that cause cell damage, but they are also helpful, in particular, they are essential for stimulating normal wound-healing response [7].

When normal anatomical structure and function of skin tissue are disrupted, a complicated and multifaceted process known as wound healing occurs. [8]. Among natural antioxidants, mounting evidence points to polyphenols as potential treatment options for oxidative stress-induced impared wound healing [9]. In this situation, an ideal therapeutic method to accelerate wound healing is the use of safe and efficient antioxidants in the wound bed to combat excessive reactive oxygen species (ROS). Therefore, these *Basella* phytochemicals can control one or more stages of the wound-healing process [7]. Many scientific studies have been conducted on *Basella* in the past few decades. Numerous biomaterials

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have been designed and tested in response to an increased interest in employing antioxidant compounds for wound therapy [7]. We belive that no bibliometric analysis of published data on *Basella* as an antioxidant has been done. The goal of this study is to conduct a bibliometric analysis of the research on *Basella*'s antioxidant properties in the Scopus database using the VOSviewer and RStudio tools. An increase in publications, nation, institution, source contributions, authorship analysis; paper and keyword occurrences on *Basella* as an antioxidant are specifically mentioned. This review can serve as a useful starting point for future studies on *Basella* as an antioxidant.

2 Methodology

2.1 Study technique and search strategy

Research articles included in this study were taken from the Scopus database (https://www.scopus.com) on July 2, 2023. The keywords "*Basella*" AND "antioxidant" were given particular attention. All articles, reviews, and conference proceedings in English from the Scopus database were eligible for inclusion criteria. Articles that are not in the Scopus database and are not in English are excluded. Following a thorough data cleaning process, our search confirmed that the collected papers covered *Basella* and antioxidants, and then we checked for data duplication. The articles from Scopus were imported into Microsoft Excel and saved as Comma Separated Values (CSV) files.

2.2 Data Analysis

The CSV files were imported into VOSviewer 1.6.19 from the Center for Science and Technology at Leiden University in the Netherlands to perform the bibliometric analysis. This program examines organizations, sources, writers, works, and co-occurrences of keywords. To prevent data duplication, data cleansing used the thesaurus in Excel. Then, the bibliometric data were analyzed using the RStudio software 2023.03.0-386 via the bibliometrics from the Department of Economics and Statistics, University of Naples Federico II, Italy. This program examines publication trends and the contributors' sources, nations, and writing styles.

3 Result and discussion

3.1 Data searches

Searches with the terms "Basella" AND "antioxidant" from the Scopus database returned 56 articles. A bibliometric analysis of Basella and antioxidant using the Scopus database was applied to characterize and map knowledge concepts related to the expansion of research on *Basella* as an antioxidant. The research criteria, study questions, and analytical approach selection steps were used to construct the bibliometric analysis. Performance analysis and scientific mapping are methodologies used for bibliometric analysis [10]. Performance analysis considers the contributions of academics from different countries, institutions, sources, and authors that could increase the productivity of the papers generated [11]. On the other hand, scientific mapping analysis based on bibliographic networks could be used to extract knowledge from the intellectual, social, or conceptual structures of a study topic [10].

3.2 Publication trend

The average number of citations per publication and trends in publishing data are displayed in Table 1. Only 56 documents discussing *Basella*'s antioxidant activity are listed in the Scopus database. The first journal was published in 2004, resulting in an annual production rate of 2.8 documents. The year with the highest number of publications was 2015 (7 articles), followed by 2012, 2018, 2021, and 2022 with 6 articles each. In terms of citations, the year with the highest citation rate is 2004 (8.65 citations per year), followed by 2010 (6.57 citations per year) and 2021 (5.17 citations per year). A paper with a significant number of citations is likely to have an impact on other researchers' use of the knowledge that reflects intellectual influence [12]. Citations are increasingly used in research policy and the research system as performance measurements. Citations are typically seen as indicating the importance or standard of the research [13].

Table 1. Publication data trend by year using Rstudio application

Year	Number of Articles	Mean Total of Citation per Year	Mean Total of Citation per Articles	Citable Year
2004	1	8.65	173	20
2010	2	6.57	92	14
2011	1	0.38	5	13
2012	6	2.79	33.5	12
2013	2	4.27	47	11
2014	2	3.5	35	10
2015	7	1.89	17	9
2016	4	0.97	7.75	8
2017	2	0.86	6	7
2018	6	1.75	10.5	6
2019	1	4.2	21	5
2020	5	2.05	8.2	4
2021	6	5.17	15.5	3
2022	6	1.92	3.83	2
2023	5	0	0	1
Average	2.8	2.248	23.76	

3.3 Analysis of contributing country

To determine which country contributed the most to the studies on *Basella's* antioxidant activity, analysis of contributing country was carried out using RStudio. The heatmap of all the nations included in *Basella's* research is displayed in Figure 1. Countries in darker blue had more

articles published. Countries producing the most publications were India (27 documents), Nigeria (4 documents), and China (3 documents). A pink line shows partnerships with other countries. Most collaborative articles originated in Saudi Arabia and India (2 collaborations).

In addition to the quantityof documents created, each country's citation rate was examined. Figure 2 reveals that India (554 citations), the United States (173 citations), and the United Kingdom (140 citations) were the three most cited countries. This suggests that these countries may have the most influence on research on Basella's antioxidant activity.

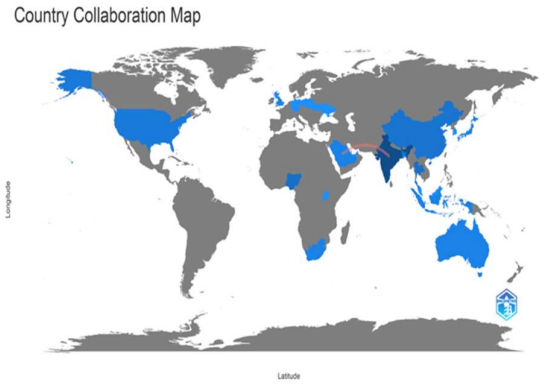

Fig. 1. Country production and colaboration heatmap of articles discussing *Basella's* antioxidant activity

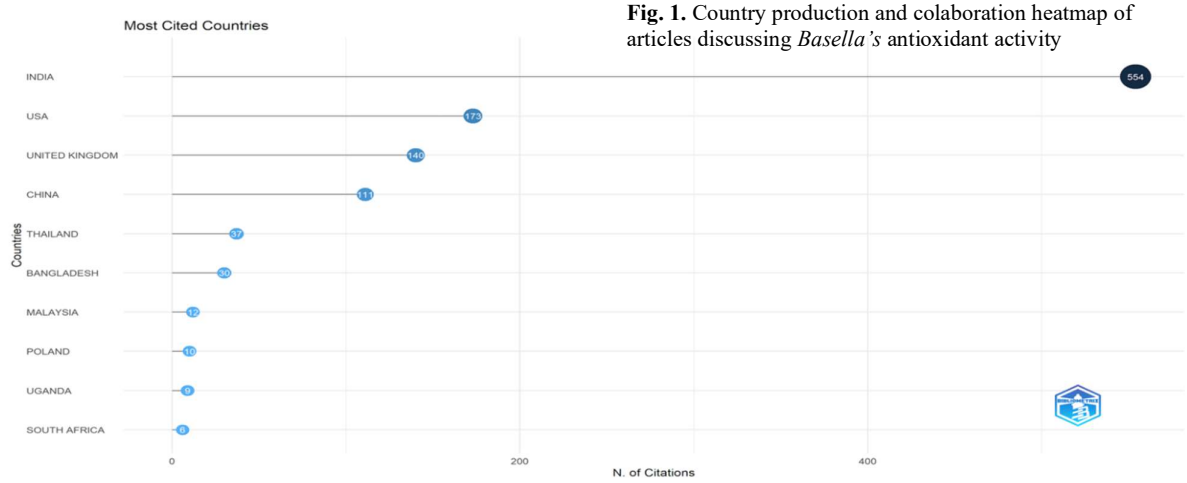

Fig. 2. Most-cited Country of articles discussing Basella's antioxidant activity

3.4 Analysis of contributing institution

Identifying the most prolific institutions was one of the most important tasks in bibliometric analysis [14]. The Scopus database was used for the analysis. According to the database, institutions with the highest number of publication of articles on *Basella* as an antioxidant were Chiang Mai University (15 documents), Icar-Indian Institute of Vegetable Research (12 documents), and three other universities each with 7 articles: Dayananda Sagar University, National Chiayi University, and the University of Tahjshahi (7 documents each) as shown in Table 2.

Table 2. The institution with the highest productivity using the RStudio application

Institution	Country	Documents
Chiang Mai University	Thailand	15
Icar-Indian Institute of Vegetable Research	India	12
Dayananda Sagar University	India	7
National Chiayi University	Taiwan	7
University of Rajshahi	India	7
Chinese Culture University	China	6

3.5 Analysis of contributing source

A total of 56 documents from 48 sources worldwide are listed in the Scopus database as research on Basella's antioxidant activity. The most productive sources, as indicated in Table 3, were the International Journal of Pharmacy and Pharmaceutical Sciences (3 articles), the Journal of Agricultural and Food Chemistry, and the Journal of Ethnopharmacology with 2 articles each. The American Journal of Clinical Nutrition, the Journal of Ethnopharmacology (149 citations), and Chemosphere were three journal with the highest number of citations relative to the number of papers published (139 citations).

Table 3. The most productive source using the RStudio application

Sources (Abbreviation)	Documents	Citations	Average
Int. J. Pharm. Pharm. Sci.	3	42	14
J. Agric. Food Chem.	2	54	27
J. Ethnopharmacol.	2	149	74.5
Am. J. Clin. Nutr.	1	173	173
Chemosphere	1	139	139
Environ. Sci. Pollut. Res.	1	67	67

The association between the author's country (AU_CO), sources/ journals (SO), and affiliation (AU_UN) is shown in Figure 3. The top 20 sources, top 20 authors, and top 20 keywords used in published works were the focus of this study Gray lines connect the three regions. The length of the rectangle indicates the number of related items in each box. The length of the rectangle and the number of items in each box become increasingly apparent as the rectangle elongates. According to the inflow analysis, the source with the greatest correlation was the Latin American Journal of Pharmacy, which had papers published by writers with two separate affiliations. The Latin American Journal of Pharmacy outflow analysis revealed that the journal published articles by writers from three of the seventeen countries that had published research about Basella's antioxidant activities

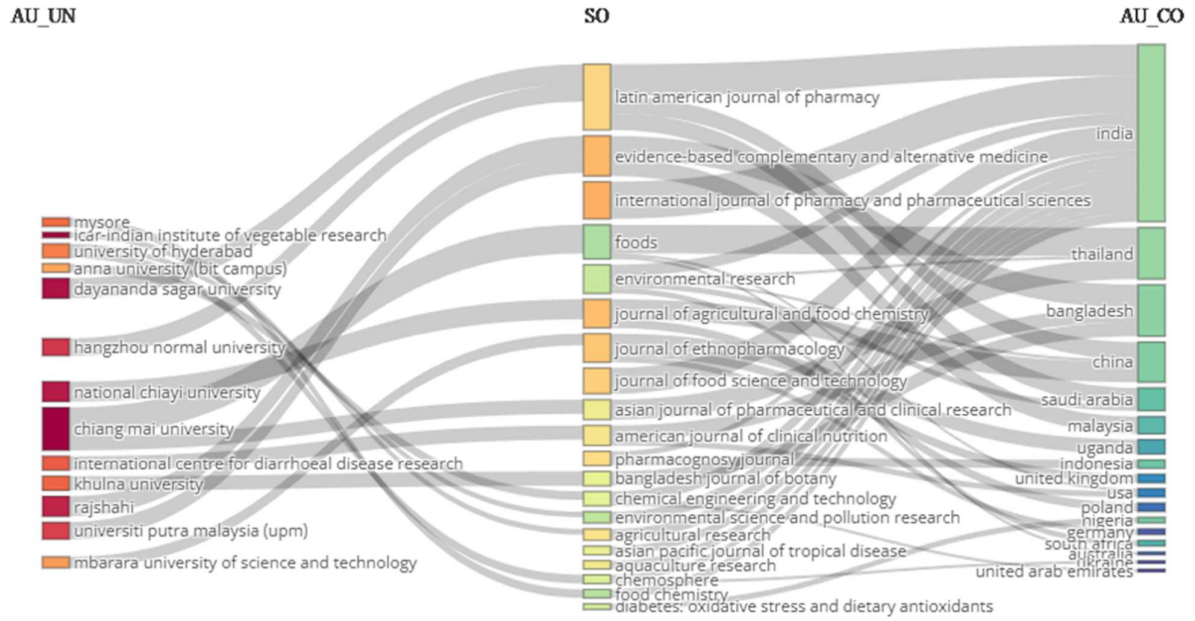

Fig. 3. Three-fields plot between author affiliations (AU_UN), Source (SO), and author country (AU_CO) using the RStudio application

3.6 Analysis of contributing author

The RStudio software was used to analyze the contributing author. The contribution of the associated author and author impact were examined using the RStudio software as well [15]. Table 4 shows the top authors who published the most articles that linked with other authors who wrote articles about *Basella* as an antioxidant. P. Giridhar published the most articles (5), followed by S.S Kumar, from the Central Food Technological Research Institute published 3 articles with an average of 28.6 citations per article. P. Manoj who had the same affiliation with P. Giridhar and S.S. Kumar published 3 articles with an average of 30.6 citations per article. D.S. Arkoyo from the Cape Peninsula University of Technology published 2 articles with an average of 3 citations per article, while V. Sagar from the Indian Institute of Vegetable Research published 2 articles with an average of 3.5 citations per article..

The author's impact is shown by the value of the H-index in Table 4. P. Giridhar's papers on Basella as an antioxidant had a significant impact, with the highest H-index of 5, followed by S.S. Kumar and P. Manoj with H-index of 3. F. Giampieri and S. Kolayli had the same H-index of 9, and V. Nanda had an H-index of 8. D.S. Arkoyo and V. Sagar had the same H-index of 1. Table 4 also shows the three most recent papers. This information is highly useful for authors, especially researchers, in planning and discussing the significance of study findings.

3.7 Analysis of contributing paper

An article's citation count shows the study that has made the most significant contribution. The higher the citation counts, the greater its impact on advancing research on Basella as an antioxidant. Fifty-six papers contributed to research on Basella as an antioxidant. Table 5 lists the top 5 most-cited articles. The most influential article, titled "Daily consumption of Indian spinach (Basella alba) or sweet potatoes has a positive effect on total-body vitamin A stores in Bangladeshi men, was written by Haskell et al. (2004) with 173 citations. The effect of 60 days of daily supplementation with 750 g retinol equivalents (RE) of cooked and puréed sweet potatoes, cooked and puréed Indian spinach (*Basella alba*), or synthetic sources of vitamin A on total-body vitamin A stores in Bangladeshi men was investigated in this study. This study found that eating cooked, puréed green leafy vegetables or sweet potatoes daily boosts vitamin A stores in populations at risk of vitamin A deficiency [16].

Table 4. Top 5 most productive authors using RStudio

No	Authors	3 Latest Tittle of Documents (Year)
1.	Giridhar P - Total Documents: 5 - Citations: 133 - Average Citation per Document: 26.6 - H index: 5 - Affiliation: Central Food Technological Research Institute	1. Nanoliposomal encapsulation mediated enhancement of betalain stability: characterization, storage stability and antioxidant activity of *Basella rubra* L. Fruits for its applications in vegan gummy candies (2020) 2. Influence of photoperiod on growth, bioactive compounds and antioxidant activity in callus cultures of *Basella rubra* L. (2020) 3. Fruit extracts of *Basella rubra* that are rich in bioactives and betalains exhibit antioxidant activity and cytotoxicity against human cervical carcinoma cells (2015)
2.	Kumar SS - Total Documents: 3 - Citations: 86 - Average Citation per Document: 28.6 - H index: 3 Affiliation: Central Food Technological Research Institute	1. Influence of photoperiod on growth, bioactive compounds and antioxidant activity in callus cultures of *Basella rubra* L. (2020) 2. Fruit extracts of *Basella rubra* that are rich in bioactives and betalains exhibit antioxidant activity and cytotoxicity against human cervical carcinoma cells (2015) 3. Nutrition facts and functional attributes of foliage of *Basella* spp. (2015)
3.	Manoj P - Total Documents: 3 - Citations: 92 - Average Citation per Document: 30.6 - H index: 3 Affiliation: Central Food Technological Research Institute	1. Fruit extracts of *Basella rubra* that are rich in bioactives and betalains exhibit antioxidant activity and cytotoxicity against human cervical carcinoma cells (2015) 2. Nutrition facts and functional attributes of foliage of *Basella* spp. (2015) 3. A method for red-violet pigments extraction from fruits of malabar spinach (*Basella rubra*) with enhanced antioxidant potential under fermentation
4.	Arokoyo DS - Total Documents: 2 - Citations: 6 - Average Citation per Document: 3 - H index: 1 Affiliation: Cape Peninsula University of Technology	1. *Basella alba*, oxidative stress, and diabetes (2020) 2. Antioxidant activities of *Basella alba* aqueous leave extract in blood, pancreas, and gonadal tissues of diabetic male wistar rats (2018)
5.	Sagar V - Total Documents: 2 - Citations: 7 - Average Citation per Document: 3.5 - H index: 1 Affiliation: Indian Institute of Vegetable Research	1. The inheritance of betalain pigmentation in *Basella alba* L. 2. Seed priming with ZnO and Fe_3O_4 nanoparticles alleviate the lead toxicity in *Basella alba* L. through reduced lead uptake and regulation of ROS

An article entitled "Traditionally used Thai medicinal plants: in vitro anti-inflammatory, anticancer and antioxidant activities" written by Siriwatanametanon et al. (2010) was the second most influential article with 140 citations. This study assessed the traditional Thai claims about the therapeutic potential of medicinal plants. It selected plants for future phytochemical research; nine plant species with anti-inflammatory properties, such as Basella alba L. and Basella rubra L. (Basellaceae), were selected from Thai textbooks. This research also investigated their in vitro anti-inflammatory, antiproliferative, and antioxidant activities. This study provides in vitro evidence of the use of Thai plants. Ethyl acetate extract of Basella alba has an antioxidant activity in inhibiting DPPH with IC50 of 5.32 µg/mL, while that of Basella rubra has a value of 34.58 µg/mL. Ethyl acetate extract of Basella alba also shows an NF-kB inhibitory activity with an IC50 value of 83.28 µg/mL, and that of Basella rubra shows a value of 162.83 µg/mL [17].

The third most influential article was "Antioxidant Activity in Extracts of 27 Indigenous Taiwanese Vegetables" written by Chao et al. (2014) with 64 citations. The objective of this study was to identify the antioxidants and antioxidant activity in 27 Taiwan's indigenous vegetables, one of them being Basella alba. This study found that Basella alba contains various antioxidant compounds in acid hydrolysates, such as polyphenol (7.12 ± 1.40 mg GAE/g DW), flavonoids

(42.71 ± 3.06 mg QUE/g DW), and flavonols (7.73 ± 2.19 mg QUE/g DW). The IC_{50} of the DPPH scavenging activity of *Basella alba* was 427.78 ± 0.48 µg/mL [18].The article "Studies on the spectrometric analysis of metallic silver nanoparticles (AgNPs) using Basella alba leaf for the antibacterial activities" written by Mani et al. (2021) was the fourth most influential article with 51 citations. In this study, AgNPs were synthesized using aqueous Basella alba leaves extract. The antioxidant studies revealed significant scavenging activity ranging from 13.71 percent to 67.88 percent. Green synthesized AgNPs have well-organized biological activities in terms of antioxidant and antibacterial activities, which can be used in various biological applications [19].

The fifth most influential article was "Fruit extracts of *Basella rubra* that are rich in bioactive and betalains exhibit antioxidant activity and cytotoxicity against human cervical carcinoma cells", written by Kumar et al. (2015) with 48 citations. Fruit extracts of *Basella rubra*, which are high in bioactive phenolics, flavonoids, and betalains, were tested for antioxidant and anticancer activities against human cervical carcinoma (SiHa) cells. Fruit extracts in water and aqueous methanol showed significant free radical scavenging and ferric-reducing antioxidant power. Fruit extracts at 50 mg/mL demonstrated strong (81%) cytotoxic activity against human cervical carcinoma cells. Thus, fruit extracts may have applications in cancer treatment and nutraceutical or dietary supplements [20].

Table 5. Top 5 most cited articles using RStudio

No	Author	Title	Source	Total Citation
1	[16]	Daily consumption of Indian spinach (*Basella alba*) or sweet potatoes has a positive effect on total-body vitamin A stores in Bangladeshi men	The American Journal of Clinical Nutrition	173
2	[17]	Traditionally used Thai medicinal plants: in vitro anti-inflammatory, anticancer and antioxidant activities	Journal of Ethnopharmacology	140
3	[18]	Antioxidant Activity in Extracts of 27 Indigenous Taiwanese Vegetables	Nutrients	64
4	[19]	Studies on the spectrometric analysis of metallic silver nanoparticles (AgNPs) using *Basella alba* leaf for the antibacterial activities	Environmental Research	51
5	[20]	Fruit extracts of *Basella rubra* that are rich in bioactives and betalains exhibit antioxidant activity and cytotoxicity against human cervical carcinoma cells	Journal of Functional Food	48

3.8 Analysis of keyword co-occurrence

The following analysis used the VOSviewer to examine keyword co-occurrence across all terms. Based on the publication's content, this analysis can map existing or future research issues on *Basella* as an antioxidant [11]. The number of documents that contain a specific keyword is displayed by occurrence. Because the calculation method was full counting, the number of keyword occurrences obtained in the study represents the total number of times certain keywords appeared in all documents. The "All keyword" category includes author keywords (article titles, abstracts, and full texts) as well as indexed keywords [21]. Network visualization of the topic by VOSviewer can be seen in Figure 4.

Twelve clusters were generated through the VOSviewer, and every cluster indicates how one subject links to the others. This software can display bibliometric mapping (Figure 4). The keywords are denoted by colored circles, and the size of the circles shows how frequently they appear in titles and abstracts. As a result, the size of the letters and circles depended on how frequently they occur. The more frequent a keyword appears, the more frequently the letters and circles exist. Based on the data gathered from the articles containing *Basella* as an antioxidant, 1,510 keywords were found from 765 articles. The clusters in each of the examined issue areas are shown in Figure 4. For example, the phrases "antioxidant", "*Basella alba*", "oxidative stress", and "lipid peroxidation" share the same circle color, indicating that they have a close link and are grouped. The most common keywords were "antioxidant" (859 occurrences with 1,340 total link strength) and "B*asella alba*" (606 occurrences with 1,048 total link strength). This data may suggest the novelties of Basella as an antioxidant.

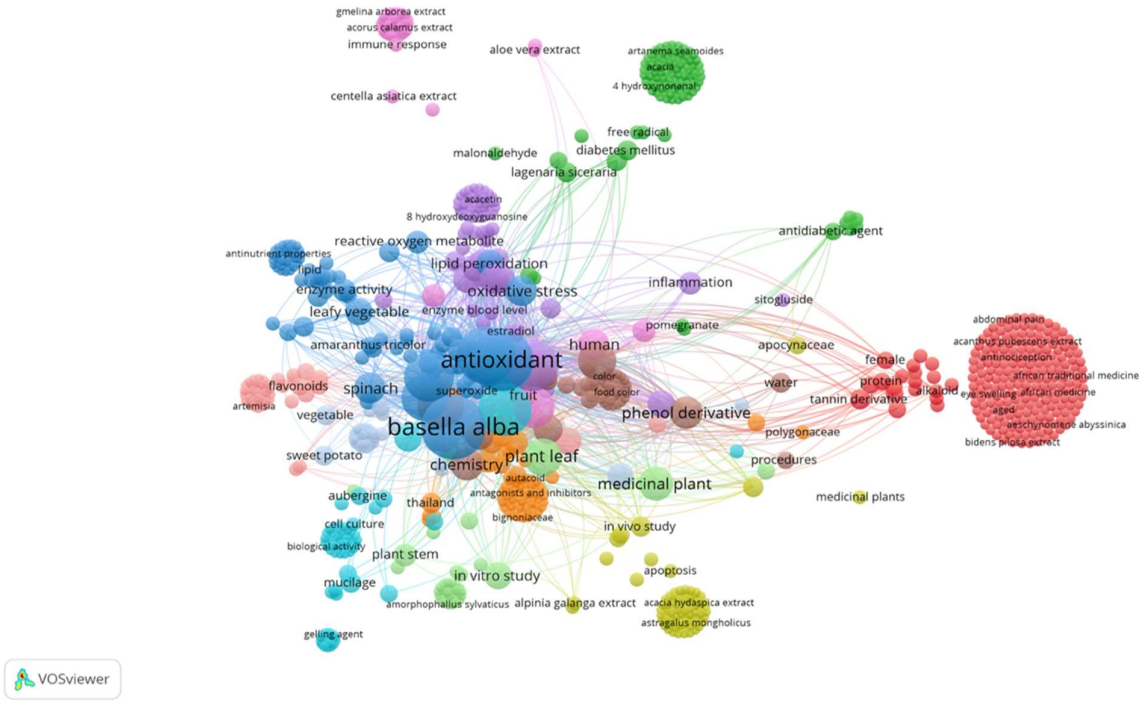

Fig 4. Network visualization of the topic by VOSviewer

4 Conclusion

Reasearch on Basella as an antioxidant has been widely undertaken in a number of countries, including Thailand which published the most (15 publications). According to this bibliometric study, P. Giridhar authored the most articles about Basella as an antioxidant and had a large impact on articles on this topic, with the highest H-index of 5. Haskell et al.'s (2004) article "Daily consumption of Indian spinach (Basella alba) or sweet potatoes has a positive effect on total-body vitamin A stores in Bangladeshi men1-3" received the most citations (173). "Antioxidant" (859 occurrences with 1,340 total link strength) and "Basella alba" (606 occurrences with 1,048 total link strength) were the most common keywords. These results provide insights to stimulate pharmaceutical research collaborations and reveal open issues about Basella as an antioxidant. Nevertheless, this study had many limitations, such as our knowledge of the literature influencing keyword selection, which could affect the amount and diversity of articles included in our analysis.

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