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Correlation of Metabolomics and Functional Foods Research in 2020 to 2023: Bibliometric Analysis

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ABSTRACT

This research was conducted to determine the development of research on metabolomics and functional food using bibliometric analysis including analysis of top citations, and publishers, visualization of the most productive authors, and a map of publication development based on keywords. This research method is descriptive quantitative with bibliometric analysis using Publish or Perish software for data collection and VOSviewer to visualize related research terms. Data collection was carried out by searching the Google Scholar database with the keywords "metabolomics" and "functional food" in the period 2020 to 2023. The research results show that research on metabolomics and functional food continues to increase. Analysis of the journals with the highest citations were 17 journals, the majority of which were published by Elsevier. The visualization results obtained 11 clusters and it was found that the most researched subjects were "metabolomics", "metabolome", and "health" with researchers Wang, Liu, and Li identified as the most productive authors on this topic. It is hoped that this research can help researchers determine the focus of their research and become a reference for further research.

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1. INTRODUCTION

Metabolomics is a branch of science that includes comprehensive metabolite measurements, integrating biology, analytical chemistry, and bioinformatics (Chen *et al*., 2022; Johnson *et al*., 2015; Monteiro *et al*., 2013; Mashabela *et al*., 2022). Metabolomics explains the course of biochemical processes and the function of a metabolite in metabolism. It can also be used simultaneously with genomics, transcriptomics, and proteomics to understand thoroughly and deeply the physiology of an organism (Theowidavitya *et al*., 2019; John Martin *et al*., 2024; Oh *et al*., 2023). The advantage of metabolomics lies in its ability to obtain analytical data that includes all metabolites in cellular systems, as well as the ability to extract information from samples using various statistical-based data analysis methods (Chen *et al*., 2022).

The field of metabolomics has an important role in the study and development of functional foods. Functional foods are foods that contain certain active ingredients, which have the potential to provide additional health benefits, apart from the essential nutrients they contain. The physiological properties of functional foods are greatly influenced by the content of bioactive components in them (Caleja *et al*., 2017; Bortolini *et al*., 2022; Vlaicu *et al*., 2023).

Metabolomics allows comprehensive analysis of chemical compounds contained in functional foods. Through metabolomics, we can also understand how compounds in functional foods interact with human biological systems. By understanding the chemical composition and biological effects, metabolomics can help optimize the formulation of functional food products including determining the optimal concentration of various active components.

To see the development of metabolomics research, you can use the bibliometric data analysis visualization method. Analysis of bibliometric data displayed visually through mapping tools is used to obtain an overview and information regarding scientific developments and research performance that has been carried out. One software that can be used to analyze bibliometric data is VOSviewer (Bukar *et al*., 2023; Al Husaeni *et al*., 2023a; Nandiyanto & Al Husaeni, 2022; Al Husaeni *et al*., 2023b).

VOSviewer is an application designed to build and display bibliometric maps (Van Eck & Waltman, 2010; McAllister *et al*., 2022). This tool provides a text mining function that allows building and visualizing correlations in article or publication citations (Shen & Wang, 2020).

Research that utilizes bibliometric analysis using VOSviewer software in the context of metabolomics research is essential to evaluate the contribution and relevance of such research to functional foods. The hope is that this research can become a reference for researchers in determining research focus, especially those related to metabolomics.

2. METHODS

2.1. Database Search

The article data that will be used in this research is research data from articles that have been published on Google Scholar. Google Scholar is currently used in bibliometric analysis because it is one of the largest free scientific bibliographic databases and its contents include data that is not available on the public internet. When searching and collecting article data, you can use Publish or Perish software. To collect article data, the keywords "metabolomics" and "functional food" were used with articles published in 2020-2023. The articles are then saved in *.csv format.

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2.2. Data Visualization

The data that has been saved is then visualized using Microsoft Excel and VOSviewer software to see trends in the form of curves and bibliometric maps. The terms in the data are filtered first before being included in the VOSviewer data mapping visualization. Data mapping in VOSviewer consists of three types, that is network visualization, overlay visualization, and density visualization.

2.3. Data Analysis

The data that has been visualized is analyzed to obtain results regarding the development of metabolomics research per year, articles with the most citations and publishers, relationships between authors and other authors, as well as examining clusters originating from the visualization results.

3. RESULTS AND DISCUSSION

3.1. Publication Trends

Figure 1 shows the research development curve on metabolomics from 2020 to 2023. Of the total 998 articles on metabolomics and functional food, the most publications occurred in 2022, namely 281 articles. The number of publications on metabolomics continues to increase, in 2020 there were 249 articles, increasing to 260 articles in 2021, and in 2023 there will be 208 articles.

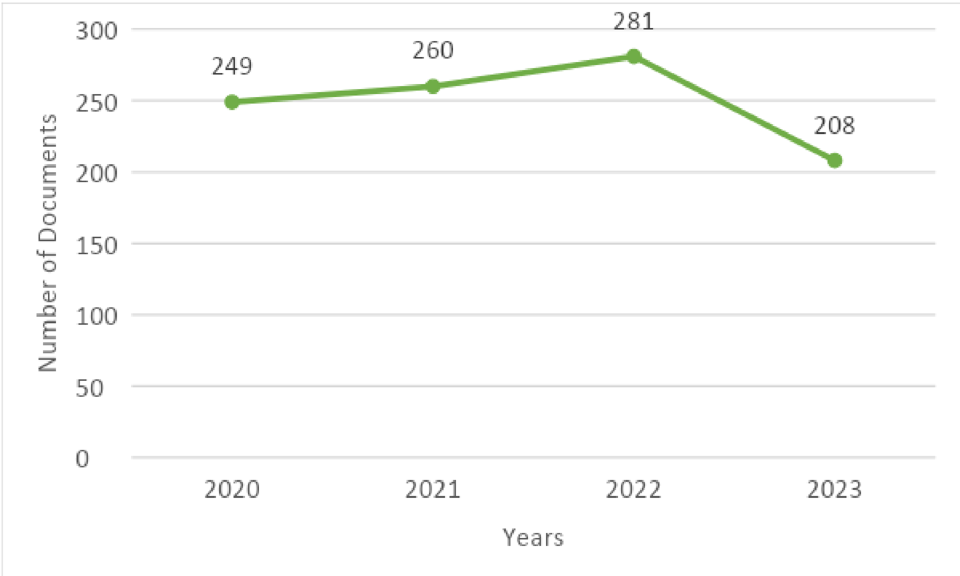

Figure 1. The number of documents published for the keywords "metabolomics" and "functional food".

Research on metabolomics and functional food is expected to continue to increase due to several factors. First, developments in high-throughput analyses, such as metabolomics, have accelerated biomarker research, especially in the context of individualized medicine (Son *et al*., 2024). Metabolomics allows comprehensive examination of small molecule metabolites in living organisms and with the advent of mass spectrometry, it has been widely applied in various research fields (Tsuchida & Nakayama, 2022). Metabolomics research has proven to be very useful in the study of chronic kidney disease (Grams *et al*., 2018), pathogenesis, asthma diagnosis, and highly heterogeneous diseases through the analysis of metabolite changes and dysregulated metabolic pathways (Wang *et al*., 2021). In addition, the development of research on functional foods has also shown positive potential for health, going beyond basic nutrition to promote optimal health and reduce the risk of disease (Graciela *et al*., 2022).

3.2. Top Articles by Citation and Publisher

Table 1 shows the 10 articles with the most citations with the top ranking, namely the article entitled "Metabolomics in Cancer Research and Emerging Applications in Clinical Oncology" which was published in 2021 with a total of 217 citations. Of the 17 articles with citations reaching more than 100, the majority are articles published in 2020. Citations themselves are a measure for journals that have a strong influence on research on the same topic.

Table 1. Top 10 citation on metabolomics and functional food.

No.	Citation	Authors	Title	Years	Jour	Publisher
1	217	Schmidt *et al*. (2021)	Metabolomics in cancer research and emerging applications in clinical oncology	2021	CA: A Cancer Journal for Clinicians	Wiley Online Library
2	209	Adams *et al*. (2020)	Skyline for small molecules: a unifying software package for quantitative metabolomics	2020	Journal of proteome research	ACS Publications
3	181	Hu *et al*. (2020)	Suppression of the SLC7A11/glutathione axis causes synthetic lethality in KRAS-mutant lung adenocarcinoma	2020	The Journal of Clinical Investigation	American Society of Clinical Investigatio n
4	163	Chojnacka *et al*. (2020)	Phytochemicals containing biologically active polyphenols as an effective agent against Covid-19-inducing coronavirus	2020	Journal of Functional Foods	Elsevier
5	157	Ma *et al*. (2020)	Evaluation of phytochemical and medicinal properties of Moringa (Moringa oleifera) as a potential functional food	2020	South African Journal of Botany	Elsevier
6	156	García-Burgos *et al*. (2020)	New perspectives on fermented dairy products and their health relevance	2020	Journal of Functional Foods	Elsevier
7	151	Zeki *et al*. (2020)	Integration of GC–MS and LC-MS for untargeted metabolomics profiling	2020	Journal of Pharmaceutica l and Biomedical Analysis	Elsevier

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Table 1 (continue). Top 10 citation on metabolomics and functional food.

No.	Citation	Authors	Title	Years	Jour	Publisher
8	139	Alves-Santos *et al*. (2020)	Prebiotic effect of dietary polyphenols: A systematic review	2020	Journal of Functional Foods	Elsevier
9	136	Behera *et al*. (2020)	Traditionally fermented pickles: How the microbial diversity associated with their nutritional and health benefits?	2020	Journal of Functional Foods	Elsevier
10	129	Diez-Gutiérrez *et al*. (2020)	Gamma-aminobutyric acid and probiotics: Multiple health benefits and their future in the global functional food and nutraceuticals market	2020	Journal of Functional Foods	Elsevier

Apart from citations, other factors characterize the strong influence of the article, such as the importance of the research objectives, the methodology used, and the contribution to the cases that occurred. The place of publication or publisher can also influence the perceived quality of an article (Busby, 2015). Overall, a publisher's influence on a journal's credibility is influenced by factors such as the concentration of top publishers, editorial decisions, and reader expectations (Krell, 2010). **Figure 2** shows the 10 publishers with the most published articles on metabolomics and functional food in the period 2020 to 2023.

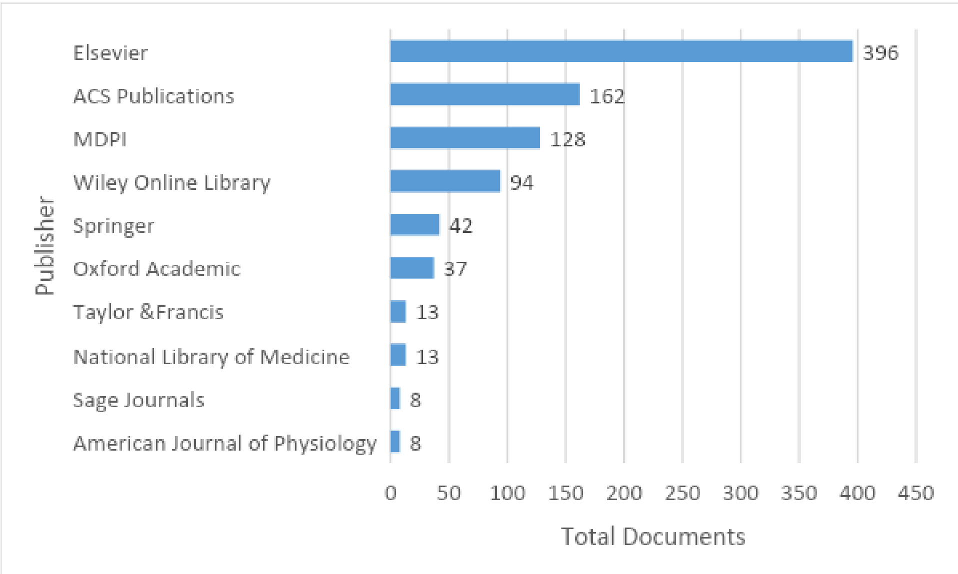

Figure 2. Top 10 publisher sources with the highest published documents.

3.3. Analysis of Co-authors between Other Authors

A visualization of the authors who are most active in metabolomics and functional food research is shown in **Figure 3**. A total of 2629 authors who participated in related research were arranged into a minimum of 5 relationship terms to obtain 125 authors who met the criteria. Each different group is given a different color as well. Cluster 1 is represented by a red circle, consisting of 30 authors, while Cluster 2 consists of 26 authors, represented by a green circle. Cluster 3, marked with a blue circle, consists of 23 authors. Cluster 4, represented by the yellow circle, consists of 19 authors. Finally, clusters 5 and 6 represent purple and light blue which consist of 15 and 12 items respectively. The size of the circle represents the number of articles. In other words, the more articles there are, the bigger the circle. As shown in the map, Wang (yellow circle), Liu (light blue circle), and Li (red circle) are considered the most productive authors in related research.

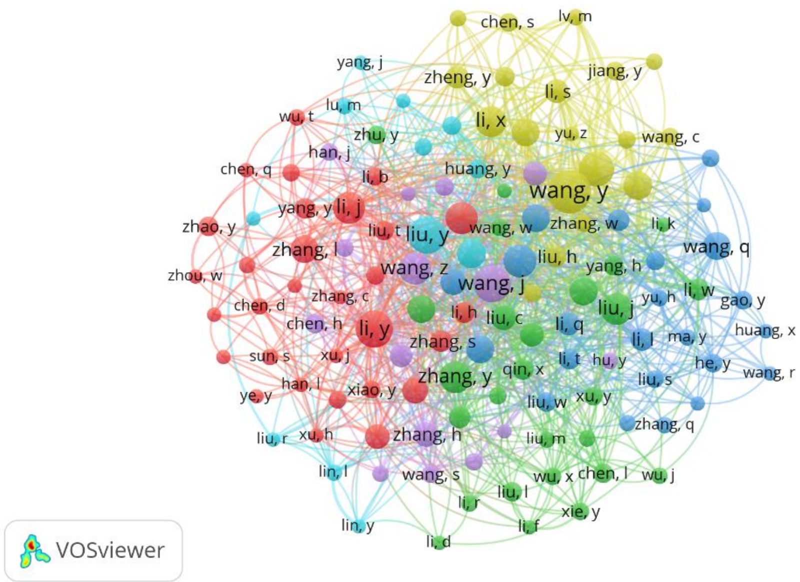

Figure 3. Co-authorship analysis of authors.

3.4. Visualization of Research Topics Areas

Based on the results of research on 998 articles on metabolomics and functional food, 6150 terms were obtained which were then visualized with a minimum number of anther-term relationships in VOSviewer, namely 5 terms, resulting in 202 terms that met the criteria. After the data was analyzed, the results showed that there were 11 clusters which could be described as follows:

(i) Cluster 1 has 37 items consisting of acid, addition, alteration, Alzheimer's, blood, cell, change, childhood asthma, diabetes mellitus, diet, differential metabolite, disease, efficacy, evidence, food intake, integrated metabolomics, liver, mass spectrometry, metabolic pathway, metabolism, metabolomic profiling, metabolomic study, metabolomics analysis, metabolomics profile, metabolomics result, nontargeted metabolomic, plasma, protein, serum, targeted metabolomics, therapeutic effect, untargeted metabolomic analysis, untargeted metabolomics analysis urine, and urine metabolome.

(ii) Cluster 2 has 30 items consisting of anthocyanin, colorectal cancer, comprehensive analysis, correlation, diabetes, fecal metabolome, fecal microbiome, flavonoid, function, gut, gut microbiome, gut microbiota, high-fat diet, intestinal microbiota, metabolome profile, metabolomics profile, metagenomics, microbiome, obesity, oxidative stress, polysaccharide, serum metabolome, t2dm, tissue, transcriptomic analysis, type, ulcerative colitis, untargeted metabolomics approach, and vitro.

(iii) Cluster 3 has 28 items consisting of characterization, comparative metabolomics, comparative metabolomics analysis, comparison, difference, fatty acid, food science,

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fruit, gas chromatography-mass spectrometry, GC/MS, GCMS, inflammatory bowel disease, integration, lactobacillus plantarum, LCMS, metabolic change, metabolite, metabolomic, metabolomics data, metabolomics investigation, metabolomics method, metabolomics, metabolomics data, microbe, milk, perspective, serum metabolomics, and untargeted metabolomic.

(iv) Cluster 4 has 23 items consisting of activity, antioxidant activity, bioactive compound, bioactivity, chemical composition, composition, compound, extract, food industry, functional food, health benefit, LCMS/MS, leafe, metabolomics analysis, metabolomics approach, nutraceutical, potential application, probiotic, process, secondary metabolite, and variation.

(v) Cluster 5 has 22 items consisting of analysis, comparative transcript, drought stress, insight, integrated analysis, integrative analysis, knowledge, metabolome, metabolome analysis, metabolome change, molecular mechanism, network analysis, nonalcoholic fatty liver, omics technology, pathway, proteome, proteomic, regulation, salt stress, transcriptome, transcriptome analysis, and transcriptomic.

(vi) Cluster 6 has 20 items consisting of application, biomarker, carbohydrate, current knowledge, food, genomic, growth, health, human health, identification, investigation, medicine, metabolomics insight, metabolomics research, novel insight, nutrition, phytochemical, plasma metabolite, potential biomarker, and research.

(vii) Cluster 7 has 17 items consisting of depression, effect, fecal metabolomics, gene expression, H NMR, hyperlipidemia, lipid, lipid metabolism, liver metabolism, mechanism, network pharmacology, NMR, nuclear magnetic resonance, patient, plasma metabolomics, treatment, and xiayaosan.

(viii) Cluster 8 has 11 items consisting of approach, metabolite, lipidomic, metabolomics method, metabolomics profiling, metabolomics study, omic, stress, systems biology, targeted metabolomics analysis, and untargeted metabolomics.

(ix) Cluster 9 has 7 items consisting of gene, metabolomics technique, metabolomics technology, mice, protective effect, rRNA gene sequencing, and serum metabolite.

(x) Cluster 10 has 6 items consisting of current study, human, influence, NMR metabolomics, plasma metabolome, and potential mechanism.

(xi) Cluster11 has 1 item which is a child.

Network visualization will display the relationships between the terms being visualized. **Figure 4** shows the relationship between terms visualized in a network or line connecting the terms. Just like interpreting the author's relationship with other authors, the size of the circles in the network visualization based on text data represents the number of keywords that are frequently used in the article. In other words, the more keywords used in an article, the bigger the circle. From **Figure 4** it can be seen that metabolomics is a keyword that is often used in articles. From the identification results, metabolomics is in cluster 3, represented by the blue circle, with a total strength of 1870 and 432 repetitions, while functional food is in cluster 4, represented by the yellow circle, with a total strength of 585 and 142 repetitions.

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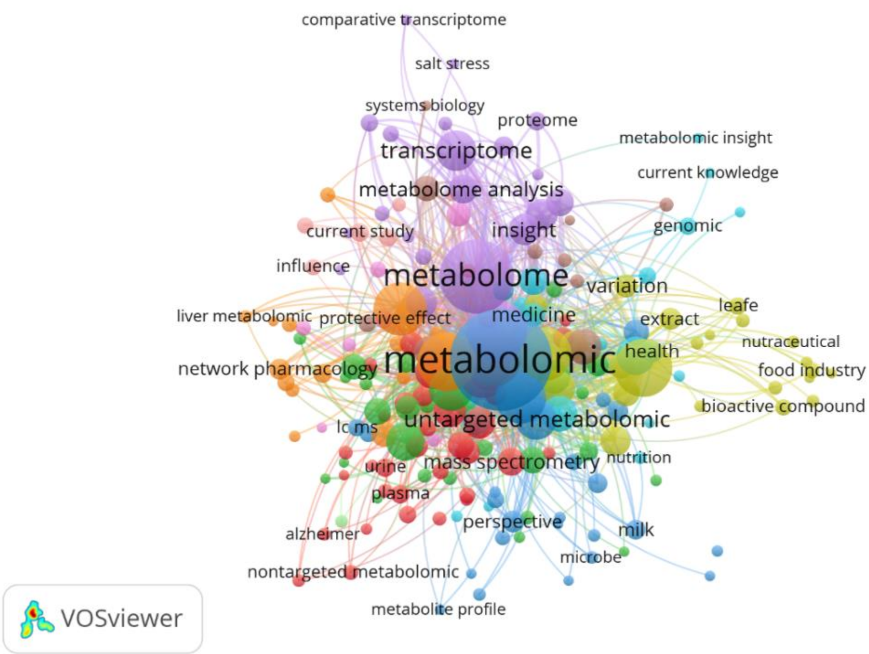

Figure 4. Network visualization.

Figure 5 visualizes the clusters according to the year the article was published. This overlay network visualization can be used to illustrate trending topics. Based on the visualization results, it can be seen that the topic of metabolomics and functional food has existed from 2020 to 2023. For functional food itself, this research began to develop in 2021 until now. The development of metabolomics research has encouraged researchers to conduct research on functional foods which are very useful and make a big contribution to the world of health.

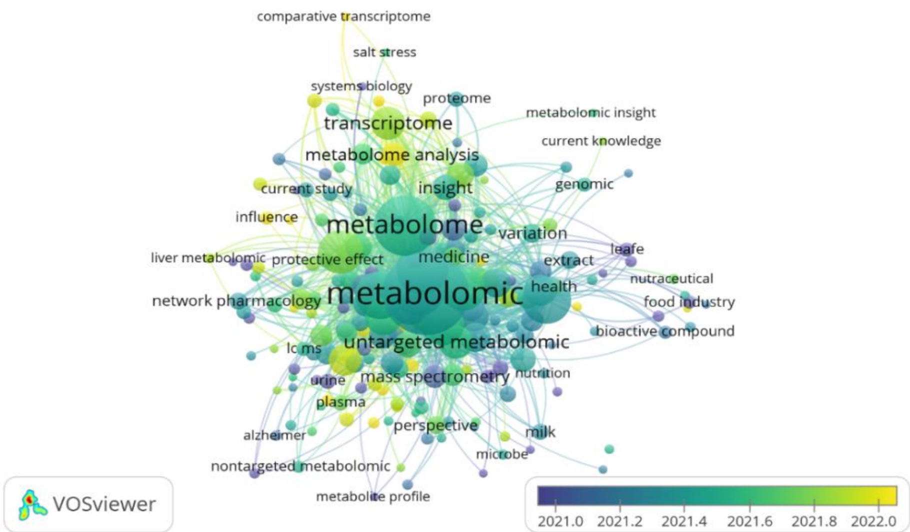

Figure 5. Overlay visualization.

Cluster density is the number of elements that have the same label as the display item. Each dot has a different hue depending on the density of the element. The color of a point on this graph is determined by the number of items associated with other objects. This visualization is very useful for understanding the basic layout of a bibliometric map by identifying which aspects are relevant to the study. **Figure 6** shows a fairly dense metabolomics density and is surrounded by many additional elements related to functional foods, namely health.

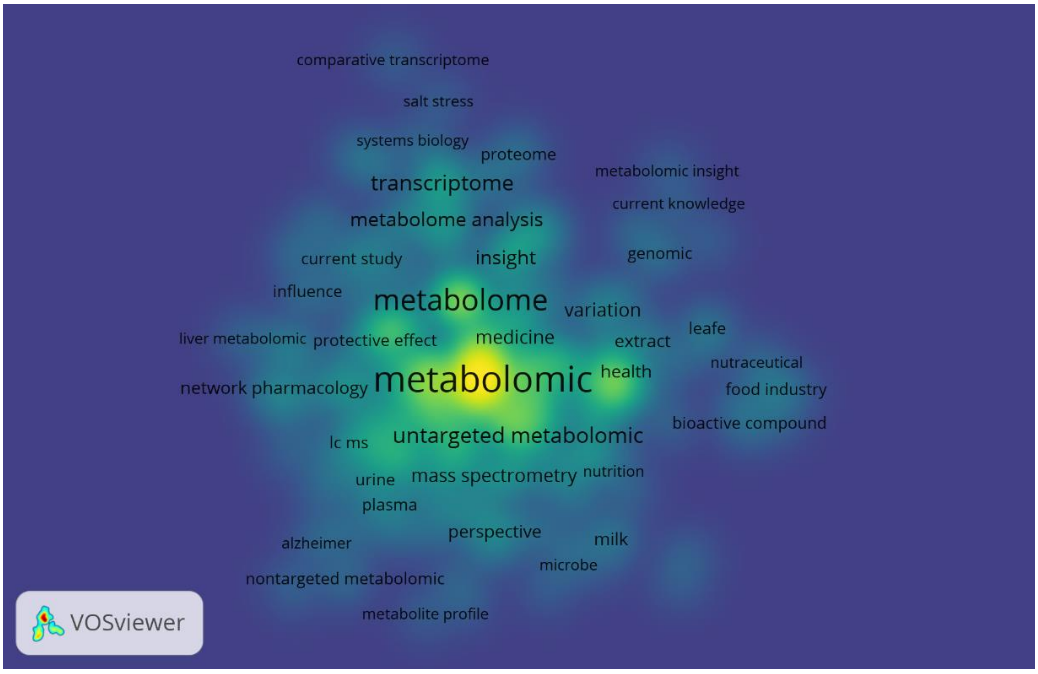

Figure 6. Density visualization.

4. CONCLUSION

Based on the results of the analysis carried out, research on metabolomics and functional food plays a very significant role. This is evident from the increase in the number of journal publications from 2020 to 2023, especially journals listed on Google Scholar. The results of the highest citation analysis show that there are 17 journals with more than 100 citations, with the majority of articles coming from the publisher Elsevier. In terms of authors, Wang, Liu, and Li were identified as the most prolific authors on this topic. The visualization analysis also indicated the existence of 11 thematic groups with the keyword "metabolomics" as the most frequently appearing. This topic has also shown a high level of research activity since 2021. It is hoped that this research can guide researchers in determining the focus of their research and can also become a reference for research related to metabolomics and functional food.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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