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Systematic Review Article

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Mapping a Decade of Research Trends on Onion Peel Waste Valorization

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ABSTRACT
The global agro-industrial industry is currently facing a major challenge in the management of organic waste, which is generated in large quantities. Onion peel/skin, one of the most neglected agricultural byproducts, holds considerable promise as a valuable source of bioactive compounds. This article aims to map the trends and directions of research related to the valorization of onion skin waste in the period 2014-2024 through a scientometric approach. Data were retrieved from the DOAJ database, with a total of 71 articles analyzed. The study showed a marked rise in publications since 2021. Primary focus on antioxidant activity, extraction methods, and applications in pharmaceutical and agro-industrial sectors. The findings indicate growing recognition of onion peel waste as a high-potential resource for sustainability and circular-economy frameworks. This review is expected to provide a foundational basis for future research and the broader development of onion peel/skin valorization.
Keywords: Onion peel/skin, waste valorization, research mapping, sustainable agro-industry

INTRODUCTION

The global agro-industrial sector is currently facing significant challenges in the management of organic byproducts, which are generated in substantial quantities. In India, for instance, approximately 18.4% of agricultural waste is incinerated annually, reflecting the inadequate level of sustainable agro-industrial waste management (Sharma, 2024). A particular type of organic byproduct that is frequently disregarded yet possesses considerable potential is onion peel/skin. India is the world's leading producer of onions, with a production of 30.2 million tons (MT), followed by China, Egypt, the United States, and Turkey as the top five producing countries (FAO, 2025). Given the substantial volume of production, a significant amount of onion peel waste is also produced. However, its utilization has not been optimized.

Onion peel is known to contain a variety of high-potential bioactive compounds, such as flavonoids, phenolic compounds, and flavanols (Kumar et al., 2022). Among these compounds, quercetin and its derivatives are the dominant components that contribute greatly to the functional activities of onions and their wastes (Jaganmohanrao, 2025). Various studies have shown that these compounds have antioxidant, antibacterial, and potential activities as natural colorants, and can be used as functional additives in the development of functional products. Therefore, onion peels have a great opportunity to be utilized as raw materials in the development of sustainable products in the agro-industrial sector.

In the context of sustainability in the food and agriculture sector, circular economy and zero waste approaches are receiving increasing attention (Chaudhary et al., 2022). Organic waste such as onion skins, previously considered worthless, can be processed into a variety of functional products that have wide applications, ranging from the food industry, pharmaceuticals, to the health sector (Sagar et al., 2021). This approach has the dual benefits of reducing the environmental impact of byproducts and generating new economic value, resulting in promoting resource efficiency.

Although various studies have been conducted on the utilization of onion skins, there is no systematic study that thoroughly maps the direction, focus, and trends of research in this field. This lack of mapping has led to limited cross-disciplinary synergies and low integration of knowledge required to produce agro-industrial waste-based innovations. In addition, the practical contribution of these studies to the agro-industrial sector has also not been studied in depth. Therefore, this study was conducted to provide a comprehensive mapping through a content analysis approach of scientific articles that discuss onion peel/skin valorization. This study aims to identify publication trends during the 2014-2024 period. It is expected that the results of this study will serve as a basis for the development of further research, as well as

a reference for industry players and policymakers in developing sustainable, innovative solutions based on onion peel/skin waste.

MATERIALS AND METHODS

This study uses a scientometric technique to analyze trends and developments in research topics related to onion peel/skin, adopted from Okolie & Ogundeji (2022) with some modifications. Scientometric techniques have been used to analyze scientific trends and outputs, as well as the evolution of research, author productivity, journals, and nations, as well as to discover and measure international collaboration (Orimoloye & Ololade, 2021). This study is descriptive and exploratory, and focuses on research articles published in the last decade (2014–2024).

Directory of Open Access Journals (DOAJ; https://doaj.org/) were used as the data source, as it provides high-quality, curated, and fully open-access journals. Hence, this research can be reproduced seamlessly with consistent metadata. The inclusion and exclusion criteria applied to all retrieved articles are summarized in Table 1.

Table 1. Inclusion and exclusion criteria for selection of articles.

Criteria	Inclusion	Exclusion
Document type	Original research article	Review, conference proceeding, book chapter, editorial, short communication
Source type	Journal	Book, book series
Language	English	Non-English
Publication period	Between 2014 and 2024 (the last decade)	Before 2014 and after 2024
Full text and abstract	Available	Not available
Open access	Yes	No
Topic	Focus on the onion peel/skin	Out of the main topic

The procedure of metadata extraction includes the manual collection of bibliographic information from articles that meet specific criteria. This includes title, link, authors, abstract, keywords, journal subjects, journal, publisher, year, country, and citation. Moreover, we added a research area field to the dataset. At this stage, this field remains unassigned. The classification was performed after the systematic review process. Based on the obtained data, a scientometric analysis was conducted to determine trends in publication distribution per year, geographical distribution based on country of publication, major journals where articles were published, and frequency of keywords and main topics. The data analysis was executed using Python (Pandas v2.2.3), Microsoft Excel 2019, and Google Spreadsheets. Visualization was executed through Python (Matplotlib v3.10.5, Seaborn v0.13.2, Wordcloud v1.9.4) and VOSViewer v1.6.20 software.

Systematic Review Process

The present review process was conducted in July 2025. The process of selecting studies followed a structured and transparent approach, as depicted in Figure 1 below.

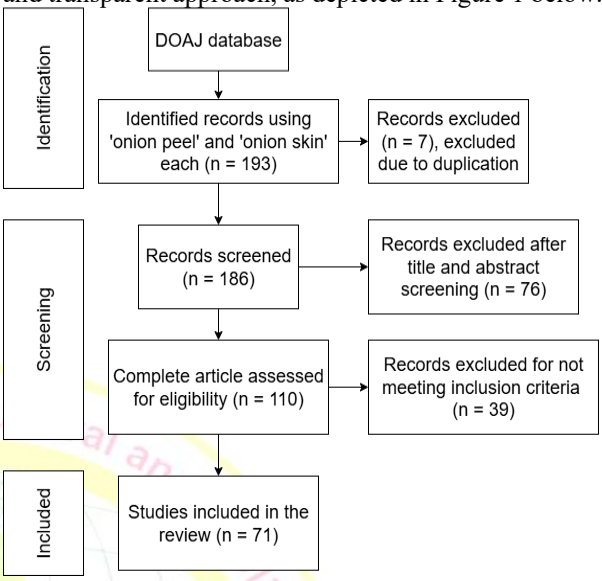

Figure 1. Flow process in the reviewing process.

The first stage involved the selection of a database, which is DOAJ. The second stage focused on determining the keywords used for the search process and searching articles for further screening. In this case, we used the keywords 'onion peel' and 'onion skin' (n= 193). The third stage was filtering and the removal of duplicate articles. Of the total (n= 193) papers eligible for evaluation at this point, a total (n= 7) papers were excluded. The fourth step was the screening of records based on a boolean search query below to ensure the article is relevant (n= 186).

("onion peel" OR "onion skin") AND ("valorization" OR "valorisation" OR "utilization" OR "utilisation" OR "value" OR "extract")

Subsequent to applying the boolean search query, we have successfully eliminated a total (n= 76) articles.

The fifth stage assessed the eligibility of the articles based on the inclusion criteria as mentioned before (n= 110). After a thorough review of the content and relevance to the topic, a total (n= 71) articles were included in the final analysis.

Coding Procedure

After obtaining the eligible articles, a single reviewer manually examined each abstract of the articles and assigned it to one of seven predefined categories reflecting the main focus, which are:

Medicine/Pharmacy/Phytochemical
Environment
Food/Agro-industry
Textile

Material & Metallurgy
Cosmetic Industry
Petrochemical

Overlapping or mixed topic cases were infrequently encountered in the article abstracts during the coding process. In such cases, the reviewer assigned the research area field by the most dominant one. Since the coding procedure is done by a single reviewer, intercoder agreement metrics were not applicable in this research. The results were compiled in Python (Pandas v2.2.3), Microsoft Excel, and Google Spreadsheet for descriptive statistical analysis and trend visualization.

RESULTS AND DISCUSSION

Number of Publications

The publication trend of articles related to onion peel/skin waste valorization shows interesting dynamics during the period 2014 to 2024. At the beginning of the period, 2014 and 2015, no relevant publications were found, indicating that this topic has not received much attention from researchers. Entering 2016, the first publications that showed interest in this issue began to appear, with a significant increase in 2017, which recorded around six articles. However, this trend fluctuated, as there was a sharp decline in 2018, until almost no publications were published.

From 2019 to 2021, publications again showed an increase, although in limited numbers. The most significant development occurred in the period 2022 to 2024. The year 2022 recorded around nine published articles, then jumped sharply to 18 articles in 2023, and reached its peak in 2024 with a total of 22 publications. This surge indicates that the topic of onion peel waste valorization has become a rapidly growing research area, in line with the increasing attention to the principle of net-zero waste accumulation and agro-industrial waste-based innovations in support of sustainable development and value-added production (Hsueh et al., 2023).

Journal Distribution in Research of Onion Peel Waste Valorization

The distribution of publications indicates a predominance of research on the valorization of onion peel byproducts, with the journal Antioxidants from MDPI featuring eight articles, followed by Heliyon and Molecules with three articles each. This observation underscores the significance of research on bioactive compounds, such as antioxidants, found in onion skins. The preponderance of journals from international publishers such as MDPI, Elsevier, and Taylor & Francis signifies the global focus on these issues, particularly in the domains of functional food, green chemistry, and circular economy. The broad array of journals from diverse fields, including chemistry, food, engineering, and natural fibers, underscores a comprehensive cross-disciplinary strategy for valorizing agro-industrial waste into high-value products.

Disciplinary Trends and Application Focus

Based on Fig. 2, during the 2014-2024 period, it can be seen that the fields of Medicine/Pharmacy/Phytochemical and Food/Agro-industry dominate publications related to the valorization of onion skin waste. The medical and phytochemical fields show consistency in publications since 2016 and experienced a sharp increase after 2021. This increase might be related to the post-COVID-19 period, when awareness of natural bioactive compounds possibly became more pronounced. For instance, the quercetin content in the onion skins is believed to have potential as a preventive agent against infections of coronavirus. This also includes MERS-CoV and SARS-CoV types, indicating the studies highlighting the antiviral and immunomodulatory activities of these compounds (Shabir et al., 2022).

Meanwhile, the food/agro-industry area experienced a significant surge since 2021, and by 2024, the number of publications was comparable to the medical field. This depicts the increasing interest in the utilization of onion skins in the development of functional foods, active packaging, and food fortification (Kumar et al., 2022; Santos et al., 2021; Masood et al., 2020). This increase is in line with the growing number of studies exploring the antioxidant, antimicrobial, and therapeutic activities of bioactive compounds in onion skins, especially sulfur-containing components like cysteine sulfoxide and phenolic compounds such as quercetin glucoside as well as quercetin, which have been extensively studied (Shabir et al., 2022).

Some other areas, such as the environment, textile, and cosmetic industry, do appear in a limited number of publications, but highlight the consistency. This indicates the interdisciplinary potential that is being explored, especially in the context of sustainability and the substitution of synthetic materials. One example is the utilization of onion skin as a bio-functional textile with UV protection and antioxidant activity (Pucciarini et al., 2019).

The trend indicates that onion skin-related research is not only developing at the laboratory scale, but is also starting to be directed towards cross-sectoral applicative solutions. This issue is gaining importance as the market continues to shift toward eco-friendly as well as high-value products.

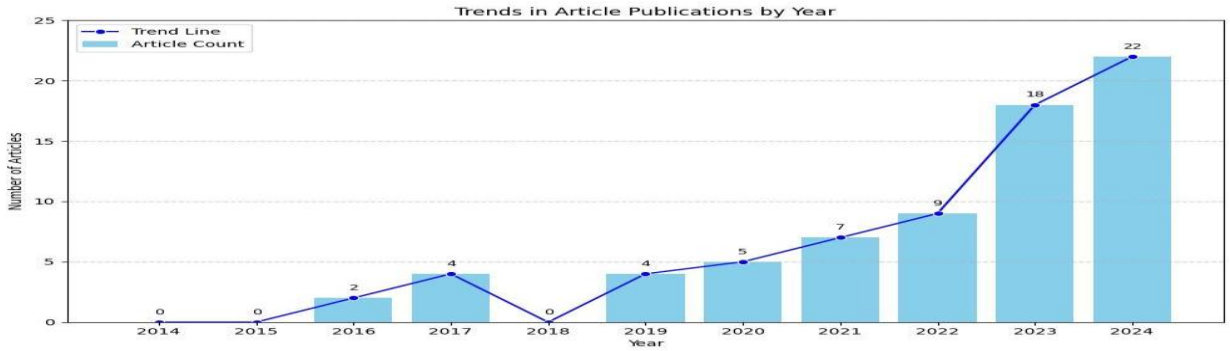

Fig. 1. Number of publications during 2014-2024.

Table 2. Most relevant sources related to onion peel valorization

No.	Journal	Publisher	Country	Website URL	Count
1	Antioxidants	MDPI AG	Switzerland	https://www.mdpi.com/journal/antioxidants	8
2	Heliyon	Elsevier	United Kingdom	https://www.cell.com/heliyon/home	3
3	Molecules	MDPI AG	Switzerland	https://www.mdpi.com/journal/molecules	3
4	Chemical Engineering Transactions	AIDIC Servizi S.r.l.	Italy	https://www.cetjournal.it/index.php/cet	2
5	CyTA - Journal of Food	Taylor & Francis Group	United Kingdom	https://www.tandfonline.com/journals/tcyt20	2
6	Journal of Natural Fibers	Taylor & Francis Group	United Kingdom	https://www.tandfonline.com/journals/wjnf20	2
7	Foods	MDPI AG	Switzerland	https://www.mdpi.com/journal/foods	2
8	International Journal of Food Properties	Taylor & Francis Group	United Kingdom	https://www.tandfonline.com/journals/ljfp20	2
9	Scientific African	Elsevier	Netherlands	https://www.sciencedirect.com/journal/scientific-african	2
10	Results in Engineering	Elsevier	Netherlands	https://www.sciencedirect.com/journal/results-in-engineering	2
11	Gels	MDPI AG	Switzerland	https://www.mdpi.com/journal/gels	2
12	Scientific Reports	Nature Portfolio	United Kingdom	https://www.nature.com/srep/	2
13	Applied Sciences	MDPI AG	Switzerland	https://www.mdpi.com/journal/applsci	2

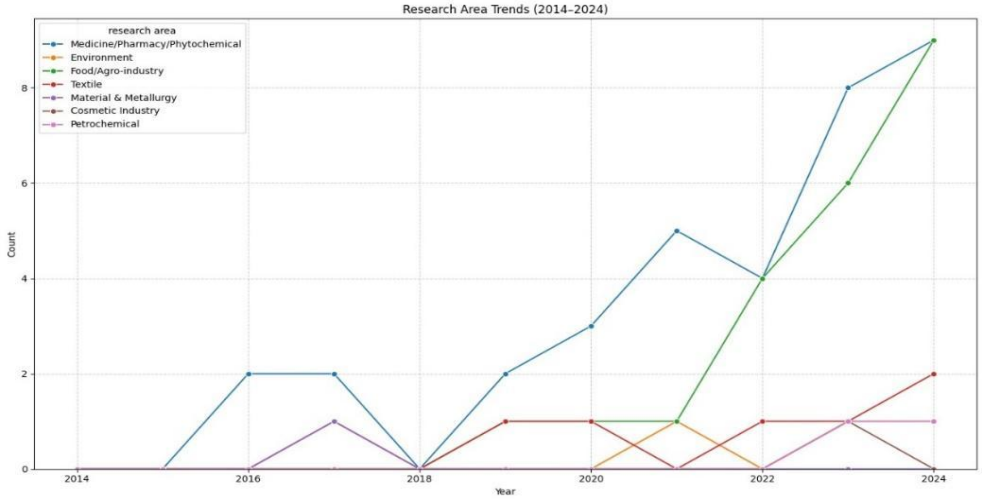

Fig. 2. Distribution of research areas in onion peel/skin waste valorization.

Citation Analysis

Citation analysis reveals how many times a specific research article has been cited in other scientific articles (Okolie & Ogundeji, 2022). Fig. 3 shows the articles with the most citations in the search results. The article with the highest number of citations is titled "Onion Peel: Turning a Food Waste into a Resource" (Celano et al., 2021), which received 106 citations, reflecting the influence of this article in raising the issue of managing onion peel waste as a valuable raw material. The second most cited article, with 104 citations, discusses the antioxidant capacity and major phenolics in horticultural crop wastes, emphasizing the great interest in the bioactive content of onion skins (Burri et al., 2017). The third and fourth articles focused on phenolic extraction using subcritical methods and the effect of onion skins on the nutritional quality of food products, garnering 83 and 69 citations, respectively (Benito-Román et al., 2020; Michalak-Majewska et al., 2020). Meanwhile, the fifth article on the effects of maltodextrin and gum arabic on onion skin phenolic compounds recorded 66 citations (Akdeniz et al., 2017). These five articles form an important reference base that shows the main direction of research, which is on the exploration of bioactive content, extraction technology, and its application in functional foods.

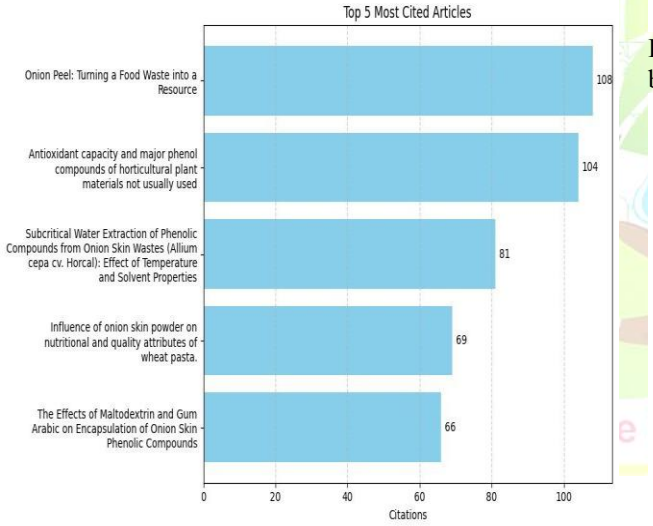

Fig. 3. Top 5 cited articles on the valorization of onion peel/skin waste.

Contributing Countries and Leading Authors

As illustrated in Figure 4, Switzerland has the highest publication output in the field of research related to the valorization of onion peel/skin waste, accounting for 28.6% of the total publications examined. The United Kingdom is the second-largest contributor, with 21.7%, followed by Indonesia, with a contribution of 7.1%. Other countries, including the Netherlands, the United States, Brazil, Italy, Turkiye, and Germany, contributed smaller portions but still reflected the global scope of this research. The preeminence of Switzerland and the UK can be attributed to the prolific activity of publishers such as MDPI and Taylor & Francis, which publish a substantial number of articles in journals dedicated to food, bioactive substances, and the environment. This multinational coverage indicates that the issue of onion skin waste management is not only locally relevant but also receiving global attention as part of sustainability and circular economy strategies (Hsueh et al., 2023).

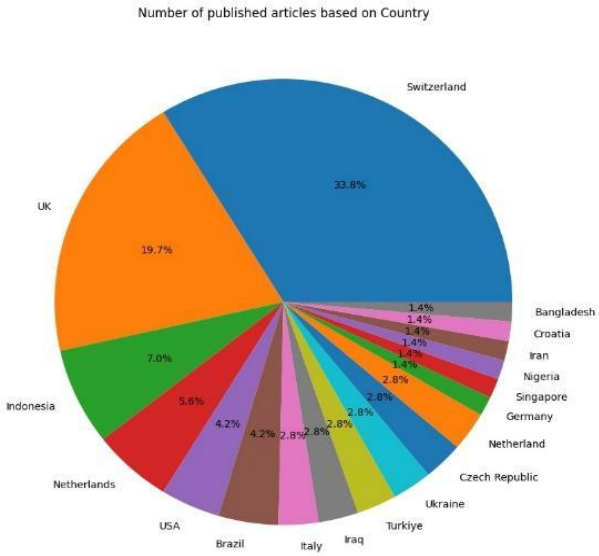

Fig. 4. Geographic distribution of journal publishers based on country.

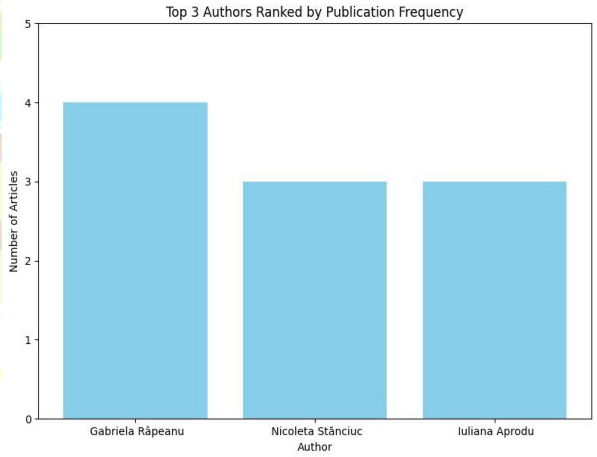

Fig. 5. Leading authors in onion peel/skin valorization.

Fig. 5 shows the most productive authors in publications related to this topic. The author with the highest publication frequency is Gabriela Milcarek Nascimento, followed by Nicolata Sikanic Mladineo and Juliana Aparecida de Souza Oliveira. These three authors have research focuses related to natural active ingredients, agricultural waste processing, and functional applications in food and pharmaceuticals.

Frequent Keywords and Keyword Co-Occurrence Networks

The word cloud is a digital mapping of keywords that appear in the publication of scientific articles. It is currently widely used because it can identify the focus of published articles (Atenstaedt, 2017). Fig. 6 illustrates the 50 most common keywords used in scientific articles related to onion peel waste valorization during the period 2014-2024. The words "Quercetin" and "Antioxidant Activity" appear most dominantly, reflecting the main focus of research on the exploration of bioactive compounds contained in onion skins. Other frequently occurring terms include "Onion Skin", "Onion Peel", "Flavonoids", "Anthocyanins', and "Extraction", indicating a research trend towards chemical characterization, extraction methods, and functional applications of these compounds. The emergence of words such as "Antimicrobial Activity", 'Encapsulation, and "Biotechnology" also indicates a research direction towards pharmaceuticals, functional foods, and nanotechnology. This word cloud visually confirms that research on onion skins focuses mainly on antioxidant and antimicrobial potential, and supports the concept of utilizing waste into high-value-added products.

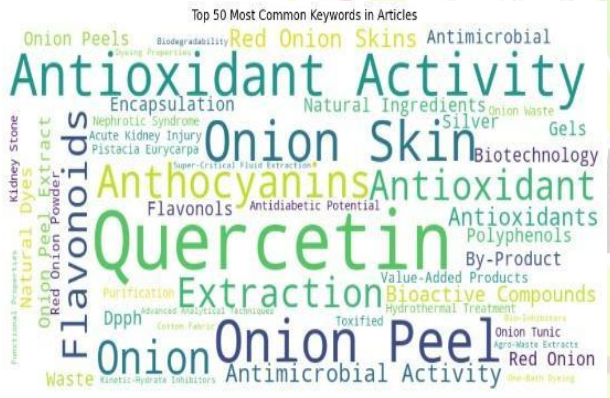

Fig. 6. Most common keywords in selected publications.

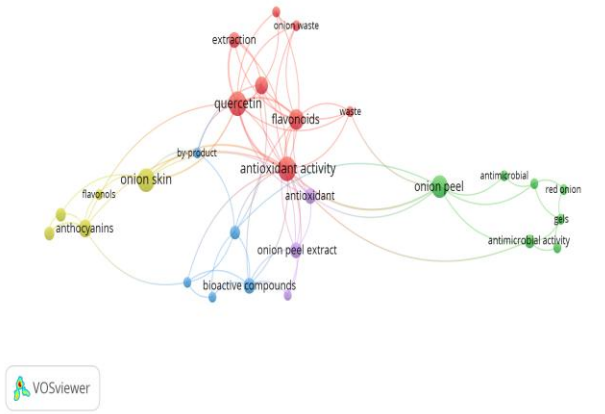

Fig. 7. Keyword co-occurrence networks in onion peel waste valorization research.

Fig. 7 depicts the linkage network between keywords that frequently co-occur in articles related to onion skin waste valorization. Each color represents a different thematic cluster. The red cluster, which is the most dominant, centers on keywords such as "antioxidant activity", "phenolic compounds", and "extraction", indicating that most studies emphasize the extraction process and antioxidant activity testing of onion peel bioactive compounds. The green cluster associates keywords such as "onion peel", 'antibacterial', and "antimicrobial activity", indicating a focus on antimicrobial applications. Other clusters, such as yellow and purple, lead to studies on anthocyanins, bioactive compounds, and onion skin, reflecting further exploration of functional chemistry. This network shows that research topics are evolving thematically and are closely interconnected, with antioxidants and bioactivity at the center of scientific attention.

LIMITATIONS

This research has some limitations. First, only articles indexed in DOAJ were included, which may bias results toward open-access journals and under-represent non-open-access or regional publications. Moreover, since this research uses a single data source, the dataset gained is considerably small in size. Second, the analysis was restricted to articles that fulfilled our inclusion criteria; it may potentially exclude relevant studies outside the criteria (e.g., journals written in non-English languages). Third, a small number of articles had overlapping or mixed topics. Because each paper was assigned to only one category, a few cases might need a subjective judgment, which may slightly affect the category-share results.

FUTURE PERSPECTIVE

Moving forward, research on the valorization of onion peel waste holds great potential for development towards broader and more sustainable industrial applications. The employment of environmentally friendly technologies, including green solvent-based extraction, microbial fermentation, and nanotechnology, can serve as a pivotal area of focus to enhance the efficiency and sustainability of the utilization process for onion skin. Furthermore, the integration of multidisciplinary research between food science, engineering, environment, and biotechnology must be strengthened to produce innovative onion peel/skin-based products that are not only economically valuable but also have tangible health and environmental benefits. Further relevant studies are also needed to explore the commercialization potential of these products. Such as incorporated in active packaging systems, functional foods, and natural cosmetic ingredients. Furthermore, there is a need for further exploration of areas that have received less attention, particularly with regard to their applications in the cosmetics and textile industries. Consequently, subsequent research endeavors should prioritize not only laboratory-based studies but also

extend their scope to production scale and practical implementation within the agro-industrial value chain. The author identified several areas of potential research advancement for onion peel/ skin waste, including the lack of research on an industrial scale and the absence of examination of numerous aspects of scalability and commercialization over the past decade. Moreover, the absence of economic and life cycle assessment studies, coupled with an overreliance on antioxidant and phenolic content alone, signifies a novel opportunity for the advancement of onion peel/skin utilization through interdisciplinary research.

CONCLUSION

This study successfully mapped the recent trends and direction of studies related to the valorization of onion skin waste during the period 2014-2024 using a scientometric approach on the content of articles published in the DOAJ database. The results indicate that this subject has undergone a substantial surge in the number of publications, particularly in the last three years. The primary focus of research endeavors is the exploration of bioactive compounds, the development of extraction methods, and the identification of their applications in the domains of food and health. The primary contributors to the publication of this topic are countries such as Switzerland, the UK, and Indonesia. A thorough analysis of the collaboration networks and keywords identified a robust thematic structure and a significant potential for interdisciplinary collaboration. This study provides a scientific foundation for the development of subsequent research and serves as a reference for industry stakeholders and policymakers interested in utilizing onion peel/skin waste/byproducts as a valuable resource.

CONFLICT OF INTEREST

The author here declares there is no conflict of interest in the publication of this article.

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