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Active Compounds, Antioxidant Potential, and Formulation Innovations of *Oxalis* sp.: A Bibliometric Perspective

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ABSTRACT

The genus *Oxalis,* belonging to the family *Oxalidaceae* R.Br., comprises approximately 504 recognized species that are widely distributed worldwide, particularly in regions ranging from South America to southern North America, as well as in the southwestern Cape region of South Africa. In Egypt, this genus is represented by five species and one variety, namely *Oxalis anthelmintica* A. Rich., *O. corniculata* L., *O. corniculata* var. repens (Thunb.) Zucc., *O. corymbosa* DC., *O. latifolia* Kunth, and *O. pes-caprae* L. However, information on the isolation and characterization of non-polar and volatile constituents from *Oxalis* species remains limited. Therefore, this study applied bibliometric analysis to evaluate the development of research on *Oxalis* sp., particularly regarding antioxidant activity, formulation development, and phytochemical studies. Data were obtained from the Crossref database, resulting in 57 selected articles published between 2015 and 2025. Bibliometric analysis was conducted using VOSviewer to map publication trends, keyword co-occurrence networks, overlay visualization, and influential articles related to *Oxalis* research. A total of 214 publications from 2015–2025 were analyzed. The results show that 22 keywords were grouped into four clusters, forming 154 links with a total link strength of 962, indicating a well-connected research structure. The dominant research themes focus on antioxidant activity, antibacterial activity, and secondary metabolites, particularly in studies on *Oxalis corniculata*. However, keywords related to formulation development and advanced phytochemical analysis appear less frequently, suggesting that these areas remain relatively underexplored. These findings provide a systematic overview of the research landscape and highlight potential directions for future studies on the development and application of *Oxalis*-derived bioactive compounds.
***Keywords*:** Oxalis; Phytochemicals analysis; Natural antioxidant; Formulation

INTRODUCTION

The genus *Oxalis*, a member of the family *Oxalidaceae,* consists of more than 500 species that are widely distributed across tropical and subtropical regions[1]. Several species of *Oxalis* have attracted considerable scientific interest due to their traditional medicinal uses and diverse pharmacological properties.[2] Previous studies have reported that *Oxalis corniculata* exhibits various biological

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activities, including antioxidant (measuring the antioxidant activity of plant materials).[8,20,29], antibacterial, anti-inflammatory, antimicrobial, analgesic, anticancer[34], and diuretic effects.[32] Other species such as *Oxalis triangularis*, *Oxalis pes-caprae*, and *Oxalis dehradunensis* have also demonstrated notable pharmacological potential.[21] Despite the increasing number of studies on *Oxalis*, existing research is largely concentrated on biological activity evaluation and preliminary phytochemical screening.[11] In contrast, detailed phytochemical characterization, identification of non-polar constituents, and formulation-based studies remain relatively limited.[38] This imbalance suggests that certain areas of *Oxalis* research remain underexplored and require further investigation. Given the growing volume of scientific publications, a systematic evaluation is necessary to understand research development, thematic trends, and knowledge structures in this field.[6] Bibliometric analysis offers a quantitative approach to map publication trends, identify dominant research themes, and reveal potential research gaps. Therefore, this study conducts a bibliometric analysis of publications on *Oxalis* species indexed in Crossref from 2015 to 2025, focusing on publication trends, keyword co-occurrence networks, citation patterns, and research clusters to provide a comprehensive overview of the current research landscape.

METHODS

1. Data Sources

The research material was obtained using the Crossref database. The article search was conducted on July 28, 2025, using the following keywords: (Oxalis) AND ("phytochemicals analysis" OR "secondary metabolite") AND ("natural antioxidant") AND ("anti-aging OR skin aging") AND (formulation). The process of searching for scientific articles can be seen in Figure 1 in the book, and articles irrelevant to the topic.

2. Screening and Selection Process

The initial search retrieved 214 publications from the Crossref database. These records were subsequently screened to ensure their relevance to the research objectives. Articles that could not be accessed were excluded (n = 22). Publications that were not directly related to the research topic were also removed (n = 117). Additionally, review articles were excluded to focus the analysis on original research contributions (n = 12). After applying these exclusion criteria, a total of 57 publications were retained for the final bibliometric analysis. The complete screening and selection procedure is illustrated in Figure 1.

3. Bibliometric Analysis

The selected publications were analyzed using bibliometric techniques to identify research trends, thematic structures, and relationships among research topics related to *Oxalis* species. Bibliometric mapping and visualization were performed using VOSviewer software. Keyword co-occurrence analysis was applied to explore relationships between frequently used research terms and to identify major research clusters within the *Oxalis* literature. This analysis allowed the identification of major research themes, emerging topics, and potential research gaps within the scientific literature related to *Oxalis* species

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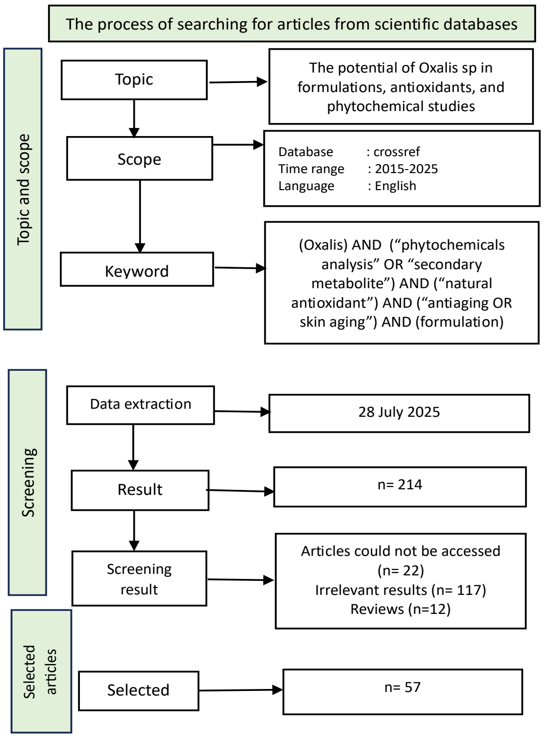

Figure 1. Search process methodology

RESULTS AND DISCUSSION

1. Trends in research innovation

Through bibliometric analysis based on network visualization, it can be seen that the presentation of data related to each term is visualized through the formation of a network connecting one keyword to another. Figure 2 presents the keyword co-occurrence network consisting of 22 items grouped into four clusters, forming 154 links with a total link strength of 962. In this network, two keywords connected by a line indicate that they co-occur in the titles or abstracts of the analyzed publications. The relatively high number of links and total link strength reflects a dense and interconnected research structure, suggesting strong thematic integration within the Oxalis research field rather than fragmentation.

The clustering pattern indicates that existing studies tend to concentrate around several dominant research themes. These themes are primarily associated with antioxidant activity, antibacterial activity, and secondary metabolites, which represent the core focus of current *Oxalis* research. The strong connectivity among these keywords suggests that pharmacological evaluation and phytochemical investigation have become the central topics explored by researchers in this field. Before the visualization process, keywords were obtained from the titles and abstracts of the selected publications and filtered to exclude irrelevant terms. The refined dataset was subsequently analyzed. using VOSviewer to generate network, overlay, and density visualizations that illustrate the relationships and structural organization of research themes within the *Oxalis* literatur

Figure 2 shows Network Visualization, which displays the relationships between keywords based on their co-occurrence frequency in the research data set, allowing for the identification of the main themes of each cluster 1. The analysis results show that there are several main topics that dominate research on Oxalis sp. The dominant topics that frequently appear are secondary metabolites, antioxidant , and antibacterial activity.

Based on the relationships among nodes and clusters, antioxidant activity appears as one of the most prominent keywords, showing strong associations with inhibition, molecular docking, isolation, and secondary metabolites. In the VOSviewer network visualization, the spatial proximity between nodes reflects the strength of keyword co-occurrence relationships. Keywords positioned closer together indicate stronger thematic connections, whereas those located further apart represent relatively weaker associations.

In this context, keywords such as formulation and phytochemical activity show weaker connections with the main antioxidant-related cluster, suggesting relatively limited co-occurrence relationships within the existing literature. However, spatial distance in the network should be interpreted cautiously, as it primarily reflects the strength of associations between keywords rather than direct evidence of research gaps.

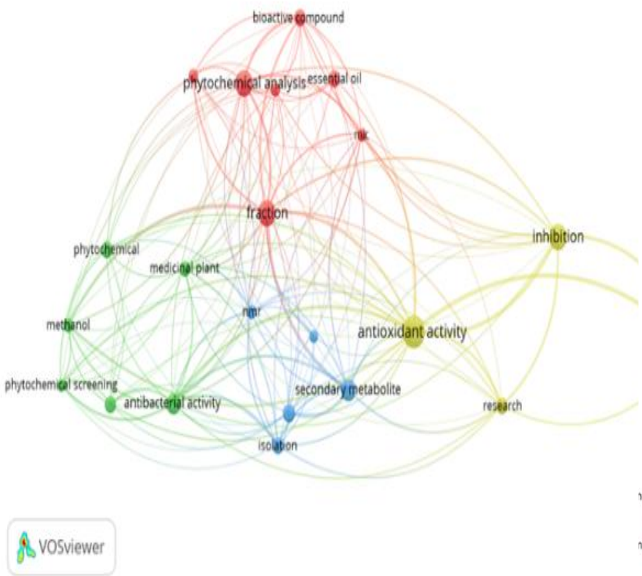

Figure 2. Keyword co-occurrence network

Overlay visualization introduces a temporal perspective to the keyword network by applying a color gradient to each node according to the average publication year of the related studies. Keywords shown in yellow or green represent more recent research trends, whereas blue or purple colors indicate topics that appeared earlier in the literature.

The keyword co-occurrence network is organized into four clusters, each representing a distinct thematic focus within *Oxalis* research. Cluster 1 primarily focuses on antioxidant-related studies and includes dominant keywords such as antioxidant activity, inhibition, molecular docking, and secondary metabolites. Cluster 2 is associated with antibacterial activity and microbial inhibition studies. Cluster 3 centers on phytochemical investigation, including keywords such as isolation, compound identification, and chemical characterization. Cluster 4 relates to formulation and applied research involving *Oxalis*-derived compounds.

The relationships among these clusters indicate that pharmacological activity evaluation and phytochemical investigation constitute the central themes of existing research. In contrast, formulation-related studies appear less frequently connected within the network, suggesting that applied research on *Oxalis*-derived bioactive compounds remains comparatively limited within the current literature.

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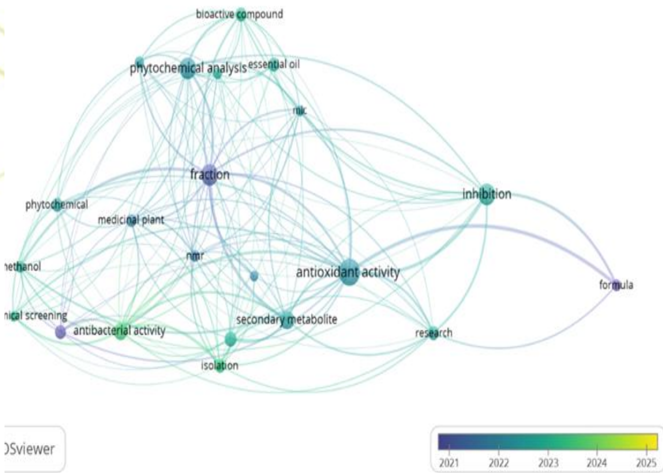

Figure 3. Keyword co-occurrence overlay with timeline

The results of bibliometric mapping based on density visualization are marked by the formation of circles in yellow and green. Yellow indicates that the research topic has been studied frequently, while dark green indicates that the research topic has not been explored and developed much. The results of the density visualization analysis in this article review show that research topics related to the keywords formula, molecular docking, and NMR are still rare. Density visualization illustrates the intensity of research topics based on the frequency and co-occurrence of keywords within the analyzed publications. Areas with higher density indicate topics that have been extensively studied, whereas areas with lower density represent themes that appear less frequently in the current literature. These patterns reflect the distribution of research attention within the *Oxalis* research field and help identify topics that have received comparatively less focus.

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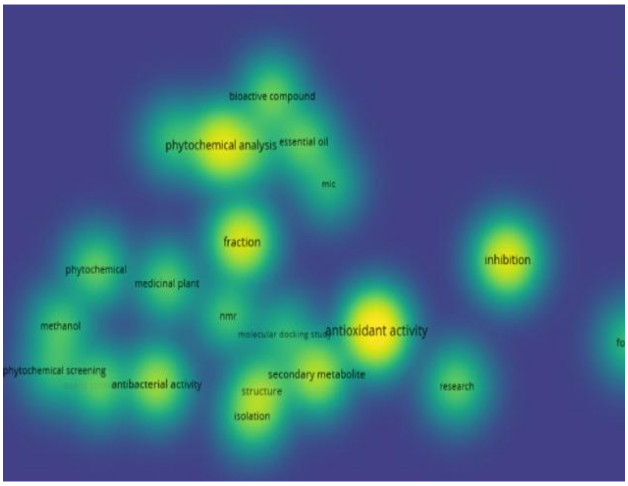

Figure 4. Keyword co-occurrence overlay with density visualization

2. Bibliometric analysis of authors' trends viewed from a timeline

The research trend on *Oxalis* sp is dominated by several researchers, where two authors occupying the same node have a close research correlation. From Figure 5, it can be seen that Misra *et al*., Bhartendu et al., and Nath et al. conducted research related to Oxalis sp. in 2024-2025, indicated by the yellow nodes, while Sayed et al. and Sheffali *et al*. conducted research earlier in 2021-2022.

3. Analysis based on research results

Figu

Research related to *Oxalis* sp has been conducted extensively, including by Pawar[34], who stated that *Oxalis corniculata* has antibacterial, antioxidant, anti-inflammatory, anticancer, antimicrobial, analgesic, and diuretic. [32]

Oxalis triangularis has antibacterial properties.[7] *Oxalis per-carpae* inhibits the vasopressor effects of norepinephrine.[14] *Oxalis dehradunensis* exhibits antioxidant and anti-aging activity.[28] *Oxalis latifolia* and *O. stritca* possess antioxidant activity. Research on the activities of *Oxalis* sp and their chemical composition can be seen in Table 1.

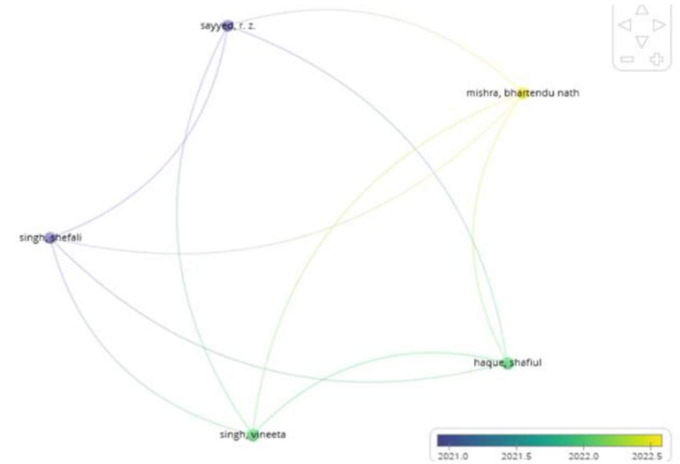

Figure 5. Keyword co-occurrence overlay with timeline

Table 1. Research results based on the article research

Types of Oxalis	Plant Parts	Extract	Analysis	Active Ingredient	Usability	Literature
O. corniculata	leaf	water, ethanol	soxhlet	-	antibacterial	Pawar, Mr. H. S. (2023).
O. corniculata	root, stem, leaf	-	-	alkaloids, steroids, flavonoids, tannins, saponins, phenolic compounds, reducing sugars, terpenoids, and cardiac glycosides [26]		B.D, Wagh., A.S, J., & Chavan, S. P. (2021).
O. corniculata	-	methanol	-	alkaloids, proteins, phenols, flavonoids, glycosides [6]	antioxidant, anti-inflammatory, anticancer, antimicrobial, analgesic, and diuretic	Pandey, K., & Pokhrel, S. (2022
O. corniculata	-	methanol		Flavonoids, terpenoids, coumarins, glycosides, as well as steroids and phytosteroids.	antioxidant	Tibuhwa, D. D. (2017
O. corniculata	-	ethanol	soxhlet,	carbohydrates, glycosides, flavonoids, phenols, tannins,	anthelmintic, astringent, diuretic,	Karunanithi,2016

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				essential oils, amino acids, and proteins	emmenagogue, antipyretic, cardiac	
O. corniculata	leaf	-	KCKT	carotenoid	antioxidant	Zeb, A., & Imran, M. (2019).
O. corniculata	-	methanol fraction	HPTLC	caffeic, vanillic acid, and syringic acid [30]		Gupta, 2018
O. corniculata	-	extract	GCMS	-	diabetes, antioxidants	Ansari *et al* 2024
O. corniculata	-	soxhlet	-		antioxidant	MS, N. (2021).
O. corniculata	-	-	-	flavonoids, tannins, ascorbate, and other essential oils	antibacterial, anti-inflammatory	Manohar MP, 2018
O. corniculata	leaf	ethanol fraction, methanol	spectrophotometry	flavonoid	antioxidant, anti-aging, antidiabetic, antipruritic	Baghel S. (2022). Feng, Q et al, (2024), Oku, H., Kitagawa, 2019
Types of Oxalis	**Plant Parts**	**Extract**	**Analysis**	**Active Ingredient**	**Usability**	**Literature**
O. corniculata	-	water extract	-	-	antioxidant, anti-inflammatory	Kim, J. H., Hong, 2022
O. corniculata	-	water extract	silver nanoparticles	-	antibacterial	Das *et al*, 2019
O pes-caprae	flower	methanol	-	flavanoid	antidiabetic, antioxidant	Fonsesca *et al* 2019 Kabach,2023
O pes-caprae	stem, leaf, flower	PE, CHCl3, ethyl acetate, ethanol, MeOH, and water	-	flavonoid, polyphenol	antibacterial	Halouani, A. 2021.
Oxalis corymbosa	-	methanol extract, ethyl	KCKT	chlorogenic acid as the main component, followed by gallic acid, caffeic acid, quercetin, and salicylic acid.	-	Attique, S,2024
Oxalis latifolia	-	leaf extract	UV-Vis, FTIR	-	anti-inflammatory, antidiabetic	Gopikrishnan, R, 2024
Oxalis latifolia	leaf	methanol	HPLC, GCMS	-	antioxidant	Krishnan, 2021
		ethyl acetate extract	TLC GCMS	phenolic (122.52 ± 4.27 GAE mg/100 mg), total flavonoids (91.86 ± 2.65 QE mg/100 mg), and alkaloids (82.18 ± 0.72 COLE mg/100 mg).	anticancer	Vignesh *et al*. 2024
O. stricta Linn	herb	methanol	-	oxalate, flavonoids, tannins, phenols, and glycosides	antioxidant	Dzinyela, R, 2021
Oxalis cernua	-	methanol extract	-	-	antioxidant, analgesic, anti-inflammatory, neuroprotective, antihypertensive	Belghoul *et al* ,2020
Oxalis tuberosa	bark	hexane, acetone, and ethanol	-	-	antioxidant	Güemes-Vera *et al*, 2019
Oxalis stricta L	-	ethanol	-	-	hepatoprotective, antioxidant [20]	Patel, S. A
O dehradunensis	-	ethanol	-	phenolic flavonoid	antioxidant, effervescent granules	Mayhano *et al*, 2024
O dehradunensis	-	ethanol	-	-	antioxidant	Mahyuni, E. L., & Harahap, U. 2024
O dehradunensis	leaf	ethanol	-	flavonoids, carbohydrates, phenols, and tannins.	analgesic	Khausik *et al*. 2025

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Table 1 shows that the compound content of *Oxalis* sp varies depending on the type of *Oxalis* species and the part of the plant used. The extraction methods and techniques for obtaining compounds also differ depending on polarity and the activity of the components to be studied, including HPLC, NMR, HPTLC, GCMS, TLC, while extraction methods include maceration, soxhletation, and fractionation. From previous studies, the major compounds that dominate the content of *Oxalis* sp are phenols and flavonoids, glycosides and terpenoids, although some studies mention carotenoids, caffeic acid, chlorogenic acid, apigenin, quercetin, orientin, and vitexin.

4. Analysis based on antioxidant activity

The use of antioxidants in skin care products is a good approach to reducing the damaging effects of free radicals and helping to maintain skin health. Previous studies on *Oxalis* species reported that the ethyl acetate extract of *Oxalis corniculata* demonstrated potential antioxidant activity in the DPPH radical scavenging assay, with IC_{50} values ranging from 28.62 to 48.53 µg/mL, whereas the methanol fraction exhibited the strongest DPPH and H_2O_2 radical scavenging activities with IC_{50} values of 23.43 ± 0.12 and 19.71 ± 0.16, respectively, through a mechanism of inhibiting the increased expression of matrix metalloproteinases (MMPs) associated with a decrease in dermal elasticity due to collagen degradation[5]. *Oxalis triangularis* ethanol extract showed higher DPPH (IC_{50} = 2.403 µg/ml) and ABTS (IC_{50} = 22.94 µg/ml) radical scavenging activity compared to water extract[35]. Meanwhile, *Oxalis Corymbosa* research has the highest antioxidant activity (IC_{50}) DPPH and FRAP, which are 0.07±0.00 mg/mL and 0.08±0.00 mg/ml[26]. *Oxalis dehradunensis* showed a higher total phenolic content (191.88 mg/g GAE) than flavonoid content (27.066 mg/g GAE), where the presence of phenols and flavonoids indicates that *Oxalis dehradunensis* R. leaf extract has antioxidant.[27]

5. Analysis based on formulation

Another study on the formulation of *Oxalis corniculata* water extract in cream formulations can be applied topically to prevent skin damage caused by *S. aureus* and *E. coli*[19], also showed the inhibitory effects of *Oxalis corniculata* methanol extract in cream form against *S. aureus* and *E. coli*. Another study found that methanol extracts of *Oxalis corniculata* L. and *Hypericum oblongifolium* leaves have strong wound-healing properties in gel form[36]. Research by Mahyuni et al. (2024) [29] states that effervescent granules of *Oxalis dehradunensis* extract have antioxidant activity. Acem-acem in the form of hand soap with concentrations of 5% and 7% in binding chlorpyrifos pesticide residue compounds was considered good. In 2024, Mahyuni stated that the formula with a 5% concentrate and 7% extract of *O. dehradunensis* provided more than 300% change in skin moisture, concealed pore size and pigmentation well, and reduced wrinkles in farmers who were constantly exposed to chemicals and free radicals, whereas the anti-aging cream made from leaf extract showed more significant changes in skin moisture and pigmentation.

CONCLUSION

Oxalis sp has shown various health benefits. This study is the first bibliometric analysis of the potential of *Oxalis* sp and its phytochemical study. The number of publications fluctuated between 2015 and 2025. This analysis identified that the most extensively explored species within the *Oxalis* genus is *Oxalis corniculata*, particularly regarding extraction, NMR methods, and isolation. However, research on formulations, cosmetics, active compounds, and phytochemical analysis related to other *Oxalis* species remains limited. Several suggestions for further research based on this bibliometric study include determining consistent therapeutic doses based on pharmacokinetic profiles and long-term safety studies. Additionally, exploring innovative formulation technologies, such as nanoparticle-based delivery systems, is recommended to optimize the application of *Oxalis* sp as an antioxidant.

Conflict of Interest

The author declares that there is no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that all responsibility for claims related to the content of this article lies with the authors.

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