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Medicinal Chemistry Review Of Bioactive Compounds In *Moringa Leaves (Moringa Oleifera)* As Natural Antioxidants

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Abstract

Moringa oleifera leaves are widely used in the health sector due to their rich content of bioactive compounds with potential as natural antioxidants. Secondary metabolites such as flavonoids, polyphenols, alkaloids, tannins, saponins, steroids, and triterpenoids play an important role in scavenging free radicals and protecting cells from oxidative damage. This article aims to review the potential of bioactive compounds in Moringa oleifera leaves as antioxidants from a medicinal chemistry perspective. The study was conducted using a literature review method by analyzing national and international scientific articles published between 2020 and 2026 from Google Scholar, PubMed, and ScienceDirect databases. The findings indicate that the antioxidant activity of Moringa oleifera leaves is mainly influenced by flavonoids and phenolic compounds. In addition, extraction methods, drying processes, fermentation, and formulation techniques also affect the effectiveness of antioxidant activity. Several studies further report that Moringa oleifera leaves have strong potential to be developed into pharmaceutical preparations and health products due to the stability of their active compounds. Overall, Moringa oleifera leaves represent a promising natural antioxidant source for further development in the field of pharmaceutical science based on natural products.

Keywords: ***Moringa Oleifera, Antioxidants, Medicinal Chemistry.***

INTRODUCTION

The use of natural ingredients as sources of active compounds in the health sector continues to grow. This growth is driven by the widespread use of herbal plants, which is based on the public's perception that natural ingredients tend to have fewer side effects than synthetic compounds. Indonesia, as a country with a high level of biodiversity, has various types of plants with the potential for development in the pharmaceutical industry, including as a source of natural antioxidants. These various plants are known to contain secondary metabolites such as flavonoids, alkaloids, tannins, saponins, and phenolic compounds that have biological activity and have the potential for further development as basic ingredients for health products and herbal medicines (Amin & Guspiana, 2025).

Antioxidants are compounds that play a crucial role in protecting the body from the negative effects of free radicals. Excessive amounts of free radicals can trigger oxidative stress, a condition where the balance between free radical production and the body's ability to neutralize them is disrupted. This can cause damage to various cellular components, such as lipids, proteins, and DNA. This damage is known to be associated with various degenerative diseases, including cancer, diabetes mellitus, cardiovascular disorders, and accelerated aging. Therefore, antioxidants are essential to help maintain the balance of the body's biological systems. Currently, the use of antioxidants derived from natural ingredients is increasingly being developed because they are considered safer for long-term use than synthetic antioxidants (Auliya & Amin, 2025).

One plant that has received considerable attention in natural product research is the *Moringa oleifera*. This plant is widely known for its diverse bioactive compounds with potential health benefits. Moringa leaves are known to contain various secondary metabolites, such as flavonoids, alkaloids, tannins, saponins, and phenolic compounds, which act as natural antioxidants. These compounds play a role in helping neutralize free radicals, thereby minimizing oxidative damage to cells (Manurung et al., 2023)Furthermore, moringa is a plant readily available in Indonesia and has long been used traditionally by local communities. This indicates that moringa has significant potential for further development as a raw material for pharmaceutical and health products.

In the field of medicinal chemistry, bioactive compounds derived from herbal plants are a primary focus of study due to their potential for development as potential therapeutic agents. A medicinal chemistry approach is used to analyze the relationship between compound content and the resulting biological activity. Through this approach, the active compounds found in Moringa leaves can be further studied for their potential as natural antioxidants and their potential development in pharmaceutical applications (Amin & Fernanda, 2025).

Numerous studies have reported that secondary metabolites found in plants possess a variety of beneficial biological activities, such as anti-inflammatory, antimicrobial, anticancer, and antioxidant properties. These diverse activities make herbal plants a highly potential source of natural ingredients for continued development in the health sector.(Amin & Guspiana, 2025)Based on this description, moringa leaves are an interesting plant to study further, particularly regarding their bioactive compounds and potential as a natural antioxidant from a medicinal chemistry perspective.

Accordingly, this review article aims to examine the bioactive compounds in *Moringa oleifera* leaves and their potential as natural antioxidants through a medicinal chemistry approach. Furthermore, this article discusses the biological activities of these bioactive compounds and their potential development in the pharmaceutical and health sectors.

RESEARCH METHODS

The method used in compiling this article is a literature review, which involves collecting and reviewing various sources related to the bioactive compounds of *Moringa oleifera* leaves and their potential as natural antioxidants in medicinal chemistry. This method was chosen because it provides a broader overview of existing research developments and helps identify research findings relevant to the topic. The review process involves reviewing, comparing, and evaluating various findings from scientific journals to obtain more focused information and support a comprehensive discussion.

A literature search was conducted through several scientific databases, namely Google Scholar, PubMed, and ScienceDirect. The search was conducted using a combination of keywords such as "*Moringa oleifera*," "moringa leaves," "bioactive compounds," "natural antioxidants," and "medicinal chemistry" in both Indonesian and English to broaden the scope of sources. The literature used included research articles and review articles published between 2020 and 2026, with clear access, and relevance to the topic under study. The selection process was carried out in stages, assessing the suitability of the title, abstract, and content of the articles, ensuring that only truly appropriate and high-quality sources were used in the analysis.

Data obtained from various literature sources were then analyzed descriptively by grouping and comparing research findings related to the bioactive compounds in moringa leaves, their antioxidant activity, and their mechanisms of action in counteracting free radicals. Furthermore, their potential uses in the pharmaceutical and healthcare sectors were analyzed, providing an overview of opportunities for further development. The analysis results were then systematically organized for ease of understanding and a clear discussion flow.

The literature selection process in this study follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) process to ensure that each selection stage is conducted systematically and transparently, from identification and screening to determining which articles to use. This process is presented in diagram form in Figure 1 as part of the research methodology..

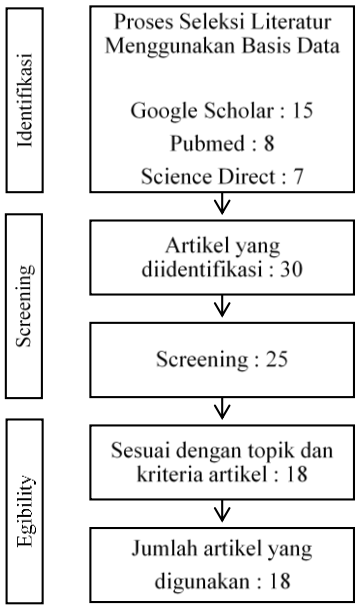

Figure 1. Prisma Flowchart of Literature Search

RESULTS AND DISCUSSION

Table1. Literature Identification Results

Writer	Title	Results
(Manurung et al., 2023)	Formulation and Evaluation of *Moringa oleifera* L. Leaf Antioxidants in Serum Preparations Using the DPPH Radical Compound Method	Moringa leaves contain bioactive compounds such as flavonoids, alkaloids, tannins, and saponins, which act as natural antioxidants. Tests showed that serums with 6% and 8% extract concentrations had strong antioxidant activity, with IC_{50} values of 83.33 ppm and 65.10 ppm, respectively. All formulas also met physical quality parameters, with the 2% concentration being the panelists' most preferred.
(Sakhi et al., 2025)	Antioxidant Activity Test of Moringa Leaf Extract (*Moringa oleifera* Lamk.) in Edible Oil.	EVOO proved more effective in extracting moringa leaf flavonoids than VCO, with the best antioxidant activity (EC_{50} 106.848 ppm) under optimal conditions of 0.4 mL Tween 80 addition and 4 hours of extraction time. This is influenced by the higher oleic acid content in EVOO, making it more capable of attracting relatively polar bioactive compounds.
(Samodra et al., 2023)	Antioxidant Activity Test of Ethanol Extract of a Combination of Cherry Leaves (*Muntingia calabura* L.) and Moringa Leaves (*Moringa oleifera* L.)	A single extract of moringa leaves exhibited strong antioxidant activity with an IC_{50} value of 68.40 ppm. However, its effectiveness increased synergistically when combined with cherry leaves (a 2:1 ratio), resulting in a very strong IC_{50} value of 6.35 ppm. This increase is influenced by the flavonoid and

		polyphenol content, which work together to ward off free radicals.
(Ansory et al., 2023)	Increasing Antioxidant Activity in Moringa (*Moringa oleifera*) Leaf Extract through Fermentation	The fermentation process using Lactobacillus bulgaricus for 72 hours was shown to increase total phenolic content to 122.578 mgGAE/gram. This increase was in line with enhanced antioxidant activity, with an IC_{50} value reaching 53.169 µg/ml, which is considered very strong compared to the pre-fermentation level.
(Paramita, 2023)	The Effect of Drying Methods on Vitamin C Content and Antioxidant Activity of Moringa (*Moringa oleifera*) Leaves	Various drying methods were able to maintain the antioxidant activity of moringa leaves in the strong category (IC_{50} 45.79–60.10 µg/ml). Interestingly, the use of high temperatures (50–60°C) actually increased the potential to become very strong due to the formation of Maillard reaction products, although on the other hand, it caused a significant decrease in vitamin C, up to more than tenfold compared to fresh leaves.
(Priyanto et al., 2023)	Antioxidant Activity of Moringa (*Moringa oleifera*) Leaves in Alloxan-Induced Diabetic Rats	Moringa leaf extract has been shown to effectively suppress oxidative stress, as demonstrated by a decrease in MDA levels from 9.77 to 2.70 mmol/ml and a 62.37% increase in SOD enzyme activity at a dose of 600 mg/kgBW. This effect is attributed to its flavonoid content, which acts as a free radical scavenger and helps improve insulin receptor function in hyperglycemic conditions.
(Hanifah et al., 2024)	Antioxidant Activity Test of Ethanol Extract Facial Serum Preparation of Moringa (*Moringa oleifera* Lam.) Leaves Using the DPPH Method	The serum formulation with a 4% extract concentration (F2) demonstrated the most optimal antioxidant activity, with an IC_{50} value of 40.24 µg/ml, which is considered very strong. This activity is influenced by the flavonoid content, which plays a crucial role in neutralizing free radicals and helping maintain the stability of the preparation during storage.
(Hidayat et al., 2025)	Development of *Moringa oleifera* Leaf Extract Nanoemulsion as an Antioxidant, Antibacterial and Anti-Wound Agent	Moringa leaf extract is known to contain various bioactive compounds, such as flavonoids, alkaloids, tannins, steroids, and triterpenoids, which have strong antioxidant activity. The use of a nanoemulsion formulation can help maintain the stability of the active compounds while increasing the effectiveness of their delivery.
(Lubis et al., 2026)	Characterization of Simplex, Phytochemical Screening, and	Ethanol extract of moringa leaves is known to contain flavonoids, alkaloids, tannins, saponins, and steroids, which act

	Antioxidant Activity Test of Ethanol Extract of Moringa Leaves (*Moringa oleifera* L.)	as natural antioxidants. Test results indicate moderate antioxidant activity, making it potentially useful as a free radical scavenger.
(Nurwanti et al., 2023)	Comparison of Alpha-tocopherol Levels of Moringa (*Moringa oleifera* L.) Leaves as Antioxidants in Coastal and Mountainous Areas	Moringa leaves are known to contain α-tocopherol (vitamin E), which acts as a natural antioxidant. Furthermore, differences in growing conditions or location can affect the levels of secondary metabolites and the antioxidant activity produced by Moringa leaves.
(Chiș et al., 2024)	Bioactive Compounds in *Moringa oleifera*: Mechanisms of Action, Focus on Their Anti-Inflammatory Properties	Moringa leaves are rich in polyphenols and flavonoids, particularly quercetin and kaempferol, with a total phenolic content of approximately 2,000–12,200 mg GAE/100 g. Medicinally, these compounds act as natural antioxidants by neutralizing free radicals and activating the NRF2 pathway, thereby reducing oxidative stress such as hydrogen peroxide and malondialdehyde (MDA).
(Nugraha et al., 2023)	Phytochemical, antioxidant, and antibacterial activity of *Moringa oleifera* nanosuspension against peri-implantitis bacteria: An in vitro study	Moringa leaf extract nanosuspension demonstrated strong antioxidant activity (EC50 64.38 µg) through DPPH assay. This activity is supported by bioactive compounds such as flavonoids, tannins, and vitamin C and E derivatives, which play a role in neutralizing free radicals and inhibiting inflammatory pathways.
(Soto et al., 2025)	Biological properties of *Moringa oleifera*: A systematic review of the last decade	Analysis shows that the bioactive compounds of Moringa leaves, especially polyphenols such as quercetin and kaempferol as well as vitamins C and E, have strong antioxidant activity in neutralizing free radicals and protecting cells from oxidative stress.
(Sowunmi & Gonzo, 2023)	The effect of *Moringa oleifera* crude extract on liver cell line, HepG2	*Moringa oleifera* extract is rich in phenolic compounds that act as natural antioxidants in protecting liver cells (HepG2). The methanol extract exhibits a higher and more stable antioxidant capacity (TAC) than ethanol and is effective in reducing the AST enzyme by protecting against oxidative stress.
(El-Sherbiny et al., 2024)	Antibacterial, antioxidant, cytotoxicity, and phytochemical screening of *Moringa oleifera* leaves	HPLC analysis showed that Moringa leaf extract is rich in phenolic compounds (15 g/100 g) and flavonoids (11.46 g/100 g), with quercetin as the dominant component (38.23%). This compound plays a major role in its strong antioxidant activity (IC50 17.5 µg/ml DPPH and 16.4 µg/ml ABTS), and is supported by ADMET studies that show

		a good pharmacokinetic profile as a candidate natural therapeutic agent.
(Fachruddin et al., 2024)	Data on characteristics of simplicia, phytoconstituents, and antioxidant activity of *Moringa oleifera* leaves ethanol extract	Ethanol extract of Moringa leaves contains 39 phytoconstituents, dominated by quercetin-3 β-D-glucoside, apigetrin, and tannins. This extract has a total phenol content of 7728.02 mg/kg and exhibits quite strong antioxidant activity (IC50 1422.45 mg/kg), making it a potential source of natural antioxidants.
(Rohit et al., 2025)	TOPSIS based comprehensive evaluation of the effect of drying methods on polyphenolic contents and associated antioxidant activities of *Moringa oleifera* leaves	The shade drying method (air drying) was the best at maintaining the stability of phenolic compounds (9.88 mg GAE/g) and antioxidant activity (67–70%). Compounds such as neochlorogenic acid and flavonoids, including quercetin, are the main components that play an important role in counteracting free radicals.
(Wang et al., 2024)	In vitro antioxidant activity of *Moringa oleifera* lam. Leaf after Monascus purpureus fermentation and chemical component changes by untargeted metabolomics	Fermentation with Monascus purpureus has been shown to significantly increase the antioxidant activity of Moringa leaves. This process enriches bioactive compounds such as melatonin, kynurenine, and 3-hydroxyanthranilic acid through the tryptophan metabolic pathway. These fermented compounds not only ward off free radicals but also protect liver cells (HepG2) from oxidative damage.

Various studies have shown that *Moringa oleifera* leaves have strong potential as a natural antioxidant source. This potential is related to their complex bioactive compounds, including flavonoids, polyphenols, alkaloids, tannins, saponins, and antioxidant vitamins such as α-tocopherol. This diversity of components allows Moringa leaves to not only act as free radical scavengers but also help maintain the balance of the body's oxidative system. Therefore, their use is not limited to prevention but also has the potential to support cell protection from damage caused by oxidative stress (Manurung et al., 2023; Lubis et al., 2026).

Flavonoids and polyphenols are the most dominant groups of compounds contributing to this activity. Compounds such as quercetin and kaempferol are known to donate electrons or hydrogen atoms to stabilize free radicals. Furthermore, they are also involved in more complex mechanisms, such as activating cellular defense pathways that play a role in controlling the formation of reactive oxygen species. With this multi-layered mechanism of action, the resulting antioxidant activity is not only immediate but also capable of providing more sustained protection (Chiș et al., 2024; Soto et al., 2025).

Based on reported IC_{50} values, the antioxidant activity of moringa leaves varies from moderate to very strong. This difference is generally influenced by the extraction method, solvent type, and treatment of the ingredients. While a single extract of moringa leaves has generally demonstrated quite good activity, more significant improvements can be achieved through combination with other ingredients. This combination allows for a synergistic effect between bioactive compounds, resulting in a more optimal free radical neutralization ability compared to either single extract (Samodra et al., 2023).

In addition to the composition of the ingredients, the processing method also significantly influences the resulting antioxidant activity. Fermentation is one method proven to improve the quality of moringa leaf extract. This process not only increases the levels of phenolic compounds but also forms new compounds with biological activity. These fermented compounds contribute to enhancing antioxidant activity while providing a protective effect on cells, particularly against oxidative stress (Ansory et al., 2023; Wang et al., 2024).

Drying methods also play a crucial role in determining the stability of active compounds. Under certain conditions, using higher temperatures can increase antioxidant activity due to the formation of specific reaction products, although on the other hand, it can also reduce the content of heat-sensitive vitamins. Conversely, natural drying methods tend to be more effective in maintaining a balance between bioactive compound content and antioxidant activity, thus maintaining the quality of the product (Paramita, 2023; Rohit et al., 2025).

Differences in solvent type and extraction technique are also important factors. Solvent characteristics, particularly their polarity, significantly determine the types of compounds that can be extracted. Certain solvents have been reported to be more effective at extracting flavonoids than others, resulting in higher antioxidant activity. This suggests that selecting the right extraction method is crucial for optimizing the potential of Moringa leaves as an antioxidant source (Sakhi et al., 2025).

On the other hand, advances in formulation technology have contributed to increasing the effectiveness of moringa leaf utilization. The use of modern delivery systems such as nanoemulsions and nanosuspensions can enhance the stability of active compounds and improve their bioavailability. Smaller particle sizes allow active compounds to be more easily absorbed and distributed, resulting in optimal biological activity (Hidayat et al., 2025; Nugraha et al., 2023).

Furthermore, the antioxidant activity of moringa leaves has not only been proven through in vitro testing but also demonstrated significant effects in biological systems. Studies in laboratory animals have shown that administering moringa leaf extract can reduce levels of oxidative stress markers while increasing the activity of antioxidant enzymes in the body. These effects indicate that the active compounds in moringa leaves work not only chemically but also play a role in supporting the body's overall defense system (Priyanto et al., 2023).

Furthermore, protective effects were also observed at the cellular level, particularly in liver cells, indicating that moringa leaf extract can protect against damage caused by oxidative stress. This supports the hypothesis that moringa leaves have potential not only as a preventive agent but also as a therapeutic adjunct for conditions associated with free radical-induced cell damage (Sowunmi & Gonzo, 2023).

Overall, the antioxidant activity of moringa leaves is the result of the interaction of various factors, ranging from bioactive compound content, processing methods, to formulation techniques. Supported by consistent scientific findings, moringa leaves have very promising prospects for further development as an active ingredient in the pharmaceutical and health sectors, particularly in efforts to control oxidative stress and related diseases.

CONCLUSION

From various research results reviewed, it can be concluded that *Moringa oleifera* leaves have strong potential as a source of natural antioxidants. This activity is primarily influenced by the presence of bioactive compounds such as flavonoids and polyphenols, which play a role in counteracting free radicals and helping maintain the balance of the body's oxidative system. Reported antioxidant activity varies from moderate to very strong, influenced by extraction method, solvent type, and treatment of the material.

Furthermore, processing processes such as fermentation and drying also affect the quality of antioxidant activity, both by increasing the levels of active compounds and changing their chemical composition. Formulation development also shows that the effectiveness of bioactive compounds can be enhanced through appropriate technological approaches. Overall, moringa leaves have quite

promising prospects for development as a natural ingredient in the pharmaceutical and health sectors, particularly in efforts to control oxidative stress.

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