



## Review: Antioxidant Activity of Moringa Leaves (*Moringa oleifera*)

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### Keywords:

Moringa leaves  
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Free radicals;  
Antioxidants

**Abstract.** Free radicals are generated in the human body from normal metabolic processes. Apart from that, environmental factors such as UV, infrared and visible light, environmental pollution, including ozone and particulate matter and oxidative stress. The antioxidant system in the body is responsible for neutralizing or reducing the impact of free radicals in the body. If these free radicals exceed the body's antioxidant capacity, it will result in oxidative stress. There are many natural alternatives to ward off free radicals, one of which is Moringa leaves. Moringa leaves (*Moringa oleifera*) are found in many tropical regions, one of which is Indonesia, where they have high antioxidant activity. The method used is a literature study which is reviewed one by one, after which the journals obtained are collected and the information is compiled by summarizing the contents of the journals used as sources. This article focuses on reviewing antioxidant phytochemical compounds and the level of antioxidant activity contained in Moringa leaves. The antioxidant compounds that are abundant in Moringa leaves are a group of flavonoid compounds, namely quercetin and kaempferol. The results showed that the highest antioxidant activity.

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### 1. Introduction

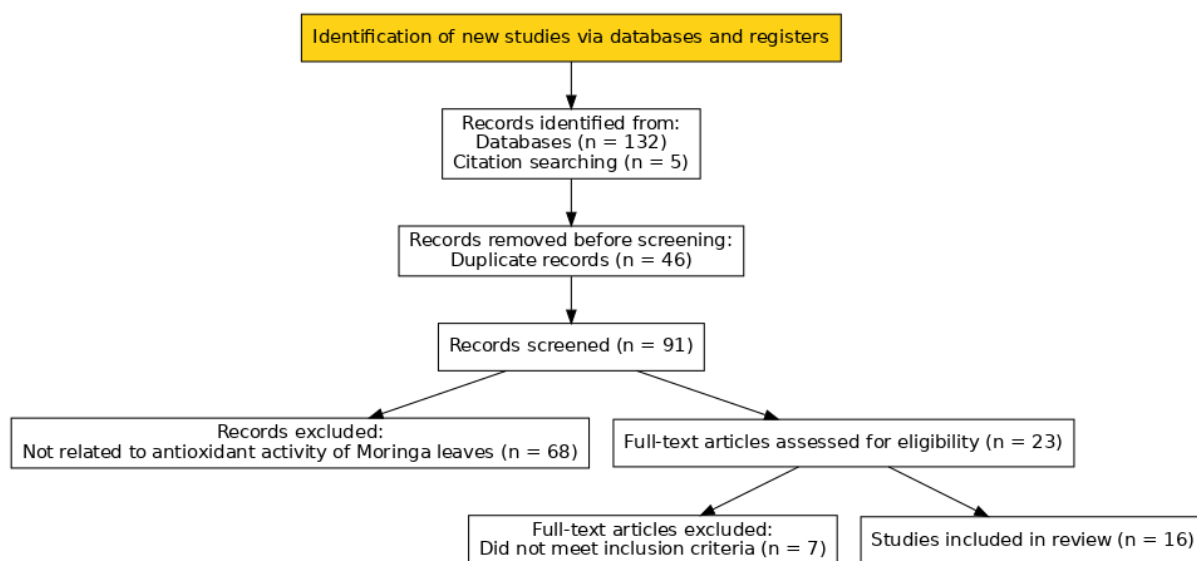
Currently, human exposure to free radicals is extremely high due to various factors such as ultraviolet (UV) rays, infrared and visible light, environmental pollution including ozone and particulate matter, as well as psychological stress (Odinga et al., 2020). In addition, free radicals are also produced as by-products of normal metabolic processes in the body. Increased exposure to free radicals can elevate the risk of various diseases. Oxidation reactions occur when highly reactive free radicals interact with components of the body (Nwozo et al., 2023; Ionita, 2021). Therefore, antioxidants are essential in preventing cellular damage and inhibiting these oxidative reactions. Maintaining an effective balance between oxidation and antioxidant activity is crucial for preserving cellular function, DNA integrity, and gene expression signaling (Nwozo et al., 2023).

Indonesia is rich in medicinal plants that contain high levels of antioxidants, one of which is *Moringa oleifera*, commonly known as the moringa or “miracle tree.” This highly nutritious plant is characterized by rapid growth, drought resistance (Devkota & Bhusal, 2020), and has been proven to possess potent natural antioxidant properties (Rajbhar et al., 2018). The species is widely used across various industries, including pharmaceuticals, food, and cosmetics. Its leaves, bark, seeds, and flowers are valuable sources of antioxidant compounds essential for human health (Iqbal et al., 2021). Phytochemical studies on moringa leaves have demonstrated strong antioxidant activity against free radicals, highlighting their high nutritional value (Khalid et al., 2023).

Based on this background, the present review focuses on examining the antioxidant activity of *Moringa oleifera* leaves. This study summarizes and discusses relevant scientific literature that explores the antioxidant potential of moringa leaves, providing insights derived from previous research findings.

## 2. The Methods

This study employed a literature review method based on the preferred reporting items for systematic reviews and meta-analyses (PRISMA) model as shown in Figure 1 with research questions summarized in Table 1. The literature analyzed consisted of scientific journal articles published within the last ten years, focusing on the topic of antioxidant compounds in *Moringa oleifera* leaves.



**Figure 1.** PRISMA flow diagram of literature screening of *Moringa oleifera*.

**Table 1.** Key research questions

ID	Research question	Motivation
RQ1	What antioxidant compounds have been identified in <i>Moringa oleifera</i> leaves?	Identifying antioxidant compounds in <i>Moringa</i> leaves is essential to understand their potential health benefits.
RQ2	What is the relationship between the extraction method used and the antioxidant activity value (IC <sub>50</sub> ) obtained from <i>Moringa</i> leaf extracts?	Understanding the influence of extraction methods on antioxidant activity helps determine the most effective technique to maximize the potential of antioxidant compounds in <i>Moringa</i> leaves.

Data were collected from Google Scholar, Elsevier, and Taylor & Francis databases using the following keywords: free radicals, antioxidants, free radical mechanisms, antioxidant compounds, and antioxidant activity tests in *Moringa oleifera* leaves.

The initial search identified 132 articles from the databases, along with five additional articles obtained through citation tracking. After removing duplicates, 91 unique publications remained for further analysis. Of these, 68 articles were excluded because they did not specifically discuss the antioxidant activity of Moringa leaves. The remaining 23 articles underwent a full-text review, after which 7 articles were excluded for not meeting the inclusion criteria. Consequently, 16 articles met all eligibility requirements and were included in this systematic literature review.

### 3. Result and Discussion

#### 3.1 Free radicals

During normal biological oxidation processes that occur within human cells or tissues, reactive oxygen species (ROS)—also known as free radicals—are formed (Vidya et al., 2022). These reactive oxygen molecules are primarily generated during cellular metabolism involving oxidase enzymes, such as hydrogen peroxide ( $H_2O_2$ ), superoxide ion ( $O_2^-$ ), peroxy radical ( $OOH\bullet$ ), and singlet oxygen ( $^1O_2$ ) (Yuslianti, 2018).

Free radicals are molecules that contain one or more unpaired electrons and have the ability to exist independently (Suryadinata, 2019). Oxidation is an integral component of aerobic life processes—it involves the transfer of electrons or hydrogen atoms during chemical reactions from one substance to another, leading to the formation of free radicals. These radicals are highly reactive and can initiate a chain of reactions that damage cellular components (Nwozo et al., 2023).

Excessive formation of free radicals that exceeds the body's antioxidant capacity results in oxidative stress (Suryadinata, 2019). Oxidative stress arises from an imbalance between the production of reactive oxygen species and the body's ability to neutralize their harmful effects. This condition may lead to slowed growth, increased susceptibility to disease, and impaired system performance (Shastak et al., 2023). Oxidative damage has been linked to premature aging (Christophe & Duangjai, 2020), neurodegenerative disorders (Konovalova et al., 2019), metabolic dysfunctions (Niedzielska et al., 2016), and the development of various chronic diseases including diabetes mellitus (Ganjifrockwala et al., 2017), inflammatory disorders (Pouvreau et al., 2018), cardiovascular diseases (Yang et al., 2019), cancer (Arfin et al., 2021), and chronic obstructive pulmonary disease (Xiaoqin et al., 2017).

#### 3.2 Antioxidants

Antioxidants are essential compounds that protect the human body from cellular damage caused by free radicals (Saleem et al., 2020; Nurulita et al., 2019). They function by neutralizing free radicals, maintaining the redox balance, and supporting long-term health. Antioxidants are found abundantly in foods such as fruits, vegetables, green tea, and dietary supplements (Benzie & Choi, 2014). A diet rich in antioxidant-containing foods helps maintain health and prevents chronic diseases (Nwozo et al., 2023).

The body naturally produces endogenous antioxidants to limit the spread of free radicals (Senja et al., 2023). These antioxidants play a crucial role in preventing aging and degenerative diseases by counteracting reactive oxygen species (ROS) formed through oxidative metabolism and biochemical reactions (Britany & Sumarni, 2020). The formation of ROS is a major factor in cellular damage, and their levels are regulated by both enzymatic and non-enzymatic antioxidant systems (Andarina & Djauhari, 2017). To enhance this natural defense, exogenous antioxidants from food sources are needed to help neutralize free radicals (Irianti et al., 2017).

Fruits and vegetables are among the richest natural sources of antioxidants. They provide water, nutrients, vitamins, and diverse antioxidant compounds, including beta-carotene, vitamins C and E, flavonoids, lycopene, lutein, selenium, manganese, zinc, resveratrol, pycnogenol, and catechins (Gusti Made Aman, 2017). Important antioxidant groups include polyphenols (flavonoids, anthocyanins, catechins, resveratrol) and carotenoids, such as beta-carotene (found in green vegetables, carrots, mangoes, papayas, and sweet potatoes), lutein (in leafy greens and egg yolks), cryptoxanthin (in oranges), zeaxanthin (in corn), and lycopene (in tomatoes and watermelon).

### 3.3 Methods for testing antioxidant activity in Moringa leaves

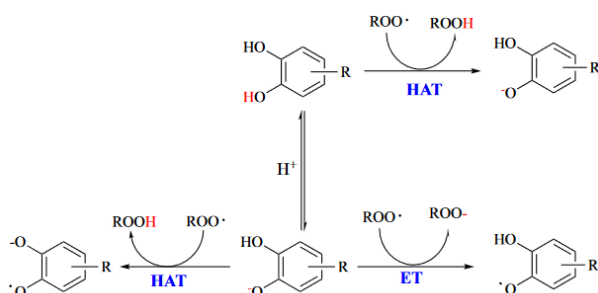
Several methods are commonly used to evaluate antioxidant activity, including BCB (Beta-Carotene Bleaching), DPPH (2,2-diphenyl-1-picrylhydrazyl), FRAP (Ferric Reducing Antioxidant Power), ABTS (2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)), and maceration extraction.

- BCB method measures the ability of antioxidants to protect  $\beta$ -carotene from oxidation by free radicals, where color reduction indicates antioxidant activity (Nurulita et al., 2019).
- FRAP method evaluates the ability of a compound to reduce  $\text{Fe}^{3+}$  (ferric ion) to  $\text{Fe}^{2+}$  (ferrous ion), observed through color change or absorbance variation (Maryam et al., 2016).
- ABTS method assesses the reduction of oxidized ABTS radicals by antioxidant compounds, indicated by color changes (Fitriana et al., 2015).
- Maceration involves soaking plant material in solvents to extract bioactive antioxidant compounds (Susanty et al., 2019).
- DPPH method measures a sample's ability to reduce purple-colored DPPH radicals; the decrease in color intensity reflects antioxidant strength (Fitriana et al., 2015).

These methods have been applied across diverse samples—including meat (Liu et al., 2019), flowers (Alam et al., 2017), fruits (Li et al., 2022), vegetables (Sami & Rahimah, 2015), and mushroom extracts (Deveci et al., 2018)—to assess antioxidant capacity against free radicals and oxidative agents.

### 3.4 Mechanism of antioxidants in neutralizing free radicals

The antioxidant mechanism is a vital biochemical process for maintaining human health. When the body is exposed to free radicals—due to pollution, radiation, or normal metabolism—antioxidants act as protective agents by terminating free radical chain reactions that damage cells (see Figure 2). Antioxidants such as vitamin C, vitamin E, and glutathione stabilize free radicals by donating electrons or chemically interacting with them (Gulcin et al., 2020).



**Figure 2.** Mechanism of antioxidants in neutralizing free radicals (Gulcin, 2020).

Through this mechanism, antioxidants prevent oxidative damage to DNA, lipids, and cellular proteins (Andarina & Djauhari, 2017). This defense system is crucial in preventing various diseases, including cancer, cardiovascular disorders (Santosa & Baharuddin, 2020), and premature aging (Zalukhu et al., 2016). Understanding antioxidant mechanisms is therefore essential for promoting health and disease prevention (Khalid Abbas et al., 2018).

One medicinal plant known for its strong antioxidant properties is *Moringa oleifera*. Moringa leaves contain  $\beta$ -sitosterol (Tjong et al., 2021), phenolic compounds (Marhaeni, 2021),  $\beta$ -carotene (Satriyani, 2021), and flavonoids, which are associated with antioxidant activity. Ethanolic extracts of Moringa leaves have demonstrated hepatoprotective and antioxidant effects (Nawir et al., 2021; Abasa & Ishak, 2022). Moringa is reported to contain 46 potent antioxidants capable of protecting the body from free radical damage (Senja et al., 2023).



Figure 3. Photograph of Moringa tree in India (Patel et al., 2014)

### 3.5 Antioxidant compounds in Moringa leaves

Table 2. Antioxidant compounds identified from *Moringa oleifera* leaves using various extraction methods

No.	Extraction Method	Identified antioxidant compounds	Structure	Ref.
1.	Dried leaves extracted with 90% ethanol (HPLC-UV/ESI-MS/MS)	Kaempferol, Quercetin	<p>Quercetin      Kaempferol</p>	(Xu et al., 2021)
2.	Dried leaf ethanol extract (HPLC)	Isoquercetin		(Vongsak et al., 2014)
3.	Methanol extract of Moringa leaves	Quercetin, Kaempferol glycoside	<p>Quercetin      Kaempferol</p>	(Leone et al., 2015)
4.	Methanol extract of Moringa leaves	4-[(2'-O-acetyl- $\alpha$ -L-rhamnosyloxy) benzyl] glucosinolate	<p>R<sub>1</sub>      R<sub>2</sub>      R<sub>3</sub></p> <p>Ac      H      H</p>	(Tumer et al., 2015)
5.	Moringa leaf powder extracted with 80% acetone (HPLC)	Gallic acid		(Feitosa et al., 2020)
6.	Ethanol extract of Moringa leaves	Kaempferol-acetyl-glycoside	<p>8: R<sub>1</sub>=F 11: R<sub>1</sub>= 12: R<sub>1</sub>= 17: R<sub>1</sub>=OH, R<sub>2</sub>=H, R<sub>3</sub>=Ac</p>	(Yong-Bing et al., 2019)

*Moringa oleifera* leaves are rich in a variety of bioactive compounds beneficial to human health and nutrition. These include vitamins, minerals, proteins, pigments, fibers (Khalid Abbas et al., 2018), and antioxidant constituents such as flavonoids, quercetin, kaempferol (Dessalegn & Rupasinghe, 2021), tannins, saponins, cardiac glycosides, alkaloids, essential oils, and saponin glycosides (Gulcin et al., 2020).

Moringa leaves are particularly abundant in essential vitamins (Khalid Abbas et al., 2018; Lenin et al., 2021), plant-based proteins (Trigo et al., 2023), and beta-carotene (Muteeb et al., 2023). These compounds possess strong antioxidant properties, protecting cells from free radical-induced damage (Saleem et al., 2020).

Due to their rich chemical composition, Moringa leaves are recognized as a highly nutritious food source with remarkable health benefits. Containing a comprehensive array of vitamins, minerals, proteins, pigments, and antioxidants, they represent a valuable functional food with significant potential for improving human nutrition and health (Peñalver et al., 2022; Natsir et al., 2019).

### **3.6 Antioxidant activity assay of *Moringa oleifera* leaves**

The antioxidant activity assay aims to determine the percentage of antioxidant compounds present in *Moringa oleifera* leaves. Commonly used analytical methods include DPPH, FRAP, ABTS, BCB, and maceration extraction techniques. The antioxidant potential of a compound is typically expressed as its IC<sub>50</sub> value—the concentration required to inhibit 50% of free radical activity. Specifically, an antioxidant compound is categorized as very strong if IC<sub>50</sub> < 50 µg/mL, strong if IC<sub>50</sub> ranges from 50–100 µg/mL, moderate if between 100–250 µg/mL, weak if between 250–500 µg/mL, and inactive if IC<sub>50</sub> > 500 µg/mL (Riskianto et al., 2021; Suriawati & Rachmawati, 2023; Muna, 2022). Table 2 summarizes the antioxidant activity of Moringa leaves evaluated using various methods and solvents.

A study by Fatmawati (2022) reported that Moringa leaves collected from Yogyakarta exhibited the highest antioxidant activity, whereas seeds showed the lowest, with roots having intermediate activity. Using DPPH and FRAP methods, the ethanolic leaf extract demonstrated an IC<sub>50</sub> value of 1.60 ± 0.03 mg/mL (Fatmawati et al., 2022). Similarly, Rizkayanti (2017) employed the DPPH method with UV-Vis spectrophotometry and found that the aqueous leaf extract had an IC<sub>50</sub> of 57.54 ppm, while the methanolic extract had a stronger activity with an IC<sub>50</sub> of 22.18 ppm (Rizkayanti et al., 2017).

Senja et al. (2023) investigated the antioxidant activity of Moringa leaf ethanol extract formulated into lotions at various concentrations. The IC<sub>50</sub> values ranged from 357.85 to 562.13 ppm, remaining below the positive control, indicating moderate antioxidant strength. Xu et al. (2019) analyzed Moringa leaves, roots, and seeds from Kenya using ABTS, FRAP, and DPPH assays with ethanol extracts. The results showed the highest antioxidant reduction in the FRAP assay, with an IC<sub>50</sub> value of 0.99 ± 0.06 mM (Yong-Bing et al., 2019).

In another study, Nurulita et al. (2019) employed the BCB (Beta-Carotene Bleaching) method to assess the antioxidant potential of Moringa leaf extracts, showing 5.53% collagenase inhibition, indicating potential anti-aging properties. Kurang (2020) evaluated Moringa leaf extracts using the DPPH method with ethyl acetate as the solvent, identifying the presence of flavonoids, terpenoids, and phenolics that exhibited strong antioxidant activity with an IC<sub>50</sub> value of 14.30 µg/mL.

Meigaria et al. (2016) conducted an antioxidant activity test on Moringa leaves collected from the Eka Karya Botanical Garden in Bedugul, Bali. The dried, ground leaves were extracted using maceration with acetone solvent, and the antioxidant activity was measured using a UV-Vis spectrophotometer. Similarly, Fachriyah et al. (2020) macerated 300 g of Moringa leaf powder in 96% ethanol to obtain a concentrated extract. The antioxidant activity, measured against quercetin as a standard, indicated moderate activity with an IC<sub>50</sub> value of 118.61 mg/L.

**Table 3.** Antioxidant activity (IC<sub>50</sub> values) of *Moringa oleifera* leaf extracts using various methods and solvents

No.	Method	Solvent	IC <sub>50</sub> Value	Key Findings	Ref.
1	DPPH, ABTS	Methanol, Dichloromethane	1.60 ± 0.03 mg/mL (DPPH); 1.02 ± 0.06 mg/mL (ABTS)	Methanol extract exhibited stronger radical scavenging ability than dichloromethane extract.	Suphachai (2014)
2	DPPH, FRAP	Ethanol	1.02 ± 0.13 mg/mL (DPPH); 0.99 ± 0.06 mM (FRAP)	Ethanol leaf extract showed high antioxidant capacity in both DPPH and FRAP assays.	Yong-Bing et al. (2019)
3	DPPH	Ethyl acetate	14.30 ppm	Ethyl acetate extract of scented <i>Moringa</i> leaves showed very strong antioxidant activity.	Kurang (2020)
4	DPPH	Ethanol	562.13 ppm; 491.58 ppm; 357.86 ppm	Ethanol extract formulated as lotion at 0.8%, 1.6%, and 2.4% showed weak antioxidant activity.	Senja et al. (2023)
5	BCB	70% Ethanol	10.45 mg GAE/g (total phenolics); 5.53% (flavonoids)	Extract contained 10.45 mg GAE/g phenolics and 5.53% flavonoids, indicating moderate antioxidant potential.	Nurulita et al. (2019)
6	Maceration	Ethanol	118.61 mg/L	Ethanol extract exhibited moderate antioxidant activity.	Fachriyah et al. (2020)
7	DPPH	Methanol	181.45 µg/mL (young leaves); 318.57 µg/mL (mature leaves)	Young <i>Moringa</i> leaves had higher antioxidant activity than mature leaves.	Salim & Eliyarti (2019)
8	DPPH	Water, Ethanol	57.54 ppm (water); 22.18 ppm (ethanol)	Ethanol extract showed stronger antioxidant activity than aqueous extract.	Rizkayanti et al. (2017)
9	DPPH	Ethanol, Ethyl acetate	23.14 ± 2.54 ppm (ethanol); 182.98 ± 2.89 ppm (ethyl acetate)	Ethanol extract exhibited much higher antioxidant potency than ethyl acetate fraction.	Fatmawati et al. (2022)
10	Maceration	Acetone	427.49 µg/mL	Acetone extract showed weak antioxidant activity and contained alkaloids, flavonoids, tannins, and steroids.	Meigaria et al. (2016)

Suphachai (2014) compared methanol and dichloromethane extracts of *Moringa* leaves using DPPH and ABTS assays, reporting IC<sub>50</sub> values of 1.60 ± 0.03 mg/mL and 1.02 ± 0.06 mg/mL, respectively. Meanwhile, Salim and Eliyarti (2019) examined young and mature *Moringa* leaves from Mukomuko, Bengkulu, revealing that young green leaves had stronger antioxidant activity with an IC<sub>50</sub> of 181.45 µg/mL, while mature leaves showed a weaker activity with an IC<sub>50</sub> of 318.57 µg/mL.

Overall, the antioxidant activity of *Moringa oleifera* varies depending on geographical origin, leaf maturity, extraction method, and type of solvent used. These variations highlight the importance of standardizing experimental conditions to accurately compare antioxidant capacities across different studies.

#### 4. Conclusion

Based on the literature review on antioxidant compounds in *Moringa oleifera* leaves, it can be concluded that the plant contains a variety of significant antioxidant compounds, particularly flavonoids such as quercetin and kaempferol, as well as other antioxidants like gallic acid and isoquercitrin. These findings indicate that *Moringa oleifera* leaves have strong potential as a natural source of antioxidants capable of protecting the body from free radical-induced damage. Moreover, research evidence shows that the extraction method has a significant effect on the antioxidant activity obtained. Among the various techniques, ethanolic extracts exhibited the highest antioxidant activity, with an  $IC_{50}$  value of  $0.99 \pm 0.06$  mM using the FRAP method. This underscores the importance of selecting an appropriate extraction method to maximize the antioxidant potential of *Moringa oleifera* leaves. Further studies are therefore recommended to explore the health benefits of these bioactive compounds and their potential applications in preventing diseases related to oxidative stress.

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