



Review Article

A Literature Review on Conventional vs. Non-Conventional Extraction Methods: Maximizing Phenolic and Flavonoid Yields from Moringa oleifera L. Leaves**Ninda Salsabila Azzahra^{1*}, Muhammad Ridwan Harahap¹**¹ Department of Chemistry, Faculty of Science and Technology, Universitas Islam Negeri Ar-Raniry, Banda Aceh, Aceh, Indonesia.* Corresponding author, tel: 081375926517, email: 230704008@student.ar-raniry.ac.id**ABSTRACT**

Moringa oleifera L., commonly known as moringa, is a plant rich in secondary metabolites, particularly phenolic and flavonoid compounds, which act as natural antioxidants. This study aimed to evaluate the effectiveness of conventional and non-conventional extraction methods in obtaining the bioactive compounds of Moringa oleifera leaves through a literature review approach. The study employed a descriptive qualitative method by analyzing 20 research articles published between 2016 and 2026. The results showed that Moringa oleifera leaves consistently contain phenolic and flavonoid compounds, although the profiles of other phytochemical constituents vary depending on the geographical origin of the plant, environmental conditions, and the extraction method used. In terms of extraction efficiency, Ultrasonic-Assisted Extraction (UAE) demonstrated higher efficiency than conventional methods, producing an extraction yield of up to 35.89% within 30 minutes. The use of 96% ethanol as the extraction solvent resulted in the highest Total Phenolic Content (TPC), reaching 3783.58 mg GAE/g. In addition, an extraction temperature of 50°C was found to be the optimum condition for maintaining flavonoid stability, whereas temperatures above 70°C may lead to the degradation of bioactive compounds. Based on the findings, the combination of Ultrasonic-Assisted Extraction (UAE), 96% ethanol as the extraction solvent, and an extraction temperature of 50°C represents the most effective condition for producing Moringa oleifera leaf extract with an optimal content of bioactive compounds.

Keywords: Extraction methods, flavonoids, Moringa oleifera L., phenolic compounds, Ultrasonic-Assisted Extraction (UAE)

1. INTRODUCTION

Moringa oleifera L., commonly known as moringa, is a plant widely recognized in many countries for its high nutritional value and diverse health benefits. Therefore, it is often referred to as the Miracle Tree (Farabi et al., 2023). In Indonesia, moringa grows well under various geographical conditions, both in lowland and highland areas, such as Wonosobo, Tasikmalaya, and North Lombok (Rianto et al., 2020). The utilization of moringa is also

extensive, ranging from functional food ingredients and dietary supplements to support breast milk production in lactating mothers to traditional medicine for helping manage various degenerative diseases (Musyaropah & Cahyanto, 2025).

The pharmacological potential of moringa leaves is attributed to their secondary metabolite content, particularly phenolic and flavonoid compounds (Farabi et al., 2023). These groups of compounds are known to function as natural antioxidants capable of scavenging free radicals and protecting body cells from oxidative stress-induced damage (Anggraini et al., 2024). In addition, the high flavonoid content in moringa leaf extract has been reported to exhibit anti-inflammatory activity through the inhibition of protein denaturation. Therefore, the stability and integrity of these bioactive compounds should be maintained during processing to preserve their biological activity (Anwar et al., 2024).

The identification of bioactive compounds in moringa leaves is generally carried out through phytochemical screening to determine the classes of secondary metabolites present. Based on findings from various studies, moringa leaves consistently contain a wide range of bioactive compounds, although their composition and concentration may vary depending on the geographical origin of the plant. Moringa leaf samples collected from North Sumatra were reported to contain flavonoids, saponins, tannins, and steroids (Yulia et al., 2022). Meanwhile, samples from Garut, West Java, were found to contain alkaloids, flavonoids, saponins, tannins, quinones, and steroids/triterpenoids (Najihudin et al., 2023). Similarly, moringa leaves collected from Bali were reported to contain alkaloids, flavonoids, tannins, and steroids (Meigaria et al., 2016). Differences in phytochemical composition are thought to be influenced by the plant's genetic characteristics as well as environmental factors, including geographical location, altitude, soil fertility, temperature, and pH. Consequently, the phytochemical characteristics of moringa leaves may vary depending on their geographical origin and growing conditions (Najihudin et al., 2023).

Extraction is an important step in obtaining secondary metabolites from plant tissues (Rifkia & Prabowo, 2020). One of the most commonly used extraction methods is maceration because it is relatively simple to perform and does not require high-temperature heating, thereby reducing the risk of thermal degradation of heat-sensitive compounds. However, this method has several limitations, including a relatively long extraction time and the need for large volumes of solvent to achieve optimum extraction efficiency (Susanty et al., 2019). In

contrast, heat-assisted extraction methods such as decoction can produce higher extraction yields within a shorter period. Nevertheless, prolonged exposure to high temperatures may alter or reduce the concentration of bioactive compounds present in the plant material (Anggraini et al., 2024).

As an optimization strategy, non-conventional extraction methods such as Ultrasonic-Assisted Extraction (UAE), also known as sonication, have been increasingly developed because of their higher extraction efficiency. Ultrasonic waves disrupt plant cell walls through the cavitation phenomenon, thereby accelerating the diffusion of metabolites into the solvent within only 10–30 minutes (Rifkia & Prabowo, 2020). However, the effectiveness of this modern extraction method largely depends on physical parameters, such as the solid-to-solvent ratio and extraction temperature. Previous studies have shown that temperatures above 70°C may cause significant degradation of flavonoid compounds, whereas a moderate extraction temperature of approximately 50°C is generally considered more suitable for maintaining the chemical stability of these metabolites (Rifkia & Prabowo, 2020).

Although various extraction methods for *Moringa oleifera* leaves have been widely studied, comparative evaluations regarding the balance between extraction yield, bioactive compound stability, and time-energy efficiency remain limited. Extraction selection should not focus solely on yield, but also on preserving thermolabile compounds such as flavonoids. Therefore, identifying extraction techniques that maximize yields without degrading active constituents is essential. This review compares the Total Phenolic Content (TPC) and Total Flavonoid Content (TFC) obtained via conventional and non-conventional extraction methods (Razak & Indah, 2026). The analysis evaluates the influence of extraction techniques and process conditions on compound recovery to identify optimal parameters for producing stable, high-potency extracts to support the future standardization of moringa-based health products.

2. RESEARCH METHODOLOGY

This study employed a literature review approach to comparatively evaluate the effectiveness of conventional and non-conventional extraction methods in terms of the recovery and stability of phenolic and flavonoid compounds from moringa leaves (*Moringa oleifera* L.).

2.1 Literature Search Strategy and Selection Criteria

A systematic literature search was conducted using Google Scholar for publications from 2016 to 2026, using the keywords *Moringa oleifera*, extraction, phenolics, flavonoids, and Ultrasonic-Assisted Extraction (UAE). Eligible studies were primary research articles in Indonesian or English investigating *Moringa oleifera* L. leaf extraction and reporting detailed extraction parameters and TPC or TFC data. Reviews, books, patents, studies on non-leaf organs, and articles with insufficient extraction data were excluded. A total of 20 articles met the selection criteria and were included in the primary dataset.

2.2 Data Extraction and Analytical Modeling

All data from the 20 selected scientific articles were transcribed into a structured matrix. The extracted parameters were categorized into independent variables, consisting of operational extraction parameters (solvent type, temperature, and extraction duration), and dependent variables, comprising quantitative responses (extraction yield percentage, Total Phenolic Content (TPC), and Total Flavonoid Content (TFC)). The categorized data were subsequently analyzed using a descriptive-comparative approach to evaluate the relationship between operational variables and extraction yield efficiency, as well as to assess the stability of flavonoid compound structures.

3. RESULTS AND DISCUSSION

3.1. Bioactive Compound Profile of *Moringa oleifera* Leaves

The bioactive compound profile of *Moringa oleifera* leaves is generally determined through phytochemical screening, which aims to identify the classes of secondary metabolites present in plant tissues. Based on various studies, *Moringa oleifera* leaves have been reported to contain a wide range of secondary metabolites, including alkaloids, flavonoids, saponins, tannins, steroids, triterpenoids, and quinones, although their composition may vary depending on the geographical origin of the plant (Anwar et al., 2024). A study conducted on samples from North Sumatra reported that the ethanolic extract of *Moringa oleifera* leaves contained flavonoids, saponins, tannins, and steroids, whereas alkaloids were detected only in samples collected from Raja Maligas Village (Yulia, Idris, & Rahmadina, 2022). Meanwhile, a study on *Moringa oleifera* leaves from Buleleng, Bali, using acetone as the extraction solvent,

identified alkaloids, flavonoids, tannins, and steroids, whereas saponins were not detected (Meigaria, Mudianta, & Martiningsih, 2016).

Differences in phytochemical profiles were also observed in *Moringa oleifera* leaf samples collected from Garut, West Java, which contained alkaloids, flavonoids, saponins, tannins, quinones, and steroids/triterpenoids in the dried plant material (Najihudin et al., 2023). However, after extraction with ethanol, saponins and steroids/triterpenoids were no longer detected. These findings indicate that the extraction process may affect the stability of certain secondary metabolites, potentially leading to structural changes or degradation of bioactive compounds. In addition, variations in phytochemical profiles are influenced by environmental factors, including geographical location, altitude, soil pH, and growth temperature. Therefore, the bioactive compound profile of *Moringa oleifera* leaves is determined by the combined effects of environmental conditions and the extraction method employed, making the selection of appropriate extraction conditions essential for preserving the stability of secondary metabolites (Najihudin, Hindun, Rantika, Magfiroh, & Sujana, 2023).

The high efficiency of UAE is attributed to ultrasonic irradiation and cavitation, which generate mechanical energy that disrupts plant cell wall integrity. The continuous collapse of cavitation bubbles produces shear forces that disrupt the cellular structure of *Moringa oleifera* leaves, facilitating solvent penetration into the cellular matrix and accelerating the release of secondary metabolites into the extraction medium (Rifkia & Prabowo, 2020). In contrast, maceration relies primarily on passive diffusion, resulting in a considerably longer extraction time and potentially lower yields due to limitations in solvent saturation (Anwar et al., 2024).

The presence of phenolic compounds as major secondary metabolites in moringa leaves (*Moringa oleifera* L.) has been strongly established in previous literature (Farabi et al., 2023). Solvent optimization research confirmed that these leaves contain a highly significant amount of phenolic compounds (Farabi et al., 2023). These phenolic compounds, together with flavonoids, play a crucial role in the natural antioxidant capacity and pharmacological activities of the extract through free radical scavenging mechanisms and cellular protection against oxidative stress (Anggraini et al., 2024). Consequently, a comprehensive understanding of the phytochemical profile and the optimization of extraction parameters are paramount in determining the quality standards of the resulting moringa leaf extract (Najihudin et al., 2023).

3.2. Comparison of Extraction Yield and Extraction Time Efficiency

The effectiveness of an extraction method can be evaluated based on the extraction yield, which is expressed as the percentage of concentrated extract obtained relative to the initial weight of the dried plant material. Based on the literature review, considerable differences in extraction efficiency were observed between conventional and non-conventional extraction methods, as presented in Table 1.

Table 1. Comparison of *Moringa oleifera* Leaf Extraction Yields Using Different Extraction Methods

Extraction Method	Solvent	Extraction Time	Extraction Yield (%)
Decoction	Distilled water	6 h	26.22
Maceration	Methanol	3 × 24 h	15.90
Maceration	96% Ethanol	3 days	12.69
UAE (Sonication)	70% Ethanol	30 min	35.89
UAE (Sonication)	Distilled water	1.5 h	37.97

Based on the data presented in Table 1, Ultrasonic-Assisted Extraction (UAE) demonstrated higher extraction efficiency than the maceration method. UAE produced an extraction yield of up to 35.89% within only 30 minutes, whereas maceration required a considerably longer extraction period. This finding indicates that ultrasonic waves enhance extraction efficiency through the cavitation phenomenon, which generates mechanical energy capable of disrupting plant cell walls. As a result, the solvent penetrates the cellular matrix more effectively, accelerating the release of secondary metabolites (Rifkia & Prabowo, 2020). In contrast, maceration relies solely on passive diffusion, resulting in a substantially longer extraction time (Anwar et al., 2024). Decoction also produced a relatively high extraction yield (26.22%) because hot water effectively dissolves polar compounds. However, prolonged exposure to high temperatures during extraction may lead to the degradation of heat-sensitive bioactive compounds. Therefore, each extraction method possesses its own advantages and limitations in terms of extraction yield and preservation of bioactive compound quality (Susanty et al., 2019).

3.3. Comparison of Total Phenolic Content (TPC) Among Different Extraction Methods

The amount of phenolic compounds extracted from *Moringa oleifera* leaves depends on the extraction method, solvent type, and extraction temperature employed. The efficiency of each extraction method can be evaluated based on the Total Phenolic Content (TPC) obtained. Various extraction conditions reported in the literature have resulted in different TPC values.

A comparison of TPC values obtained using different extraction methods and conditions is presented in Table 2.

Table 2. Total Phenolic Content (TPC) of *Moringa oleifera* Leaves Obtained Using Different Extraction Methods

Author	Extraction Method	Solvent	Temperature (°C)	Total Phenolic Content (mg GAE/g)
Farabi et al. (2023)	UAE (Sonication)	96% Ethanol	Room temperature	3783.58
Rifkia & Revina (2023)	UAE (Sonication)	70% Ethanol	30	25.90
Sagala et al. (2021)	Maceration	96% Ethanol	30	745.17
Anwar et al. (2024)	Maceration	Methanol	Room temperature	190.70
Ansory et al. (2023)	Maceration	96% Ethanol	Room temperature	71.24

As shown in Table 2, Ultrasonic-Assisted Extraction (UAE) using 96% ethanol produced the highest Total Phenolic Content (TPC), reaching 3783.58 mg GAE/g. The superiority of UAE was also confirmed by the high phenolic extraction efficiency of 25.90 mg GAE/g obtained within a short extraction time at 30°C using 70% ethanol (Rifkia & Revina, 2023). This result indicates that the combination of ultrasonic waves, an appropriate extraction solvent, and controlled temperature effectively enhances the extraction of phenolic compounds from *Moringa oleifera* leaves compared to conventional maceration (Farabi et al., 2023). In addition to the extraction method, phenolic content is also influenced by the geographical origin of the plant. *Moringa* leaves collected from highland areas, such as Wonosobo, contained 142.92 mg GAE/g of phenolic compounds, which was higher than the 99.40 mg GAE/g reported for leaves collected from lowland areas such as Wonosari (Guntarti et al., 2021). This difference is likely associated with plant adaptation to environmental conditions, including temperature, climate, and other stress factors that may influence phenolic biosynthesis. Therefore, both extraction methods and environmental conditions contribute to the phenolic content of *Moringa oleifera* leaves (Guntarti et al., 2021).

3.4. Stability of Flavonoid Compounds (TFC) Under Different Extraction Temperatures

Flavonoids are thermolabile secondary metabolites that are sensitive to the extraction method, solvent type, and extraction temperature employed. Consequently, extraction temperature may influence both the stability and concentration of flavonoids obtained (Rifkia & Prabowo, 2020). Therefore, the effect of extraction temperature on flavonoid content under different extraction methods should be carefully considered. The comparison is presented in Table 3.

Table 3. Effect of Extraction Temperature on Flavonoid Content

Author	Extraction Method	Solvent	Temperature (°C)	Flavonoid Content*
Rifkia (2020)	UAE	Ethanol 70%	50	2.71%
Rifkia (2020)	UAE	Ethanol 70%	70	0.68%
Anwar (2024)	Maceration	Methanol	Room temperature	338.3 mg EQ/g
Susanty (2019)	Decoction	Distilled Water (Aquades)	100	7.05 mg/kg

*Note: TFC values follow the original units of each study (% w/w, mg EQ/g, and mg/kg). Due to non-uniform quantification units, these values are not directly comparable in absolute magnitude but illustrate temperature-dependent trends within each method.

Based on the data presented in Table 3, an extraction temperature of 50°C was found to be the optimum condition for maintaining flavonoid content during extraction. This result indicates that moderate temperatures are more effective in preserving the stability of thermolabile flavonoid compounds. In contrast, increasing the extraction temperature to 70–100°C may lead to flavonoid degradation, resulting in a reduction in flavonoid content. This degradation is driven by two main chemical pathways: hydrolytic deglycosylation and oxidative C-ring cleavage. High thermal exposure (>70°C) accelerates the cleavage of O-glycosidic bonds at the C₃ position of flavonols (such as rutin and isoquercitrin) into less stable aglycones, while simultaneously promoting radical-mediated opening of the central heterocyclic pyran ring (C-ring) into smaller phenolic acids (Rifkia & Prabowo, 2020). Furthermore, excessive sonication or heating in UAE can induce solvent sonolysis ($\text{H}_2\text{O} \rightarrow \text{OH} + \text{H}$), accelerating radical-induced oxidation of polyphenols. This phenomenon is evident in the decoction method, which produced a relatively low flavonoid content despite yielding a relatively high extraction yield (Susanty et al., 2019). Therefore, extraction temperature is a critical parameter that should be carefully controlled to obtain optimal flavonoid content.

3.5. Effect of Solvent Type on Extraction Selectivity

The efficiency of the extraction process depends on the compatibility between the physicochemical properties of the target compounds and the extraction solvent. According to the principle of like dissolves like, compounds are more readily dissolved in solvents with similar polarity. Therefore, solvent selection is a crucial factor in the successful extraction of secondary metabolites (Farabi et al., 2023). Ethanol is one of the most widely used extraction solvents because of its polar nature, ability to dissolve a broad range of bioactive compounds, and relatively safe application. Consequently, ethanol is considered an effective solvent for extracting secondary metabolites from *Moringa oleifera* leaves (Qonitah et al., 2023).

Based on the literature review, the use of 96% ethanol generally produced higher phenolic compound contents than ethanol–water mixtures. This finding indicates that highly concentrated ethanol is more selective for extracting phenolic compounds from *Moringa oleifera* leaves. Although the addition of water may increase the overall extraction yield, it does not necessarily result in a higher phenolic content because water also dissolves various other polar compounds (Farabi et al., 2023). Furthermore, comparisons among different solvents demonstrated that ethanol extracts exhibited stronger antioxidant activity, as indicated by an IC_{50} value of 103.98 $\mu\text{g/mL}$, compared with extracts obtained using non-polar solvents such as n-hexane. Therefore, the combination of Ultrasonic-Assisted Extraction (UAE), high-concentration ethanol, and a controlled extraction temperature represents an effective strategy for producing *Moringa oleifera* leaf extracts with an optimal content of bioactive compounds (Rianto et al., 2020).

4. CONCLUSION

This review demonstrates that Ultrasonic-Assisted Extraction (UAE) is significantly superior to conventional methods (maceration and decoction) in terms of extraction yield and time efficiency. The combination of UAE with 96% ethanol proved to be the most effective condition for maximizing phenolic recovery (yielding a peak TPC of 3783.58 mg GAE/g), while an operational temperature of 50°C serves as the critical parameter to maintain the stability of thermolabile flavonoids and prevent thermal degradation.

The main limitations of this review stem from the non-uniform analytical quantification units (notably for TFC) across cited studies and the phytochemical variability linked to diverse geographical origins. Consequently, future investigations should focus on pilot-scale modeling for techno-economic evaluation, the exploration of sustainable green extraction systems using Deep Eutectic Solvents (DES), and in vivo validation of the biological activities of the standardized extracts.

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AUTHOR CONTRIBUTIONS

The authors developed the research concept, conducted the literature search, analyzed and synthesized the data, and wrote, revised, and approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this article.

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