



A Comprehensive Review of the Phytochemical Constituents and Hepatoprotective Potential of *Moringa oleifera* Flowers

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ABSTRACT :

Moringa oleifera Lam., belonging to the family Moringaceae, is a widely distributed medicinal and nutritional plant with considerable pharmacological potential. Different parts of the plant contain diverse bioactive constituents, including flavonoids, phenolic compounds, glucosinolates, carbamates, terpenoids, steroids, tannins and vitamins [1,2]. Although leaves and seeds have received extensive scientific attention, the flowers of *M. oleifera* remain comparatively less investigated. Phytochemical studies of the flowers have identified flavonoids, tannins, alkaloids, glycosides, terpenoids and phenolic compounds, while isolated-compound studies have demonstrated the presence of several low-molecular-weight constituents [3–5]. The antioxidant and anti-inflammatory properties of flower extracts provide a plausible basis for their hepatoprotective potential [3,6]. Experimental evidence has directly demonstrated protective effects of hydroethanolic *M. oleifera* flower extract against acetaminophen-induced hepatotoxicity in rats, with improvements in biochemical and histopathological parameters [7]. Hepatoprotection may involve attenuation of oxidative stress, reduction of lipid peroxidation, preservation of endogenous antioxidant defenses and modulation of inflammatory processes. However, much of the broader mechanistic evidence for *M. oleifera* hepatoprotection originates from leaves, seeds or whole-plant preparations rather than flowers specifically [1,2,8]. This review therefore focuses on the phytochemical composition of *M. oleifera* flowers and critically examines their potential hepatoprotective mechanisms and experimental evidence. The limited flower-specific literature highlights the need for standardized extracts, detailed phytochemical characterization, molecular studies and further in-vivo investigations.

Keywords: *Moringa oleifera*, flowers, hepatoprotection, phytochemicals, flavonoids, oxidative stress, liver injury, antioxidant, inflammation.

1. Introduction

The liver is a vital organ involved in metabolism, detoxification, biotransformation of xenobiotics, protein synthesis and maintenance of physiological homeostasis. Exposure to drugs, environmental toxins, alcohol, infections and metabolic abnormalities can disturb hepatic function and produce hepatocellular injury. Oxidative stress, lipid peroxidation, mitochondrial dysfunction, inflammation and apoptosis are among the major mechanisms involved in liver damage.

Medicinal plants have attracted considerable interest as sources of natural compounds with antioxidant, anti-inflammatory and hepatoprotective properties. *Moringa oleifera* Lam., commonly known as drumstick tree or horseradish tree, is one of the extensively studied medicinal plants of the family Moringaceae. Traditional and experimental literature has associated *M. oleifera* with antioxidant, anti-inflammatory, antimicrobial, antidiabetic, anticancer and hepatoprotective activities [1,2].

Phytochemical investigations have demonstrated that different parts of *M. oleifera* contain numerous classes of secondary metabolites. A systematic review identified 163 chemical constituents from the plant, including flavonoids, phenols, carbamates and glucosinolates [1]. Another comprehensive review similarly reported diverse phytochemical constituents and pharmacological activities, including hepatoprotective activity [2].

However, pharmacological investigations have predominantly focused on leaves and seeds. In comparison, the flowers have received relatively less attention despite containing several potentially bioactive constituents [4,5]. Therefore, a focused assessment of the phytochemistry and hepatoprotective potential of *M. oleifera* flowers is warranted.

2. Botanical Profile of *Moringa oleifera*

Moringa oleifera Lam. belongs to the family **Moringaceae**. It is a rapidly growing perennial tree that is widely cultivated in tropical and subtropical regions. The plant possesses a slender trunk, compound leaves, fragrant flowers and elongated pods containing seeds [1,2].

Table 1. Taxonomic classification of *Moringa oleifera*

Taxonomic category	Classification
Kingdom	Plantae
Family	Moringaceae
Genus	<i>Moringa</i>
Species	<i>Moringa oleifera</i> Lam.
Common names	Drumstick tree, horseradish tree, moringa

**Figure 1. Flowers of *Moringa oleifera* Lam.**

The plant is native to the Indian subcontinent but is now cultivated in several parts of Asia, Africa and other tropical regions [1,2].

3. *Moringa oleifera* Flowers

The flowers of *M. oleifera* are fragrant, bisexual and generally white or creamy-white in appearance. They occur in branched inflorescences and are traditionally consumed as food in several regions.

Phytochemical investigations indicate that the flowers contain several classes of secondary metabolites. Earlier studies identified flavonoids, tannins, alkaloids, glycosides, terpenoids and steroids in flower extracts [3]. A review of the phytochemistry of *M. oleifera* specifically reported compounds such as quercetin, isoquercetin, kaempferol, kaempferitrin and ascorbic acid among constituents associated with the flowers [4].

More recent flower-focused research has further demonstrated antioxidant, anti-inflammatory and enzyme-inhibitory activities of flower extracts, supporting the view that the flowers contain biologically active compounds [6].

4. Phytochemical Constituents of *M. oleifera* Flowers

The pharmacological properties of medicinal plants are strongly influenced by their secondary metabolites. The phytochemical composition of *M. oleifera* varies according to plant part, geographical origin, maturity, extraction solvent and analytical method [1,4].

Table 2. Important phytochemical constituents reported from *M. oleifera* flowers

Phytochemical group	Reported constituents/examples	Potential pharmacological relevance
Flavonoids	Quercetin, isoquercetin, kaempferol, kaempferitrin	Antioxidant, anti-inflammatory
Phenolics	Phenolic compounds	Radical scavenging
Tannins	Tannin-type compounds	Antioxidant, antimicrobial
Alkaloids	Alkaloidal constituents	Pharmacological activity
Glycosides	Cardiac/other glycosides	Biological activity
Terpenoids	Terpenoid constituents	Antioxidant/anti-inflammatory potential
Steroids	β -sitosterol and related compounds	Anti-inflammatory potential
Vitamins	Ascorbic acid and other nutrients	Antioxidant activity

The presence of flavonoids and phenolic compounds is particularly relevant because these compounds can participate in free-radical scavenging and modulation of oxidative and inflammatory processes [3,4].

5. Flavonoids in *M. oleifera* Flowers

Flavonoids are an important group of polyphenolic compounds associated with the biological activity of *M. oleifera*. Quercetin, isoquercetin, kaempferol and kaempferitrin have been reported among the constituents associated with the flowers [4].

Quercetin is of particular interest because it possesses antioxidant and anti-inflammatory properties and has been investigated extensively in experimental models of oxidative tissue injury. However, the presence of a compound in *M. oleifera* flowers does not by itself establish that the compound is responsible for hepatoprotection; this requires specific pharmacological and mechanistic investigation.

A flower-specific phytochemical study also demonstrated the presence of flavonoids and tannins along with other phytochemical classes and measured the total phenolic content of an ethanolic flower extract at 19.31 ± 1.79 mg gallic acid equivalents/g dry extract [3].

6. Phenolic Compounds and Antioxidant Potential

Phenolic compounds are important plant-derived antioxidants. They can donate hydrogen atoms or electrons to reactive species and thereby reduce oxidative damage.

An investigation of *M. oleifera* flowers reported that the ethanolic extract possessed measurable total phenolic content and moderate DPPH radical-scavenging activity [3]. More recent research examining flower extracts using DPPH, ABTS, CUPRAC and FRAP assays has also demonstrated antioxidant activity, although antioxidant capacity differed according to extraction method and solvent [6].

This solvent-dependent variation is important because it indicates that extraction conditions can substantially influence the phytochemical profile and biological activity of flower preparations [6].

7. Hepatic Injury and Oxidative Stress

The liver is continuously exposed to endogenous and exogenous compounds requiring metabolic processing. During excessive exposure to hepatotoxic substances, reactive oxygen species (ROS) can accumulate beyond the capacity of endogenous antioxidant systems.

Excess ROS may result in:

- Lipid peroxidation
- Protein oxidation
- DNA damage
- Mitochondrial dysfunction
- Membrane disruption
- Inflammatory signaling
- Hepatocyte necrosis or apoptosis

Lipid peroxidation can damage hepatocyte membranes and promote leakage of intracellular enzymes into the circulation. Consequently, elevations in ALT, AST and ALP are commonly used as biochemical indicators of hepatic injury.

Because *M. oleifera* contains numerous antioxidant phytochemicals, attenuation of oxidative stress represents one possible mechanism for its hepatoprotective activity [1,2].

8. Hepatoprotective Potential of *M. oleifera* Flowers

The most important evidence for your review is the study specifically evaluating *M. oleifera* flowers against acetaminophen-induced hepatotoxicity.

Mekonnen et al. investigated hydroethanolic extracts of *M. oleifera* leaves and flowers in an acetaminophen-induced hepatotoxicity model in rats. Flower or leaf extract was administered at 200 or 400 mg/kg after acetaminophen administration, while N-acetylcysteine was used as a positive control [7].

Acetaminophen administration increased liver injury markers and produced histopathological changes, including inflammation and bridging necrosis. Treatment with *M. oleifera* preparations reduced the severity of these changes, supporting hepatoprotective activity [7].

Table 3. Direct experimental evidence for *M. oleifera* flowers

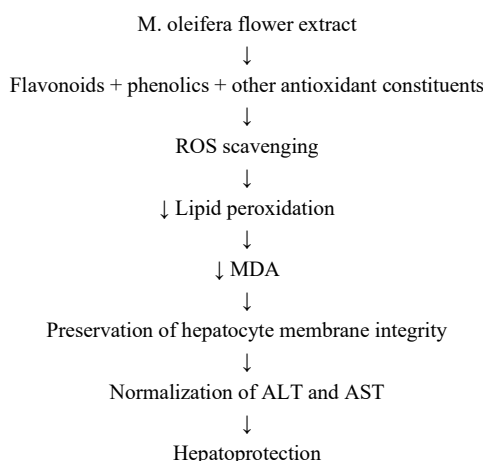
Study	Plant part	Model	Extract	Dose	Major findings
Mekonnen et al. [7]	Flowers and leaves	Acetaminophen-induced hepatotoxicity in rats	Hydroethanolic	200 and 400 mg/kg	Improvement in liver biochemical parameters and histopathology
Verma et al. [3]	Flowers	In-vitro antioxidant model	Ethanolic	—	Phenolic content and DPPH antioxidant activity
Recent flower study [6]	Flowers	In-vitro antioxidant/anti-inflammatory assays	Hexane and other preparations	—	Antioxidant and anti-inflammatory activities

This table demonstrates an important point: direct hepatoprotective evidence for flowers exists, but the number of flower-specific studies is relatively small compared with the overall *M. oleifera* literature.

9. Proposed Antioxidant Mechanism

The hepatoprotective potential of *M. oleifera* flowers may involve antioxidant mechanisms.

Proposed pathway



The antioxidant potential of *M. oleifera* flowers has been demonstrated experimentally using several in-vitro assays [3,6]. Broader pharmacological literature on *M. oleifera* also supports antioxidant activity as one of the mechanisms underlying its hepatoprotective effects [1,2].

10. Effect on Endogenous Antioxidant Defense

Hepatotoxicity is often associated with depletion or impairment of endogenous antioxidant defenses.

Important antioxidant systems include:

- Reduced glutathione (GSH)
- Superoxide dismutase (SOD)
- Catalase (CAT)
- Glutathione peroxidase (GPx)

A potential hepatoprotective response can therefore be represented as:

Hepatotoxic agent

- ↑ ROS
- ↓ GSH/SOD/CAT/GPx
- ↑ lipid peroxidation
- hepatocellular injury

Whereas:

M. oleifera flower phytochemicals

- antioxidant activity
- ↓ ROS
- preservation/restoration of endogenous antioxidant defenses
- ↓ lipid peroxidation
- hepatoprotection.

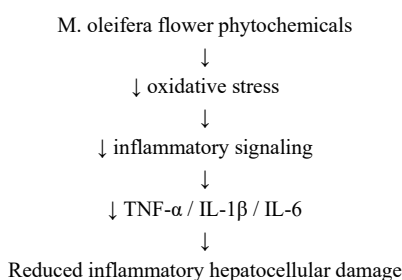
However, these specific antioxidant-enzyme effects should be experimentally confirmed for flower extracts rather than extrapolated directly from leaf studies.

11. Anti-inflammatory Mechanism

Oxidative stress and inflammation are closely interconnected in liver injury. ROS can activate inflammatory pathways, resulting in increased production of cytokines such as TNF- α , IL-1 β and IL-6.

M. oleifera is widely reported to possess anti-inflammatory activity [1,2]. Importantly, flower-specific experiments have demonstrated significant anti-inflammatory activity of ethanolic flower extract in an in-vitro protein-denaturation assay [3]. More recent work has similarly demonstrated anti-inflammatory properties of flower preparations [6].

A proposed pathway is:



This pathway should be described as a proposed mechanism until it is directly demonstrated using molecular studies of flower extracts.

12. Biochemical Parameters for Evaluating Hepatoprotection

The following parameters are commonly useful for evaluating hepatoprotective activity:

Table 4. Biochemical markers

Parameter	Liver injury	Expected hepatoprotective effect
ALT/SGPT	↑	↓
AST/SGOT	↑	↓
ALP	↑	↓
Total bilirubin	↑	↓
Direct bilirubin	↑	↓
Total protein	↓	Normalization
Albumin	↓	Normalization
GSH	↓	↑
SOD	↓	↑
CAT	↓	↑
GPx	↓	↑
MDA	↑	↓

For a strong experimental assessment, biochemical findings should be combined with oxidative-stress measurements and histopathological examination.

13. Histopathological Evidence

Histopathological examination is an important component of hepatoprotective studies because it provides direct information regarding structural changes in the liver.

Typical changes associated with experimental hepatotoxicity include:

- Hepatocyte degeneration
- Cellular swelling
- Inflammatory infiltration
- Sinusoidal changes
- Fatty degeneration
- Necrosis

Protection would be indicated by:

- Preservation of hepatic architecture
- Reduced hepatocyte degeneration
- Reduced inflammatory infiltration
- Reduced necrosis
- Improved cellular organization

In the acetaminophen model, liver inflammation and bridging necrosis were observed in the hepatotoxic control animals, while treatment with *M. oleifera* preparations produced protective changes [7].

14. Evidence From Other Parts of *M. oleifera*

It is important to distinguish flower evidence from evidence obtained using other plant parts.

The extensive literature on *M. oleifera* leaves, seeds and other tissues demonstrates antioxidant, anti-inflammatory and hepatoprotective properties [1,2,8]. However, these studies cannot automatically be considered direct evidence for flowers because phytochemical composition varies between plant organs. Therefore:

Flower-specific evidence

→ Direct evidence for flower hepatoprotection

Leaf/seed evidence

→ Supportive evidence for the overall biological potential of *M. oleifera*

Whole-plant evidence

→ General pharmacological background

This distinction should be maintained throughout your manuscript.

15. Safety and Toxicological Considerations

Although *M. oleifera* is widely consumed as a food and medicinal plant, safety cannot be assumed solely on the basis of traditional use.

The systematic review by Liu et al. reported that toxicity studies identified potential effects involving the liver, kidney and blood at certain doses and emphasized the need for appropriate dose determination and further toxicological evaluation [1].

Therefore, future studies of *M. oleifera* flowers should include:

- Acute toxicity
- Subacute toxicity
- Chronic toxicity where appropriate
- Hematological parameters
- Renal function
- Liver function
- Histopathology

Standardization of the extract and identification of its major constituents are also important for reproducibility [1].

16. Conclusion

Moringa oleifera Lam. flowers contain a diverse range of phytochemical constituents, including flavonoids, phenolic compounds, tannins, alkaloids, glycosides, terpenoids and steroids [3,4]. Experimental investigations have demonstrated antioxidant and anti-inflammatory properties of flower extracts [3,6]. Importantly, direct animal evidence indicates that hydroethanolic extracts of *M. oleifera* flowers can attenuate acetaminophen-induced hepatotoxicity, supporting their potential hepatoprotective activity [7].

The hepatoprotective effects may involve attenuation of oxidative stress, reduction of lipid peroxidation, preservation of antioxidant defenses and modulation of inflammatory processes. Nevertheless, the current evidence base remains limited specifically for flowers compared with leaves and other plant parts. Further studies involving standardized flower extracts, detailed phytochemical profiling, molecular mechanism investigations, dose optimization and comprehensive toxicity assessment are required before the hepatoprotective potential of *M. oleifera* flowers can be firmly established.

REFERENCES

1. Liu R, Liu J, Huang Q, Liu S, Jiang Y. *Moringa oleifera*: a systematic review of its botany, traditional uses, phytochemistry, pharmacology and toxicity. *J Pharm Pharmacol*. 2022;74(3):296–320. doi:10.1093/jpp/rgab131.
2. Abd Rani NZ, Husain K, Kumolosasi E. *Moringa* genus: a review of phytochemistry and pharmacology. *Front Pharmacol*. 2018;9:108.
3. Verma AR, Vijayakumar M, Mathela CS, Rao CV. Estimation of total phenolic content, in-vitro antioxidant and anti-inflammatory activity of flowers of *Moringa oleifera*. *Asian Pac J Trop Biomed*. 2013;3(8):623–627.
4. Saini RK, Sivanesan I, Keum YS. Phytochemicals of *Moringa oleifera*: a review of their nutritional, therapeutic and industrial significance. *3 Biotech*. 2016;6:203.
5. Punia J, Singh R. Isolation, characterization and biological potential of compounds from flowers of *Moringa oleifera*. 2018.
6. *Moringa oleifera* flowers: insights into their aroma chemistry, anti-inflammatory, antioxidant, and enzyme inhibitory properties. *BMC Complement Med Ther*. 2024. doi:10.1186/s12906-024-04579-y.
7. Mekonnen N, et al. Therapeutic potential of *Moringa oleifera* extracts against acetaminophen-induced hepatotoxicity in rats. *Pharmacognosy Research*. 2012.
8. *Moringa oleifera*: an updated comprehensive review of its pharmacological activities, ethnomedicinal, phytopharmaceutical formulation, clinical, phytochemical, and toxicological aspects. *Int J Mol Sci*. 2023;24:2098.