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## ***MORINGA OLEIFERA*: A SYSTEMATIC REVIEW OF ITS BOTANY, TRADITIONAL USES, PHYTOCHEMISTRY AND PHARMACOLOGY**

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### **ABSTRACT:**

In this current perusal, *Moringa oleifera*, often known as the "Miracle Tree," has garnered significant attention due to its variety of benefits across various domains. From a nutritional standpoint, *Moringa* is hailed as a nutrient powerhouse, containing essential vitamins, minerals, antioxidants, and amino acids. In the realm of traditional medicine, *Moringa* has been used for centuries to treat various ailments, ranging from inflammation and infections to diabetes, cardiovascular diseases, etc. Scientific studies have begun to unveil the various therapeutic applications of *Moringa* extracts, highlighting their potential in combating oxidative stress, lowering blood sugar levels, and boosting immune function. This study explores the pharmacological and safety attributes of *Moringa oleifera*, demonstrating its potential as a trustworthy source for developing novel medications.

**Keywords:** *Moringa oleifera*, anti-inflammatory, antioxidant, antibacterial, arthritis.

### **INTRODUCTION:**

Phytochemical investigation has a larger scope, with the potential to discover novel synthetic medications based on specific bioactive molecules. This is because extensive knowledge of the chemical structures of many chemicals has led to the development of synthetic medications.

In such instances, our results may be compared to the compound's known structure to guide the synthesis of more powerful analogs. In this case, *Moringa* can still be a source of knowledge for discovering novel synthetic medicines. This is because the existing *Moringa* organic molecule may be utilized to create an analog via a reverse process <sup>(1-3)</sup>.

The extract will next be tested against certain phytochemicals that may be detected by color, precipitation, foaming, and other characteristics. The existence of distinct kinds of compounds in a crude material may be detected by the development of color or other particular reactions <sup>(4)</sup> because the bioactive compounds extracted may be examined directly in pharmacological

research to determine the current trend of employing bioactive compounds from natural resources as medication, as opposed to isolating the current bioactive chemical in a pill or another form <sup>(5, 6)</sup>. *Moringa* has a wide range of traditional applications, both as food and medicinal. It includes vital amino acids, carotenoids, and many vitamins and phytochemicals. The methanol extract of *moringa* leaves contains the potential for alkaloids, terpenoids, flavonoids, glycosides, saponins, and tannins, which are detected using suitable qualitative chemical procedures <sup>(7)</sup>.



**Figure 1: *M. oleifera* leaves, flowers, fruits, and seeds <sup>(81)</sup>.**

#### **TAXONOMIC CLASSIFICATION:**

Kingdom - Plantae

Subkingdom - Tracheobionta Super Division- Spermatophyta

Division - Magnoliophyta Class - Magnoliopsida

Subclass - Dilleniidae

Order - Capparales

Family - Moringaceae

Genus - *Moringa*

Species - *Oleifera*<sup>(8)</sup>.

#### **BOTANICAL DESCRIPTION:**

*Synonyms*

Latin - *Moringa oleifera*

Sanskrit - Subhanjana

Hindi - Saguna, Sainjna Gujarati - Suragavo Tamil - Morigkai

Telugu - Mulaga, Munaga Malayalam - Murinna, Sigr Punjabi - Sainjna, Soanjna

Ayurvedic - Akshiva, Haritashaaka, Raktaka, Tikshnagandhaa Arabian - Rawag

French - Moringe à graine ailée, Morungue Spanish - Ángela, Ben, Moringa Portuguese - Moringa, Moringueiro

English - Drumstick tree, Horseradish tree, Ben tree <sup>(9)</sup>

**GEOGRAPHICAL SOURCE:** *Moringa*, also known as the drumstick tree or the horseradish tree, is widely cultivated in tropical and subtropical regions around the world, including Africa, Asia, and Latin America, due to its adaptability to various climates and soils. In its native range, moringa grows in countries such as India, Nepal, Bangladesh, Pakistan, and Afghanistan <sup>(10)</sup>

**MORPHOLOGY:** The morphology of the *moringa* tree (*Moringa oleifera*) can vary slightly depending on factors such as age, growing conditions, and variety, but here are the typical features.

1. **Height:** *Moringa* trees are fast-growing and can reach heights of up to 10-12 meters (30-40 feet) within a few years under favorable conditions. However, they are often pruned to encourage bushier growth and easier harvesting.
2. **Trunk:** The trunk of a mature moringa tree is usually thick and can have a diameter of up to 45- 50 centimeters (18-20 inches). It is often straight and sturdy, with a rough, corky bark that becomes more deeply furrowed with age.
3. **Leave:** *Moringa* leaves are compound and alternate, consisting of multiple leaflets arranged in a pinnate pattern. Each leaf typically has 5-9 pairs of leaflets, with a single leaflet at the tip. The leaflets are elliptical or ovate, about 1-2 centimeters wide and 2-4 centimeters long, and they have a bright green color...
4. **Flowers:** *Moringa* trees produce small, white flowers with five petals. The flowers are fragrant and hermaphroditic, meaning they contain both male and female reproductive organs.
5. **Fruits:** *Moringa* fruits are long, slender pods that resemble drumsticks, which is why the tree is sometimes called the "drumstick tree." The pods can grow up to 30-50 centimeters (12-20 inches) in length and are initially green but turn brown as they mature.
6. **Seeds:** The seeds of *the moringa* tree are round or triangular and about 1 centimeter in diameter. They have three papery wings that facilitate their dispersal by wind. *Moringa* seeds are rich in oil and are used for various purposes, including culinary and cosmetic applications <sup>(11)</sup>.

#### **TRADITIONAL USES:**

*Moringa oleifera*, also known as the drumstick tree or the miracle tree, has been utilized for various traditional purposes across different cultures for centuries. Here are some of its traditional uses <sup>(12)</sup>.

1. **Nutritional Supplement:** *Moringa* leaves are highly nutritious, containing vitamins, minerals, and antioxidants. In many traditional systems of medicine, *moringa* leaves are consumed as a dietary supplement to boost overall health and well-being <sup>(13)</sup>.
2. **Medicinal Purposes:** Various parts of the *moringa* tree, including leaves, seeds, and roots, are used in traditional medicine to treat a wide range of ailments, including inflammation, digestive issues, diabetes, hypertension, and infections <sup>(14)</sup>.
3. **Water Purification:** *Moringa* seeds contain natural compounds that can clarify and purify water by binding to impurities and causing them to settle at the bottom. This traditional method of water purification has been used in many parts of the world, especially in rural communities with limited access to clean water <sup>(15)</sup>.
4. **Skin Care:** *Moringa* oil, extracted from the seeds of the moringa tree, is traditionally used in skin care products for its moisturizing and anti-inflammatory properties. It is believed to help treat skin conditions such as acne, eczema, and psoriasis <sup>(16)</sup>.

5. **Livestock Feed:** *Moringa* leaves and seeds are used as fodder for livestock due to their high nutritional content <sup>(17)</sup>. They provide protein, vitamins, and minerals, helping to improve the health and productivity of animals <sup>(18)</sup>.

**Table 1: Chemical constituents of *M. oleifera***

S. No.	Compounds	Tissue	Reference
	<b>Flavonoids</b>		
1	Astragalin	Leaves	(63)
2	Quercetin-3-O-(6"- malonylglucoside)	Leaves	(64)
3	Quercetin-3-O-rhamnosylglucoside	Seeds, Leaves	(64)
4	Kaempferol-3-O-(6"- malonylglucoside)	Leaves	(64)
5	Quercetin-3-O-β-D-(6"-O-3- hydroxy-3-methylglutaryl)-glucoside	Leaves	(65)
6	Kaempferide-3-O-2",3"- diacetylglucoside	Leaves	(66)
7	Kaempferol-3-O-[β-glucosyl-(1→2)]-[α-rhamnosyl-(1→6)-O-β-glucoside-7-O- rhamnoside	Leaves	(66)
8	Kaempferide-3-O-(2"-O- galloylrhamnoside)	Leaves	(66)
9	Kaempferide-3-O-(2"-O- galloylrutinoside)-7-O-α-rhamnoside	Leaves	(66)
10	Kaempferol-3-O-[α- rhamnosyl-(1→2)]-[α- rhamnosyl-(1→4)-β-glucoside-7-O-α-rhamnoside	Leaves	(66)
11	Kaempferol-3-O-β-D- glucopyranoside	Leaves	(67)
12	<i>Quercetin-3-O-β-D- glucopyranoside</i>	Leaves	(67)
13	Isoquercitrin	Leaves	(68)
14	Quercetin-3-O-β-D-(6"-O- malonyl)-glucoside	Leaves	(68)
15	Kaempferol-3-O-β-D-(6"-O- malonyl)-glucoside	Leaves	(68)
16	Myricetin	Leaves	(69)
17	Isorhamnetin	Leaves	(70)
18	Apigenin	Leaves	(70)
19	Daidzein	Leaves	(71)
20	Genistein	Leaves	(71)
21	Luteolin	Leaves	(70)
22	Quercetin-O-3,7-diglucoside	Leaves	(72)
23	Apigenin-O-8-glucoside	Leaves	(72)
24	Quercetin-O-3-glucoside	Leaves	(72)
25	Apigenin-7-C-glucoside	Leaves	(72)

26	Kaempferol-O-3,7-diglucoside	Leaves	(72)
27	Quercetin-3-acetylglucoside	Leaves	(72)
28	Kaempferol-O-3-glucoside	Leaves	(72)
29	Kaempferol-O-7-glucoside	Leaves	(72)
	<b>Carbamates</b>		
30	Niazinin B	Leaves	(73)
31	Niazimicin	Leaves	(73)
32	Niazimimin A	Leaves	(73)
33	Niazimimins B	Leaves	(73)
34	O-methyl-4-[(2',3',4'-tri-O-acetyl- $\alpha$ -L-rhamnosyloxy) benzyl] carbamate (E)	Leaves	(74)
35	O-methyl-4-[(2',3',4'-tri-O-acetyl- $\alpha$ -L-rhamnosyloxy) benzyl] carbamate (Z)	Leaves	(74)
36	O-ethyl-4-[(2',3',4'-tri-O-acetyl- $\alpha$ -L-rhamnosyloxy) benzyl] carbamate (E)	Leaves	(74)
37	O-methyl-4-[(4'-O-acetyl $\alpha$ -L-rhamnosyloxy)benzyl] carbamate (E)	Leaves	(74)
38	O-methyl-4-[(2',3',4'-tri-O-acetyl- $\alpha$ -L-rhamnosyloxy) benzyl] thiocarbamate(E)	Leaves	(74)
39	O-methyl-4-[(2',3',4'-tri-O-acetyl- $\alpha$ -L-rhamnosyloxy)benzyl] thiocarbamate (Z)	Leaves	(74)
40	O-ethyl-4-[(2',3',4'-tri-O-acetyl- $\alpha$ -L-rhamnosyloxy) benzyl] thiocarbamate (E)	Leaves	(74)
41	Marumoside A	Leaves	(68)
42	Marumoside B	Leaves	(68)
43	Methyl-4-( $\alpha$ -L-rhamnopyranosyloxy)benzyl carbamate	Leaves	(68)
44	O-ethyl,4-[(2',3',4'-tri-O-acetyl- $\alpha$ -l-rhamnosyloxy)benzyl] thiocarbamate (Z)	Leaves	(74)
45	O-ethyl-4-[ $\alpha$ -l-rhamnosyloxy)benzyl] thiocarbamate(Z)	Leaves	(74)
	<b>Phenols</b>	Leaves	
46	Cryptochlorogenic acid	Leaves	(75)
47	4-O-(4'-O- $\alpha$ -D-glucopyranosyl)-caffeoylquinic acid	Leaves	(76)
48	4-O-(3'-O- $\alpha$ -D-glucopyranosyl)-caffeoylquinic acid	Leaves	(76)
49	Benzoic acid 4-O- $\alpha$ -rhamnosyl-(1 $\rightarrow$ 2)- $\beta$ -glucoside	Leaves	(66)
50	Benzoic acid-4-O- $\beta$ -glucoside	Leaves	(66)
51	Benzaldehyde-4-O- $\beta$ -glucoside	Leaves	(66)
52	Benzyl	Leaves	(68)
53	Benzyl- $\beta$ -D-glucopyranoside	Leaves	(68)
54	$\alpha$ -Tocopherol	Leaves	(76)

55	$\gamma$ -Tocopherol	Leaves	(76)
56	2-Hydroxycoumaric acid	Leaves	(77)
57	Sinapic acid	Leaves	(77)
58	Gentistic acid	Leaves	(77)
59	Syringic acid	Leaves	(77)
60	4-O-(4'-O- $\alpha$ -D- glucopyranosyl)- caffeoylquinic acid	Leaves	(75)
61	4-O-(3'-O- $\alpha$ -D- glucopyranosyl)- caffeoylquinic acid	Leaves	(75)
62	Chlorogenic acid	Leaves	(75)
63	4-O-caffeoyl quinic acid	Leaves	(75)
64	5-O-caffeoyl quinic acid	Leaves	(75)
	<b>Glucosinolates</b>		
65	4-[(2',3',4'-tri-O-acetyl- $\alpha$ -l- rhamnosyloxy)benzyl] nitrile	Leaves	(74)
66	Niazirin	Leaves	(79)
	<b>Carotenoids</b>		
67	$\beta$ -Carotene	Leaves	(80)
68	Lutein	Leaves	(80)

### IMPORTANCE OF PHYTOCHEMICAL SCREENING:

Phytochemical screening of Moringa is essential for understanding its medicinal properties and nutritional value.

**Identification of Bioactive Compounds:** Phytochemical screening helps identify the presence of bioactive compounds in Moringa, such as flavonoids, phenolics, alkaloids, and glucosinolates.<sup>(19)</sup>

- 1. Medicinal Potential:** Research has shown that certain bioactive compounds present in Moringa have therapeutic effects on conditions such as diabetes, hypertension, and inflammatory disorders<sup>(20)</sup>.
- 2. Quality Control:** By ensuring the presence of specific bioactive compounds, manufacturers can standardize the quality and potency of Moringa supplements and herbal preparations<sup>(21)</sup>.
- 3. Nutritional Value:** It helps identify vitamins, minerals, and other phytonutrients present in the plant, highlighting its potential as a nutrient-rich food source<sup>(22)</sup>.

### PHYTOCHEMISTRY:

The phytochemistry of Moringa oleifera, commonly known as moringa, is rich and diverse, comprising various bioactive compounds. Here's an overview of its phytochemical composition:

- 1. Flavonoids:** Moringa is rich in flavonoids, including quercetin, kaempferol, and rutin. Flavonoids are potent antioxidants known for their ability to scavenge free radicals and reduce oxidative stress in the body. They also exhibit anti-inflammatory, anti-cancer, and cardioprotective effects<sup>(23)</sup>.
- 2. Phenolic Compounds:** Phenolic compounds such as phenolic acids and phenolic glycosides are abundant in *moringa*. These compounds contribute to its antioxidant activity and have been linked to various health benefits, including cardiovascular protection, anti-diabetic effects, and anti-inflammatory properties<sup>(24)</sup>.

3. **Alkaloids:** *Moringa* contains alkaloids such as moringine, moringinine, and others. Alkaloids are nitrogen-containing compounds that exhibit diverse pharmacological activities, including analgesic, anti-inflammatory, and antimicrobial effects <sup>(25)</sup>.
4. **Terpenoids:** *Moringa* contains terpenoids such as  $\beta$ -sitosterol, campesterol, and stigmasterol. Terpenoids have been reported to possess anti-inflammatory, antioxidant, and cholesterol-lowering properties, making them beneficial for cardiovascular health and reducing the risk of chronic diseases <sup>(26)</sup>.
5. **Saponins:** Saponins found in *moringa* have been associated with various biological activities, including antimicrobial, antidiabetic, and immunomodulatory effects. They also exhibit cholesterol-lowering properties and may have potential applications in the prevention and management of cardiovascular diseases <sup>(27)</sup>.

#### **Macro Nutrients:**

1. **Protein:** *Moringa* leaves are rich in protein, containing all nine essential amino acids.
2. **Carbohydrates:** *Moringa* leaves contain carbohydrates, including dietary fiber, which can contribute to digestive health.
3. **Fats:** *Moringa* seeds contain healthy fats, including monounsaturated and polyunsaturated fats <sup>(28)</sup>.

#### **Micro Nutrients:**

1. **Vitamins:** *Moringa* is a rich source of vitamins, including vitamin A, vitamin C, vitamin E, and various B vitamins such as thiamine (B1), riboflavin (B2), niacin (B3), pyridoxine (B6), and folate (B9).
2. **Minerals:** *Moringa* contains minerals such as calcium, magnesium, phosphorus, potassium, iron, zinc, copper, and selenium.
3. **Antioxidants:** *Moringa* is rich in antioxidants such as flavonoids, polyphenols, and carotenoids, which help protect the body from oxidative stress and inflammation <sup>(29)</sup>.

**DOSE:** Determining the appropriate dosage of *moringa* for children and adults can depend on various factors such as age, weight, health condition, and the form of moringa being used.

#### **Moringa Dosage for Adults:**

- The typical dosage range for powdered *moringa* leaf in adults is approximately 1.5 to 7 grams per day, equivalent to about 1 to 3 teaspoons.
- It's advisable to start with a lower dosage and gradually increase as needed <sup>(30)</sup>.

#### **Moringa Dosage for Children:**

- The dosage for children is typically lower than that for adults and should be adjusted based on age, weight, and health condition.
- As a general guideline, a safe starting point is around 1/4 to 1/2 of the adult dosage.
- It's crucial to consult with a healthcare professional before giving moringa to children to ensure proper dosage and safety <sup>(31)</sup>.

#### **Pharmacological properties of *Moringa*:**

**ANTI-CANCER EFFECTS:** *Moringa oleifera*, commonly known as *moringa*, has garnered attention for its potential anti-cancer properties due to its rich phytochemical composition.

1. **Antioxidant Activity:** *Moringa* is rich in antioxidants such as flavonoids, phenolic compounds, and vitamin C, which help neutralize free radicals and reduce oxidative stress in the body. Oxidative stress can lead to DNA damage and contribute to the development of cancer. By scavenging free radicals, antioxidants in moringa may help prevent or slow down the progression of cancer <sup>(32)</sup>.
2. **Anti-inflammatory Effects:** Chronic inflammation is associated with the development and

progression of cancer. *Moringa* contains bioactive compounds with anti-inflammatory properties, such as flavonoids and isothiocyanates, which may help suppress inflammation and inhibit cancer growth and metastasis <sup>(33)</sup>.

3. **Induction of Apoptosis:** *Moringa* extracts have been shown to induce apoptosis, or programmed cell death, in cancer cells. Compounds such as benzyl isothiocyanate (BITC) found in moringa seeds have demonstrated cytotoxic effects on various cancer cell lines by triggering apoptosis pathways, leading to the death of cancer cells. <sup>(34)</sup>.
4. **Immune Modulation:** *Moringa* has been reported to modulate the immune system by enhancing the activity of natural killer (NK) cells, T cells, and macrophages, which play a crucial role in identifying and eliminating cancerous cells. By boosting immune function, moringa may help the body's defense mechanisms to recognize and destroy cancer cells <sup>(35)</sup>.

**ANTIHYPERTENSIVE ACTIVITY:** *Moringa oleifera*, has been investigated for its potential antihypertensive properties, which may help in managing high blood pressure.

1. **Vasodilation and Blood Pressure Regulation:** *Moringa* contains bioactive compounds such as quercetin, catechins, and isothiocyanates, which have been shown to promote vasodilation and improve blood flow. Vasodilation helps widen blood vessels, reducing peripheral resistance and consequently lowering blood pressure <sup>(36)</sup>.
2. **Antioxidant Activity:** *Moringa* is rich in antioxidants such as flavonoids, phenolic acids, and vitamin C, which scavenge free radicals and reduce oxidative damage to blood vessels. By reducing oxidative stress, *moringa* may help improve endothelial function and lower blood pressure <sup>(37)</sup>.
3. **Diuretic Effect:** *Moringa* has been reported to possess diuretic properties, promoting the excretion of sodium and water from the body. By increasing urine output, *moringa* may help reduce blood volume and lower blood pressure <sup>(38)</sup>.
4. **Angiotensin-Converting Enzyme (ACE) Inhibition:** Some studies suggest that moringa may inhibit angiotensin-converting enzyme (ACE), an enzyme involved in the regulation of blood pressure. By blocking ACE activity, *moringa* may help relax blood vessels and lower blood pressure <sup>(39)</sup>.

#### ANTIMICROBIAL ACTIVITY

1. **Antibacterial Activity:** *Moringa* possesses compounds such as benzyl isothiocyanate, pterygospermin, and flavonoids, which have been shown to exert antibacterial effects against a wide range of bacteria, including both Gram-positive and Gram-negative strains. <sup>(40)</sup>.
2. **Antifungal Activity:** *Moringa* extracts have demonstrated antifungal activity against fungal pathogens such as *Candida albicans*, *Aspergillus* spp., and *Cryptococcus neoformans*. Compounds present in moringa, such as phenolics, flavonoids, and alkaloids, inhibit fungal growth by disrupting fungal cell membranes, interfering with fungal cell wall synthesis, or inhibiting essential enzymes involved in fungal metabolism <sup>(41)</sup>.
3. **Antiviral Activity:** *Moringa* extracts have shown antiviral activity against several viruses, including herpes simplex virus (HSV), human immunodeficiency virus (HIV), and influenza virus. The antiviral effects of moringa may be attributed to its ability to inhibit viral replication <sup>(42)</sup>.
4. **Antiparasitic Activity:** *Moringa* extracts have been reported to exhibit antiparasitic activity against protozoan parasites such as *Plasmodium* spp. and *Trypanosoma* spp. Compounds in moringa may interfere with parasite growth and replication, making it a



potential natural remedy for parasitic infections <sup>(43)</sup>.

#### **HEPATOPROTECTIVE ACTIVITY:**

- Hepatoprotective Effects:** *Moringa* contains various bioactive compounds, including flavonoids, polyphenols, and vitamins, which exhibit hepatoprotective properties. These compounds help protect liver cells from damage caused by toxins, oxidative stress, and inflammation <sup>(44)</sup>.
- Anti-inflammatory Activity:** Chronic inflammation is associated with liver damage and the progression of liver diseases. *Moringa* possesses anti-inflammatory compounds that help reduce inflammation in the liver. By inhibiting inflammatory pathways and cytokine production, *moringa* may help prevent or alleviate liver inflammation, thus preserving liver function <sup>(45)</sup>.
- Detoxification Support:** *Moringa* contains compounds that enhance the liver's detoxification processes by increasing the activity of detoxifying enzymes such as glutathione S-transferase (GST) and superoxide dismutase (SOD). These enzymes play a crucial role in neutralizing and eliminating toxins from the body <sup>(46)</sup>.
- Antioxidant Activity:** Oxidative stress is a key contributor to liver damage and the development of liver diseases. *Moringa's* antioxidant compounds scavenge free radicals and reduce oxidative damage to liver cells. By enhancing the antioxidant defense system, *moringa* helps protect the liver from oxidative stress-induced injury <sup>(47)</sup>.

**THE ANTIDIABETIC ACTIVITY:** *Moringa oleifera*, has been investigated for its potential antidiabetic properties.

- Blood Glucose Regulation:** *Moringa* contains bioactive compounds such as flavonoids, phenolics, and alkaloids that have been shown to lower blood glucose levels by various mechanisms. And reduce hepatic glucose production, thereby contributing to improved glycemic control <sup>(48)</sup>.
- Insulin Sensitizing Effects:** *Moringa* extracts have been reported to enhance insulin sensitivity in peripheral tissues, allowing cells to respond more effectively to insulin and facilitating glucose uptake. <sup>(49)</sup>.
- Antioxidant and Anti-inflammatory Activities:** *Moringa's* antioxidant and anti-inflammatory properties help mitigate oxidative damage to pancreatic beta cells, reduce inflammation in insulin-sensitive tissues, and improve overall metabolic health, thereby contributing to its antidiabetic effects <sup>(50)</sup>.
- Glycemic Control in Animal Studies:** Several animal studies have demonstrated the antidiabetic effects of *moringa* extracts, showing improvements in fasting blood glucose levels, oral glucose tolerance, insulin levels, and markers of insulin resistance. These findings support the potential therapeutic use of *moringa* in managing diabetes <sup>(51)</sup>.

**CNS ACTIVITY:** The central nervous system (CNS) properties of *Moringa oleifera*, refer to its potential effects on brain function and neurological health. Beneficial effects on the CNS.

- Neuroprotective Effects:** *Moringa* contains bioactive compounds such as flavonoids, phenolics, and antioxidants, inflammation, and neurotoxicity, which are implicated in neurodegenerative diseases such as Alzheimer's and Parkinson's disease <sup>(53)</sup>.
- Cognitive Enhancement:** Some studies suggest that *moringa* may enhance cognitive function and memory. Compounds found in *moringa* leaves have been reported to improve spatial learning and memory retention in animal models. These cognitive-enhancing effects may be attributed to the neuroprotective and antioxidant properties of *moringa* <sup>(53)</sup>.

3. **Anxiolytic and Antidepressant Effects:** Preliminary studies suggest that *moringa* extracts may have anxiolytic (anti-anxiety) and antidepressant properties. These effects may be mediated by the modulation of neurotransmitter levels <sup>(54)</sup>.
4. **Anti-inflammatory Effects:** in the Brain: Chronic neuroinflammation is associated with various CNS disorders, including Alzheimer's disease and multiple sclerosis. *Moringa's* anti-inflammatory properties may help reduce neuroinflammation and protect against neuronal damage <sup>(55)</sup>.

**ANTI-INFLAMMATORY AND ANALGESIC PROPERTIES:** *Moringa oleifera*, possesses anti-inflammatory and analgesic properties:

1. **Anti-inflammatory Effects:** *Moringa* contains bioactive compounds such as flavonoids, phenolics, and isothiocyanates, which have been shown to exert anti-inflammatory effects by inhibiting pro-inflammatory mediators and pathways <sup>(56)</sup>.
2. **Analgesic Effects:** The analgesic effects of *moringa* may be attributed to its ability to modulate pain perception pathways in the central nervous system and reduce inflammatory pain by inhibiting the release of inflammatory mediators such as prostaglandins <sup>(57)</sup>.
3. **Inhibition of Inflammatory Enzymes:** *Moringa* has been shown to inhibit the activity of inflammatory enzymes such as cyclooxygenase (COX) and lipoxygenase (LOX), *moringa* helps suppress inflammation and reduce pain associated with inflammatory conditions <sup>(58)</sup>.

#### **EFFECTS ON THE REPRODUCTIVE SYSTEM:**

##### **1. Male Reproductive Health:**

- **Sperm Quality:** Some studies suggest that *moringa* may have beneficial effects on sperm quality. *Moringa* extracts have been reported to improve sperm count, motility, and morphology in male rats <sup>(59)</sup>.
- **Hormonal Regulation:** *Moringa* may also modulate hormone levels involved in male reproductive function. In animal studies, *moringa* supplementation has been associated with increased testosterone levels and improved reproductive hormone balance <sup>(60)</sup>.

##### **2. Female Reproductive Health:**

- **Menstrual Regulation:** *Moringa* has been traditionally used to regulate menstrual cycles and alleviate menstrual discomfort <sup>(61)</sup>.
- **Fertility Enhancement:** Preliminary studies indicate that *moringa* supplementation may improve female fertility by supporting ovarian function and enhancing reproductive hormone levels <sup>(62)</sup>.

**CONCLUSION:** The diverse phytochemical composition of *moringa*, including flavonoids, phenolics, alkaloids, and vitamins, contributes to its therapeutic potential. These bioactive compounds exert their effects through multiple mechanisms, such as scavenging free radicals, modulating inflammatory pathways, inhibiting microbial growth, regulating glucose metabolism, protecting liver cells, and potentially influencing neurological and reproductive function.

**Declaration of competing interest:** The authors declare no conflict of interest.

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