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Moringa Oleifera Pharmacological Uses: Recent Advancements and Translational Research

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Abstract

Background: *Moringa oleifera* Lam., widely known as the "Miracle Tree" or "Drumstick Tree," is a perennial plant of the Moringaceae family recognized for its dual role in "medicine–food homology." Indigenous to the sub-Himalayan regions of Asia and widely naturalized in Africa, it is celebrated for its rapid growth, drought resistance, and extraordinary nutritional density.

Objective: This paper reviews the pharmacological potential, phytochemical composition, and recent translational research surrounding *M. oleifera*, focusing on its transition from traditional medicine to modern therapeutic applications.

Methods: The study synthesizes current knowledge on the nutritional and chemical profiles of various plant parts (leaves, seeds, roots, bark, and flowers) and examines their efficacy against chronic diseases through recent preclinical and clinical findings.

Results: *Moringa oleifera* is a potent source of proteins, essential amino acids, vitamins (A, C, E), and minerals (Calcium, Iron, Potassium). Phytochemical analysis reveals a rich concentration of flavonoids, polyphenols, and isothiocyanates, which contribute to its significant antioxidant, anti-inflammatory, and antimicrobial properties. Recent advancements highlight its potential in:

Oncology: Utilizing nano-encapsulation (PLGA-CS-PEG nanoparticles) to enhance the delivery of leaf extracts against colorectal, liver, and breast cancers.

Metabolic Disorders: Managing blood glucose levels in diabetes and reducing systolic/diastolic pressure in hypertension.

Dermatology & Virology: Promoting collagen synthesis and skin healing, while demonstrating inhibitory effects against respiratory viruses like HCoV-229E and Measles.

Conclusion: *Moringa oleifera* stands as a versatile, sustainable resource with the potential to combat global malnutrition and serve as a scaffold for novel pharmaceutical developments. While its safety profile is generally favourable, further clinical research is required to standardize dosages and evaluate long-term safety in specific populations, such as pregnant women and individuals with autoimmune conditions.

Keywords: *Moringa oleifera*, Phytochemicals, Translational Research, Nanotechnology, Antihypertensive, Nutritional Security.

INTRODUCTION

A perennial member of the Moringaceae family, Moringa oleifera Lam. (M. oleifera) is also referred to as

the horseradish tree or drumstick tree. It has substantial therapeutic significance and is acknowledged as a "medicine–food homology" plant. In the 1960s, the tree was brought to China's Yunnan Province. M. oleifera, also known as the "Tree of Wonders," "Tree of Life," and "Diamond of Plants," is extensively grown throughout Africa and Asia because of its resistance to drought, quick growth, and high nutritional content.

Each of this adaptable plant's edible parts—leaves, pods, fruits, seeds, blossoms, and roots—has unique biological functions. Different plant parts have long been utilized in India and Africa to treat ailments like diabetes, skin diseases, low immunity, arthritis, and even some types of cancer.

The leaves are the most nutrient-dense and medicinally significant part of the plant. These leaves have a lot of development potential and are simple to collect and process. China's health authorities authorized M in 2012. oleifera leaves as a novel source of nourishment. The leaves provide high levels of protein, calcium, fiber, vitamins, and are low in fat. They are useful in preventing or treating malnutrition because they also contain certain anti-nutritional elements (Oduro et al., 2008). Interestingly, the dry leaf matter has at least 20% protein (Avilés-Gaxiola et al., 2021; Peñalver et al., 2022), placing M. oleifera as a major plant-based protein source.(1)

Often known as the “miracle tree,” M. oleifera grows in nearly all tropical and subtropical regions, although it is believed to have originated in Afghanistan, Bangladesh, India, and Pakistan. The Moringa genus comprises 13 species, but M. oleifera is the most renowned due to its nutritional applications, as well as its uses in biogas production and fertilizers. Its remarkable resilience to drought increases its adaptability worldwide.

Nearly every component of the tree supplies vital nutrients. Calcium, potassium, minerals, and beta-carotene are especially abundant in the leaves. Dried leaves can be used in moisturizers since they contain roughly 70% oleic acid. Leaf powder is commonly consumed with beverages, with “Zija” being especially popular in India.

Other parts of the tree possess therapeutic benefits:

Bark: Traditionally used to treat hypertension, toothaches, and ulcers.

Roots: Used to treat paralysis, parasite infections, and toothaches.

Flowers: As aphrodisiac, anti-ulcer, and anti-enlarged spleen.

M. oleifera is especially useful for treating newborn and nursing mother malnutrition.(1)

History

According to numerous African languages, moringa was previously known as "Nebedaye," which translates to "the one that never dies." The plant was found in the northern part of India circa 2000 BC. The plant was dubbed "The Miracle Tree" because Indian traditional physicians were the first to recognize its effectiveness and efficiency. The plant then became an essential component of the age-old Ayurvedic medical practice due to its efficacy after being consumed by the royal family.

In ancient India, the therapeutic qualities of the plant were thought to be able to ease the tension and wounds sustained in combat while also giving their soldiers the vigor and stamina they needed to fight. Ancient Egyptians valued the plant's oil, which they used in place of sunscreen. However, ancient Greeks in Europe discovered the plant's many beneficial health benefits, and when they were introduced to the Roman Empire, the word quickly spread across the Roman Empire. Since then, the moringa plant has spread to numerous other nations worldwide.(2)

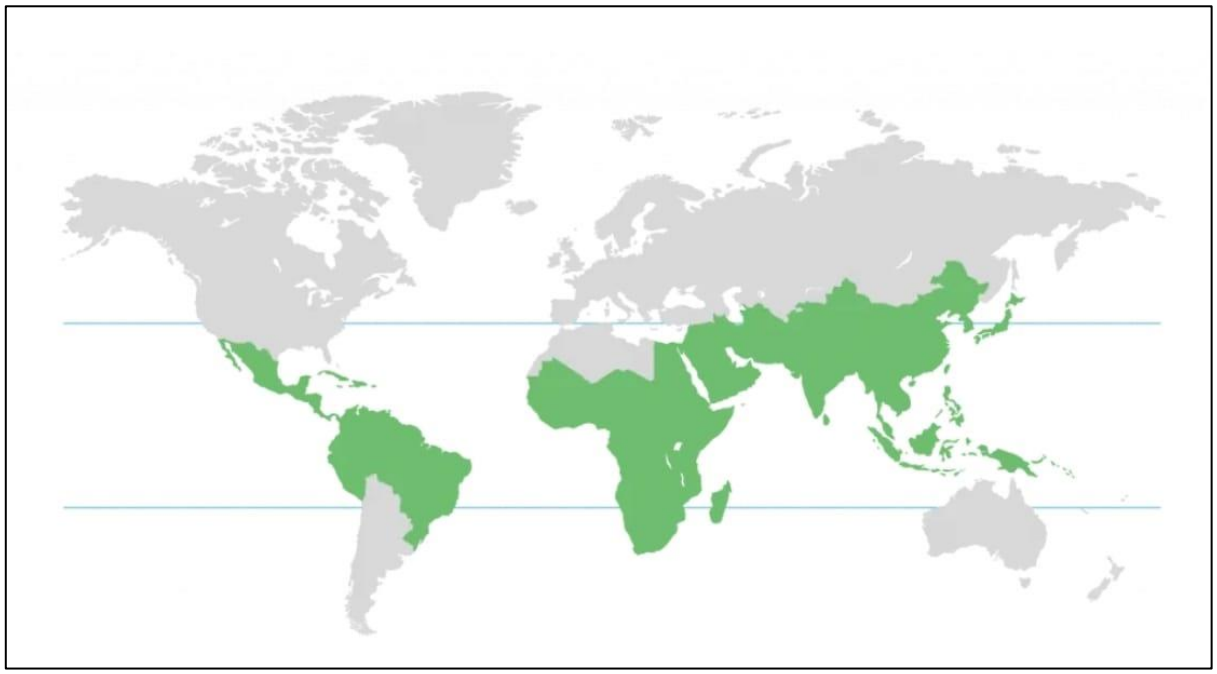


Fig 1: Expansion of Moringa in other countries in the world

Roles of Moringa oleifera in Phytochemistry

Effects of Antioxidants: The high concentration of antioxidants, especially flavonoids and polyphenols, helps scavenge free radicals and shield cells from oxidative damage, which can result in long-term illnesses including cancer and heart disease.

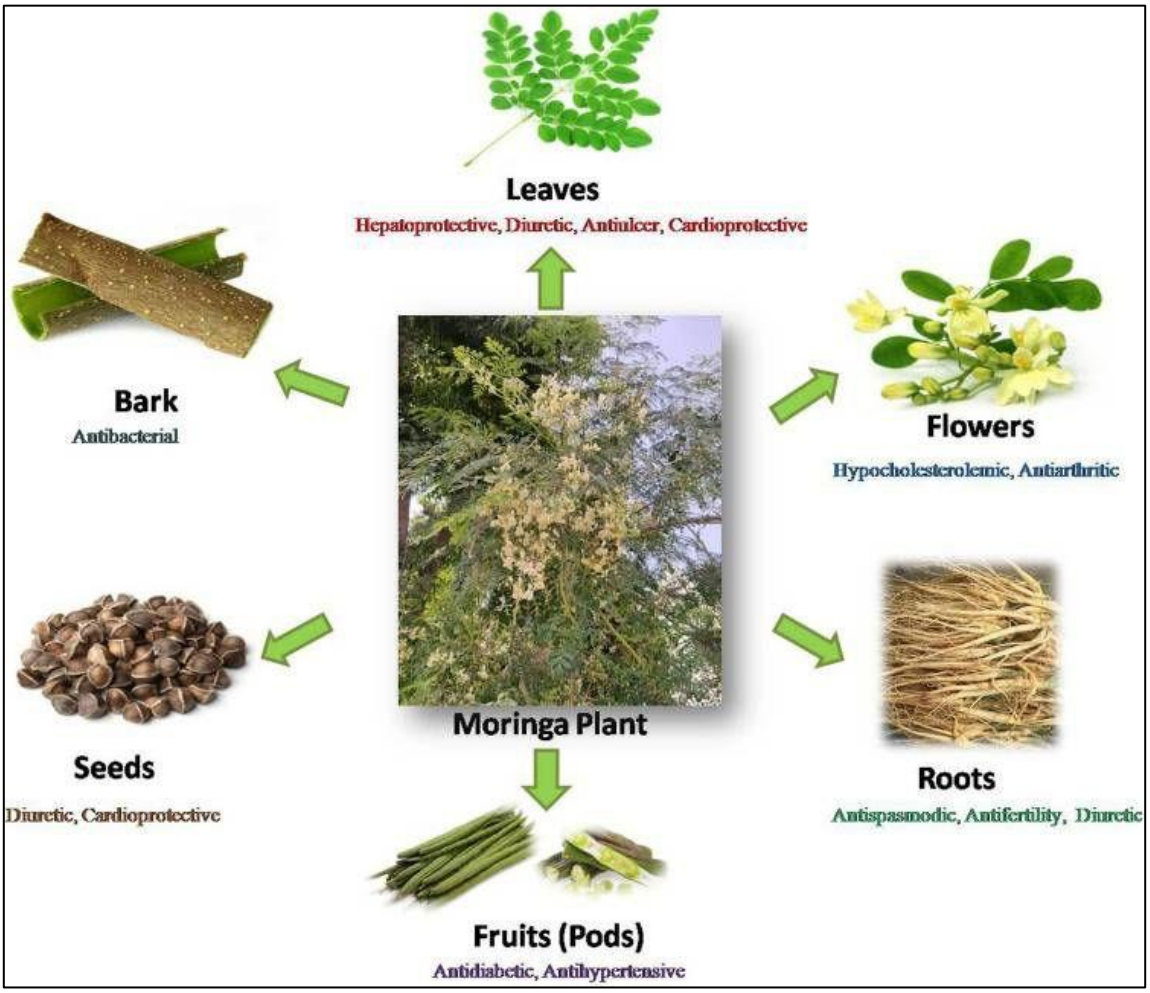
Anti-inflammatory Properties: It has been demonstrated that substances such as flavonoids, terpenoids, and tannins can lessen inflammation, which is connected to a number of chronic diseases. Disease prevention: It is thought that phytochemicals are what give plants their ability to treat diabetes, cancer, heart disease, and neurological conditions. For instance, some substances may prevent the growth of cancer cells and improve the effectiveness of chemotherapy.

Support for the Immune System: The plant includes phytochemicals with immunomodulatory qualities, which can help control and accelerate the immune system's reaction.

Nutritional value: In addition to its therapeutic properties, Moringa oleifera offers a comprehensive source of vital vitamins, minerals, and proteins.

Functions as antimicrobials and protectors: Phytochemicals help plants combat infections and shield vital organs like the liver.(3)

Moringa Oleifera - Multi-purpose tree



PLANT PROFILE:

Synonyms- Moringa pterygosperma Gaertn, Hyperanthera moringa, and Guilandina moringa. Illeg. Nom.

Biological Source- It may include dried long, thin, triangular Moringa oleifera seedpods that are part of the species. The Moringaceae.

Geographical Source- The plant known as moringa is indigenous to the sub-Himalayan regions of Bangladesh, Afghanistan, Pakistan, and India. It grows in the tropics as well. Medicine is made from the leaves, bark, fruit, flowers, seeds, and root.

- **Morphology-**

Colour - Green

Odour - Characteristics

Taste - Characteristics

Shape - Long, slender

Size - Height is 10m to 12 m and diameter is 45cm

- **Chemical Constituents –**

Isothiocyanates include 4-{(2'-O-acetyl-a-L-rhamnosyloxy) benzyl) Isothiocyanates (RBITC; a 2'-acetylated glycoside of benzylisothiocyanate), a 4'-acetylated variant (seeds), and a completely no acetylated 4-(alpha-L-Rhamnosyloxy) benzyl Isothiocyanates Nitrate, Pterygosperma, Crypto-

chlorogenic acid Quercetin, Quercetin 3-O-BD-(600-O-malonyl)-glucoside, the isomer Isoquercetin, Kaempferol and its 3-glucoside Astragalin and its rhamnoglucoside, Procyanidins.
Protease inhibitors (leaves and seeds) that exhibit efficacy against bacterial proteases and serine proteases (trypsin and chymotrypsin) but ineffectual against subtilisin esperase, pronase E, and proteinase K include 4-O-caffeoylquinic acid, 5-0-caffeoylquinic acid, and their glucosides (5).

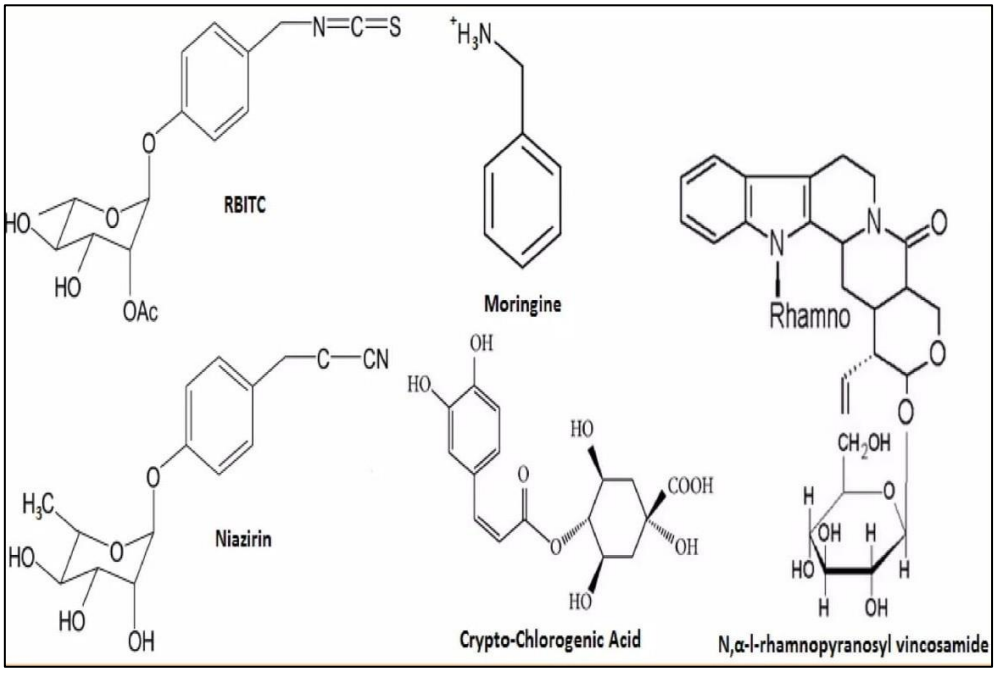


Fig 2.: Chemical Constituents of Moringa

USE –
Moringa is used to treat heart problems, high blood pressure, kidney stones, fluid retention, thyroid disorders, bacterial, fungal, viral, and parasitic infections, as well as "tired blood" (anemia), arthritis and other joint pain (rheumatism), asthma, cancer, constipation, diabetes, diarrhea, epilepsy, stomach pain, stomach and intestinal ulcers, intestinal spasms, headaches, and kidney stones. Moringa seed oil is used as a machine and in food, hair care products, and perfume.(5)

What is Moringa Oleifera?
Originally from northern India, Moringa oleifera, commonly known as "moringa," is now found throughout the tropics. Other names for Moringa include mother's best friend, horseradish tree, and drumstick tree. It grows quickly, reaching a height of 12 meters. The thick, grey bark resembles cork and is peeling in places.
In December and January, it sheds its leaves, then in February and March, new growth begins. When the plant is eight months old, moringa begins to produce cream-colored flowers. The flowering season runs from January to March. The pod is trapezoidal in cross section, 30 to 50 cm long, and contains oily, black, winged seeds. The fruit ripens between April and June (5).

NUTRITIONAL COMPOSITION OF MORINGA

Originally from northern India, Moringa oleifera, commonly known as "moringa," is now found throughout the tropics. Other names for Moringa include mother's best friend, horseradish tree, and drumstick tree. It grows quickly, reaching a height of 12 meters. The thick, grey bark resembles cork and is peeling in places.

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The leaves of Moringa oleifera are a very nutrient-dense dietary supplement because they are a great source of protein and essential amino acids, despite being low in fats and carbohydrates. They provide between 205–350 calories per gram and provide 19–29% protein and 19–37% dietary fiber. Vitamins, minerals, amino acids, and fatty acids are present in significant levels in both the leaves and seeds. Iron, magnesium, folate, and vitamins A, B6, C, and E are important micronutrients. Phytochemicals such vitamins A, B, C, D, and E, folic acid, pyridoxine, and nicotinic acid are found in a variety of plant extracts that are made from leaves, pods, and seeds. These compounds function as natural antioxidants.(8)

Another significant aspect of Moringa is its mineral content. Potassium, zinc, magnesium, iron, sodium, calcium, and copper are all found in its leaves. With a high iron content that frequently outperforms traditional sources like beets and spinach, moringa leaf powder offers more calcium than milk and is a promising natural remedy for iron-deficiency anemia. In comparison to oranges, carrots, yogurt, and bananas, it also provides higher levels of vitamin C, vitamin A, protein, and potassium. Crucially, Moringa leaves contain enough zinc (25.5–31.03 mg/kg) to promote DNA/RNA synthesis and sperm development while also meeting daily nutritional needs.

Polyunsaturated fatty acids (PUFAs), especially linoleic and linolenic acids, which help control cholesterol levels, make up roughly 76% of moringa seed oil. Because of its high PUFA content, it may be a good substitute for olive oil.

Season and location both affect the content of nutrients. For example, iron and vitamin C are more prevalent in the cool-dry season, while vitamin A levels are typically highest during the hot-wet season (9,10).

Macronutrient profile of Moringa for 100g

Nutrients	Fresh leaves	Dry leaves	Leaf powder	Seed
Calories (cal)	92	329	205	--
Protein (g)	6.7	29.4	27.1	35.97 plus/minus 0.19
Fat (g)	1.7	5.2	2.3	38.67 plus/minus 0.03
Carbohydrate	12.5	41.2	38.2	8.67 plus/minus 0.12 (g)

- **Micronutrient profile of Moringa for 100g**

Nutrients	Fresh leaves	Dry leaves	Leaf powder	Seed
Vitamin B1 (mg)	0.06	2.02	2.64	0.05
Vitamin B2 (mg)	0.05	21.3	20.5	0.06
Vitamin B3 (mg)	0.8	7.6	8.2	0.2
Vitamin C	220	15.8	17.3	4.5 + 0.17 -
Vitamin E	448	10.8	113	751.67+ 4.41 -
Calcium (mg)	440	2185	2003	45
Magnesium (mg)	42	448	368	638+8.66 -
Phosphate (mg)	70	252	204	75
Potassium (mg)	259	1236	1324	-
Copper (mg)	0.07	0.49	0.57	5.20 + 0.15 -
Iron (mg)	0.85	25.6	28.2	-
Sulphur (mg)	-	-	870	0.05

1. EFFECT OF MORINGA ON DISEASE:

A. CANCER

Ancient civilizations like Egypt and China have been using botanical-based treatments for thousands of

years. Since they provide therapeutic agents for a wide range of disorders, these natural treatments have always been significant in the healthcare industry. To prevent the negative effects and high expense of chemotherapy, people in affluent nations have been using natural and alternative treatments more and more in recent years (Abd-Rabou, 2011). Numerous studies have demonstrated that naturally occurring phytochemicals, particularly phenolic compounds like flavonoids and alkaloids that are included in regular diets, can function as chemopreventive agents and activate the pathways that lead to the death of cancer cells (Abd-Rabou, 2016; Ahmed et al., 2015; Gao et al., 2002; Goodman, 2000).(34)

One such medicinal plant is the well-known Moringa oleifera, which belongs to the Moringaceae family. It comes from the sub-Himalayan areas of India, Pakistan, Bangladesh, and Afghanistan and is commonly referred to as the drumstick tree. Because of its many medical uses, moringa was first employed by the ancient Greeks and Egyptians before spreading throughout the world (Oliveira et al., 1999).

One such medicinal plant is the well-known Moringa oleifera, which belongs to the Moringaceae family. It comes from the sub-Himalayan areas of India, Pakistan, Bangladesh, and Afghanistan and is commonly referred to as the drumstick tree. Because of its many medical uses, moringa was first employed by the ancient Greeks and Egyptians before spreading throughout the world (Oliveira et al., 1999). Extracts from the roots and leaves have demonstrated action against Trypanosoma brucei, the parasite that causes trypanosomiasis, and root decoctions have also been used to treat malaria (Mekonnen and Gessesse, 1998). Research also demonstrates that when mixed with extracts from Moringa, cultured HepG2 liver cancer cells exhibit heightened sensitivity to the hepatotoxic substance galactosamine (Mekonnen et al., 2005; Gomez-Lechon et al., 1988).(35)

Tesfay et al. recently examined the antioxidant content of different plant sections and discovered notable variations. According to Tesfay et al. (2011), roots had the highest carotenoid concentration, whereas leaves had the highest levels of phenols, ascorbic acid, total antioxidants, and crude protein.

With over 14 million new cases and 8.2 million deaths per year, cancer continues to be a major global health burden (Fuglie, 1999). Over the next 20 years, these figures are predicted to increase by 70%. Lung, prostate, colorectal, stomach, and liver cancers are the most prevalent cancers in men, whereas breast, colorectal, lung, cervical, and stomach cancers are the most common in women (WHO, 2015; De Martel et al., 2012).

More recently, Al-Asmari et al. (2015) investigated how extracts from Moringa leaves and bark affected colorectal (HCT-8) and breast (MDA-MB-231) cancer cells. They discovered that the extracts led to cell-cycle arrest, apoptosis, and observable alterations in the behavior of cancer cells. Several compounds with potent anticancer effects were also identified by GC-MS analysis (Al-Asmari et al., 2015; Al-Sharif et al., 2013; Sui et al., 2005; Matsuda et al., 2007; Peng et al., 2008). Likewise, Moringa leaf extracts exhibit a more potent anticancer impact on HepG2 liver cancer cells than bark extracts, according to Balamurugan et al. (2014).(36)

Researchers are currently investigating nano-formulations to enhance cancer treatment delivery due to the quick development of nanotechnology in medicine (Shoo et al., 2007; Park et al., 2008). The biocompatibility, biodegradability, and extended circulation time of PLGA nanoparticles coated with chitosan (CS) and polyethylene glycol (PEG), sometimes referred to as PLGA-CS-PEG, provide a number of benefits (Sumer and Gao, 2008; Parveen and Sahoo, 2011). Despite having FDA approval, phagocytes swiftly eliminate PLGA.

The nanoparticles are protected and made more stable by coating them with CS and PEG (Gref et al., 1995; Hu et al., 2008; Illum, 1998; Parveen et al., 2010). Additionally, PEG-modified chitosan enhances

body compatibility and decreases protein adsorption (Zhang et al., 2002; Amiji, 1997). Moringa extracts may become more efficient against cancer cells thanks to this technology.(37)

Examining the anticancer potential of Moringa oleifera leaf (ML), root core (Rc), and root outer (Ro) extracts cultivated in Egypt against colorectal, liver, and breast cancer cell lines as well as normal kidney cells was the goal of the current study. This study is interesting because it compares the effects of free Moringa leaf extract (ML) and its nano-encapsulated version (MLn) on drug-resistant and susceptible colorectal cancer cells utilizing PLGA-CS-PEG nanoparticles and root components.(38)

B) DIABETES

Diabetes continues to be a significant health concern for Americans, costing billions of dollars annually. Serious side effects like kidney damage, neurological issues, blindness, and stroke can result from it. Type 1 diabetes occurs when the body stops making insulin, while Type 2 diabetes occurs when the body continues to produce insulin but improperly uses it.

Traditional medicine still plays a significant part in daily healthcare in many poor nations. The World Health Organization acknowledges these customs and promotes studies on therapeutic herbs that could aid in the treatment of chronic illnesses.

Even though Moringa has showed promise in preliminary research, there is still a lack of human studies and inconclusive outcomes. As a result, a scoping review is helpful for compiling recent results, spotting patterns, and emphasizing areas that require more investigation. Examining previous research on the potential effects of moringa on blood glucose levels in humans and animals is the aim of this study.(17, 18, 19)

C) HYPERTENSION

One of the main preventable causes of cardiovascular disease (CVD) and global mortality is hypertension, which is defined as having a systolic blood pressure of 140 mm Hg or higher or a diastolic blood pressure of 90 mm Hg or higher. Its influence on the world has increased significantly; from 1990 to 2019, the number of persons with hypertension almost doubled, reaching 1.13 billion. Countries with low and moderate incomes have seen the majority of this increase. Blood pressure can be lowered by altering one's lifestyle to include eating less salt, drinking less alcohol, eating more fruits, vegetables, and low-fat dairy products, losing weight, exercising frequently, and giving up smoking. Many people, nevertheless, struggle to keep up these routines on a regular basis. These steps might not always be sufficient to return blood pressure to normal, even when taken.

Doctors frequently suggest oral medicines for these reasons. Despite their effectiveness, many medications can have negative side effects and are not always readily available, especially in underdeveloped nations where supply chains and healthcare systems confront numerous obstacles.(29, 30)

Owing to these drawbacks, there is increasing curiosity on how traditional medicinal plants and food can help prevent and treat hypertension. Natural substances found in many medicinal plants have the potential to lower blood pressure. In general, they are reasonably priced. widely available, and have fewer side effects, making them especially valuable in resource-limited settings.

Moringa oleifera is one of these plants that has drawn a lot of interest due to its nutritional content and therapeutic qualities. Specifically, its leaves are abundant in proteins, vitamins (including β-carotene and α-tocopherol), minerals (such potassium, calcium, magnesium, and iron), dietary fiber, and other bioactive substances. Moringa leaves have long been utilized in traditional medicine in developing nations to treat ailments like diabetes, heart disease, and high blood pressure because of their nutrient-dense profile.(31, 32)

While a number of reviews have examined M. oleifera's wider health advantages, including as its impact on heart function and cardiometabolic health, no recent research has particularly examined its effects on reducing blood pressure, or hypotension, based on preclinical and clinical data. By noting the limitations in previous studies, proposing probable physiological pathways and bioactive chemicals that may be responsible for these effects, and reviewing current results on how Moringa affects blood pressure, this review seeks to close that gap. It also highlights areas for further research and talks about the difficulties in employing M. oleifera as an antihypertensive drug.(33)

D) HAIR AND SKIN

Due to their potential to maintain skin that is youthful-looking, vibrant, and healthy, moringa powder and oil are often used in skincare products. These advantages are mostly due to their antioxidant concentration. Antioxidants aid in shielding the skin from free radicals, which are unstable chemicals that can harm skin tissues and cause wrinkles and other obvious aging symptoms.

Vitamin C, which helps the skin heal itself, is another component that is naturally abundant in moringa. It contains cytokinins, which are plant hormones that may slow down cell disintegration and assist preserve normal cell function. Moringa is particularly intriguing for promoting skin elasticity and firmness because of these characteristics.

Additionally, the antioxidants in moringa may help protect the skin from UV rays and other environmental stresses. Moringa has also historically been used to treat mild skin irritations. It is thought to have mild antibacterial qualities, which is why many cultures have used it for minor cuts, bruises, bug bites, abrasions, and sun-exposed skin. But even while these uses are a part of traditional practices, professional medical advice should always be sought for serious or persistent skin issues.(21)

By stopping bacteria from growing on the skin, moringa's antibacterial properties may help lessen acne. Additionally, it is frequently used to lighten blackheads, pimples, dark spots, and blemishes. To assist them get cleaner skin, some people apply a paste prepared from moringa leaves to particular parts of their face.(22)

In addition to its direct application, moringa may help the skin when ingested as a component of a healthy diet. In addition to being nutrient-dense, moringa seeds and powder are thought to aid the body's natural detoxifying processes. A healthy system may encourage a brighter complexion because interior toxins are frequently linked to skin issues, especially acne.

Additionally, moringa includes minerals that promote the formation of collagen, which is crucial for keeping skin smooth and firm. Although additional clinical study is required to completely establish these effects, this may help improve skin texture and lessen the appearance of enlarged pores.(23)

Commonly used as a moisturizer, moringa oil may improve the tone of the skin overall. It has long been thought to make skin smoother and more even-looking by lessening the visibility of dark spots, acne scars, and other small imperfections. Preparations produced from crushed moringa leaves are frequently said to offer comparable advantages.(24)

E) RESPIRATORY VIRUSES

The plant Moringa oleifera, or M. oleifera, is employed in both medicinal and non-medical industries and is well known for its many advantageous qualities. Plants are still a valuable source for the development of novel medications since they naturally produce bioactive chemicals.

Researchers used both conventional maceration and microwave-assisted extraction (MAE) to analyze two cultivars of M. oleifera leaves, Salento and Barlet. When evaluated on Vero CCL-81 and Vero/SLAM cells at doses ranging from 25 to 400 µg/mL, the extracts made by MAE demonstrated less cytotoxicity

than those made by maceration. The MAE extracts, in other words, were kinder and less damaging to the cells.(25, 26)

The scientists then assessed these extracts' antiviral properties against the measles virus (MeV) and human coronavirus 229E (HCoV-229E), two respiratory viruses. Both viruses were inhibited by the extracts, which also markedly reduced their capacity to adhere to and penetrate cells. levels ranging from 50 to 12 µg/mL. The Salento variant had an inhibitory concentration (IC_{50}) of 6 µg/mL for MeV and 21 µg/mL for HCoV-229E, indicating its exceptional efficacy.

The researchers used high-performance liquid chromatography (HPLC) to identify a number of important substances found in the extracts, such as glucomoringin (GM), quercetin 3-O-β-d-glucopyranoside (QGP), neochlorogenic acid, and chlorogenic acid.

All things considered, the results point to M. oleifera as a potential natural remedy for viral infections. It seems to work best in the early phases of infection, most likely by severing viral particles and stopping them from joining host cells.(27, 28)

INCLUSION CRITERIA OF MORINGA

Because of its remarkable nutritional content, therapeutic qualities, and adaptability, Moringa oleifera has become widely accepted worldwide. Known as a "superfood," moringa has long been utilized in Southeast Asia, Africa, and India. It is well-liked in both rural and urban areas since its leaves, seeds, pods, and flowers are recognized as abundant providers of vitamins, minerals, proteins, and antioxidants. Moringa is becoming more widely recognized as a natural treatment for inflammation, diabetes, hypertension, malnutrition, and other lifestyle-related conditions by health-conscious consumers, dietitians, and herbal practitioners.

Moringa leaf extracts and powder are commonly used in the culinary sector as supplements in baked goods, teas, smoothies, and nutraceuticals. Its low cost, sustainable cultivation, and safety profile all contribute to its increased acceptance in developing nations. Its worldwide acceptance in the health, beauty, and pharmaceutical industries has also been reinforced by scientific studies verifying its medicinal advantages. All things considered, Moringa is generally acknowledged as a multifunctional, nutrient-dense, health-promoting plant with a great deal of promise for future uses.

EXCLUSION CRITERIA OF MORINGA

Although Moringa oleifera is highly prized for its nutritional and therapeutic qualities, some restrictions and exclusions should be taken into account to guarantee suitable and safe use. People who are known to be allergic to moringa or any of its ingredients should not eat it. Extracts from the roots and bark of Moringa are not recommended for pregnant women as they may induce uterine contractions. Moringa should be used with caution by anyone taking blood thinners, diabetic medications, or antihypertensives because it may intensify their effects and cause side effects.

Because there is no information on the long-term safety of moringa oleifera, participants with autoimmune diseases, liver problems, or chronic kidney disease are frequently excluded from research trials. Furthermore, consuming too much Moringa leaf powder may upset your stomach, thus people with sensitive digestion might not be allowed to participate in supplement trials. Because they contain alkaloids that can be poisonous in high concentrations, many plant parts—especially the roots and bark—are not recommended for regular consumption.

FUTURE ADVANCEMENT OF MORINGA

Nutritional applications:

- Market for superfoods and supplements: Moringa is a common ingredient in supplements and health foods due to its high vitamin, mineral, and protein content.
- Food fortification: Its seeds can be processed into high-protein flour and used to enrich staple meals to fight malnutrition, especially in semi-arid areas.

Cosmetics-

Premium seed oil: Because of its moisturizing and anti-aging qualities, moringa seed oil is a valuable and in-demand product in the cosmetics business.

Pharmaceuticals and medicine:

- Therapeutic properties: Future medication development will concentrate on this area as research continues to examine its potential as a therapeutic agent for diseases like diabetes, inflammation, and cancer.
- medication delivery: Research is being done on the use of gum exudates in biodegradable medication delivery systems.

Sustainable agriculture and environment

Climate-smart crop: Because of its rapid growth and adaptability, this crop can be extremely important in climate change-vulnerable areas, assisting with water scarcity and food security. • Land restoration and agroforestry: Its green manure and fence-building qualities, as well as its capacity to absorb dyes and heavy metals, make it suitable for use in agroforestry systems and aid in environmental cleanup.

CONCLUSION

Often referred to as the "miracle tree," Moringa oleifera is a very abundant plant that offers an amazing combination of vitamins, minerals, proteins, antioxidants, and other beneficial substances through its leaves, seeds, pods, and roots. Moringa can help lower and support the management of common health issues like diabetes, high blood pressure, cancer, and some viral infections, according to the nutritional data and therapeutic trials evaluated. It is a potential natural supplement and a valuable component of upcoming medications, health foods, and nutritional goods because of its potent antibacterial, anti-inflammatory, and antioxidant properties. All things considered, Moringa oleifera is a very useful, sustainable, and accessible plant that has the potential to significantly enhance human health, particularly for those who are malnourished.

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