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A Comprehensive Review on *Moringa oleifera:* The Green Superfood for Wellness

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Abstract

A pan-tropical plant known as the horseradish tree, *Moringa oleifera*, is also called benzolive, drumstick tree, kelor, marango, mlonge, mulangay, and saijhan.. Every portion of the tree is useful for either nutritional or economic uses because to its high nutritional qualities. It is employed as a possible antibacterial, anticancer, anti-inflammatory, and anti-inflammatory agent. A common natural coagulant used in water treatment is *M. oleifera* seed. There are currently studies in both the academic press and the public literature praising its capacity to lessen a variety of degenerative diseases. A large portion of this enthusiasm appears to be justifiable at first glance and in light of the number of reports that are now available. However, it is crucial to distinguish between anecdotal and solid scientific proof. In order to accomplish this, pertinent experimental and review publications were sought out and carefully reviewed in order to pinpoint current patterns and trends on this subject.

Keywords: *Moringa oleifera*, Antidiabetic; Anticancer; anti-inflammatory, and antimicrobial agent.

1. Introduction

In tropical and subtropical areas, the fast-growing tree *Moringa oleifera* is commonly farmed. It has drawn a lot of attention since the tree's different parts, including the leaves, seeds, bark, blossoms, and roots, contain therapeutic qualities that have been used in traditional medicine for generations.Because of its many applications and adaptability, *Moringa oleifera* is known as a miracle tree. It also includes nutrients and secondary metabolites that have positive health effects (Biswas et al. 2020; Zainab et al. 2020). The Indian plant *Moringa oleifera* is found in tropical and subtropical climates all over the world. Its common names include "drumstick tree" and "horseradish tree." Because Moringa can resist both extreme drought and light frost, it is widely grown around the world It is a perennial softwood tree with low-quality timber that has been used for ages in traditional medicine and industry. It is currently planted in West, East, and South Africa, tropical Asia, Latin America, the Caribbean, Florida, and the Pacific Islands. It is already a significant crop in India, Ethiopia, the Philippines, and the Sudan. It is a tree that can be grown simply and

is well known for requiring little water and nutrient-rich soil, making it resistant to both drought and barren soil. It can withstand a wide range of yearly precipitation, with minimum requirements of 250 mm and high requirements of over 3000 mm.[2].

There is some evidence to support the claims that *M. oleifera* has therapeutic properties, including hypotensive, hypoglycemic, radioprotective, anticancer, thyroid hormone-regulating, antiobesity, antipyretic, antiepileptic, and diuretic properties, among others.[3-7]. Malnutrition can be treated using leaf extracts, which are also used to help breastfeeding women produce more milk. The usage of *M. oleifera* as a complementary medicine option or for use in the alleviation and prevention of disease symptoms has been suggested by numerous specialists. However, Western (traditional) medicine has been remarkably cautious in researching its nutritional and therapeutic possibilities despite these studies, evaluations, recommendations, and widespread claims. *M. oleifera* has received attention among other "healthy" options due to the recent "healthy eating" trend, in which many customers are inclined to consume wholesome foods, are dubious of synthetic drugs, as well as the advancement of "green" medicine, etc. *M. oleifera* is mostly produced in India and traded internationally as canned goods, fresh fruits, oil, seeds, and leaf powder [8].

According to Volza's India Export data, Indonesia comes in third with 124 shipments, followed by Sri Lanka with 133 and India with 3,901 shipments as the top 3 exporters of Moringa leaf powder. These statistics are current as of May 17, 2023, and are based on Volza's India Export Data of Moringa Leaf Powder, sourced from export import cargoes in 70 countries, together with names of buyers, suppliers, and senior decision makers' contact details, including phone numbers, email addresses, and Linked In profiles.

There are studies on *M. oleifera's* medicinal and functional characteristics from many different parts of the world, particularly developing regions. The phytochemical, nutritional, therapeutic, medical, environmental, agricultural, and socioeconomic properties of this plant have been claimed, and efforts have been undertaken to sort through the current scientific data supporting these assertions. The studies that have been evaluated offer persuasive, if early experimental, proof of the plant's medicinal potential. Before being used, *M. oleifera* products and preparations must be accurately chemically characterized and standardized.

2. Nutritional properties

The ability of *Moringa oleifera* to treat a wide range of ailments and its many nutritional applications have earned it the nickname "Miracle Tree." Reserved nutrients are present in all plant parts. Malnutrition, particularly in young children and nursing moms, has been combated by using moringa trees. Minerals like calcium, potassium, zinc, magnesium, iron, and copper are abundant in the leaves of the *Moringa oleifera* plant. The Leaves have a low caloric value and can be included in an obese person's diet. The leaves are abundant in protein, minerals, and all nine necessary amino acids [9]. Pods are highly prized for treating digestive issues and colon cancer and contain about 46.78% fibre and 20.66% protein [10].

Additionally prevalent in *Moringa oleifera* are vitamins such vitamin A, vitamin B, beta-carotene, pyridoxine, nicotinic acid, vitamin C, vitamin D, and vitamin E. There are now a lot of studies on the nutritional benefits of moringa, both in academic and lay literature. Any readers who are familiar with the *Moringa* plant will be able to identify the oft-repeated claim made by the Trees for Life organisation many years ago that "ounce-for-ounce, *Moringa* leaves contain more Vitamin A than carrots, more calcium than milk, more iron than spinach, more Vitamin C than oranges, and more potassium than bananas," as well as the claim that the protein quality of Moringa leaves rivals that of milk and eggs.

3. Phytochemical Composition

The bioactive substances flavonoids, phenolic acids, alkaloids, terpenoids, and glucosinolates are abundant in moringa oleifera. Its numerous therapeutic effects, including as its antioxidant, anti-inflammatory, antibacterial, anticancer, hepatoprotective, and immunomodulatory properties, are a result of these substances.

Flavonoids: The Moringa genus' remarkable antioxidant activity is mostly attributable to its high flavonoid concentration. The flavanol and glycoside forms of flavonoids make up the majority of those found in the genus. The genus contains rutin, quercetin, rhamnetin, kaempferol, apigenin, and myricetin as its most prevalent flavonoids.

Glucosinolate: Glucosinolates are present in large quantities in the Moringa species. Glucomoringin (GMG), also known as 4-O-(L-rhamnopyranosyloxy)-benzyl glucosinolate, is the most prevalent glucosinolate found in the species.

Phenolic Acid: Gallic acid is the primary phenolic acid present in the leaves of M. oleifera. Additionally found in the leaves are elagic, ferulic, caffeic, o-coumaric, and chlorogenic acids. Gentisic, syringic, -coumaric, and sinapic acids were found in trace levels.[11,12]

Terpenes: According to [13,14], lutein was the main carotenoid found in the leaves of M. oleifera. According to [14], M. oleifera was devoid of -carotene, which is typically present in green leafy plants. The author made the assumption that lutein had completely replaced all of the -carotene. All-E-luteoxanthin, 13-Z-lutein, 15-Z-carotene, and all-E-zeaxanthin (61) are additional carotenoids that can be found in the plant [14]. From an ethanol extract of the aerial portion of M. peregrina, lupeol acetate, amyrin, and amyrin- were isolated[15].

Medicinal properties: M. oleifera is often referred as a panacea and can be used to cure more than 300 diseases. Moringa has long been used in herbal medicine by Indians and Africans. The presence of phytochemicals makes it a good medicinal agent. Their phenolic compounds in M. oleifera leaves and their health benefits are shown in Table 1

4. Medicinal properties

Since *M. oleifera* may treat more than 300 ailments, it is frequently described to as a panacea. Africans and Indians have traditionally employed moringa in herbal therapy. It works well as a medicinal agent because of the phytochemicals present. **Table 1.** Phenolic compounds in *M. oleifera* leaves and their health benefits are shown in Table 1:

Constituents	Function	Disease protection	Reference
Polyphenols: catechin, epicatechin, ferulic acid, ellagic acid, and myricetin	increases antioxidant enzymes, Suppresses ROS (reactive oxygen Species) formation and scavenges free radicals	kidney protection	[16]
Polyphenols: gallic acid, caffeic acid, and querceti	scavenges free radicals, promotes antioxidant activity and reduces the expression of liver disease markers	non-alcoholic fatty liver antihypertensive	[17] [18]

Flavonoids Quercetin	prevents the increased level of Interleukin 17 (IL-17) via theNFκB (nuclear factor kappa-light-chain enhancer enhancer) pathway, supports a decrease of the level of soluble vascular endothelial growth factor receptor 1 (sFlt-1), and angiogenesis prevents fat accumulation and increases lipolysis by stimulating the AMPK (5' adenosine monophosphate-activated protein kinase) signalling pathway modulates the expression of gene antidiabetes glycogen synthase and stimulates insulin release	antiobesity	[19]

5. Anti-diabetic properties

Type 1 and Type 2 diabetes have both been found to be cured by moringa. Patients with type 1 diabetes do not produce insulin, a hormone that is necessary to keep blood glucose levels at the desired normal range. Insulin resistance is one that is connected to type 2 diabetes. Beta cell malfunction, which fails to detect glucose levels and lowers insulin signalling as a result, may also contribute to type 2 diabetes and result in excessive blood sugar levels[17].

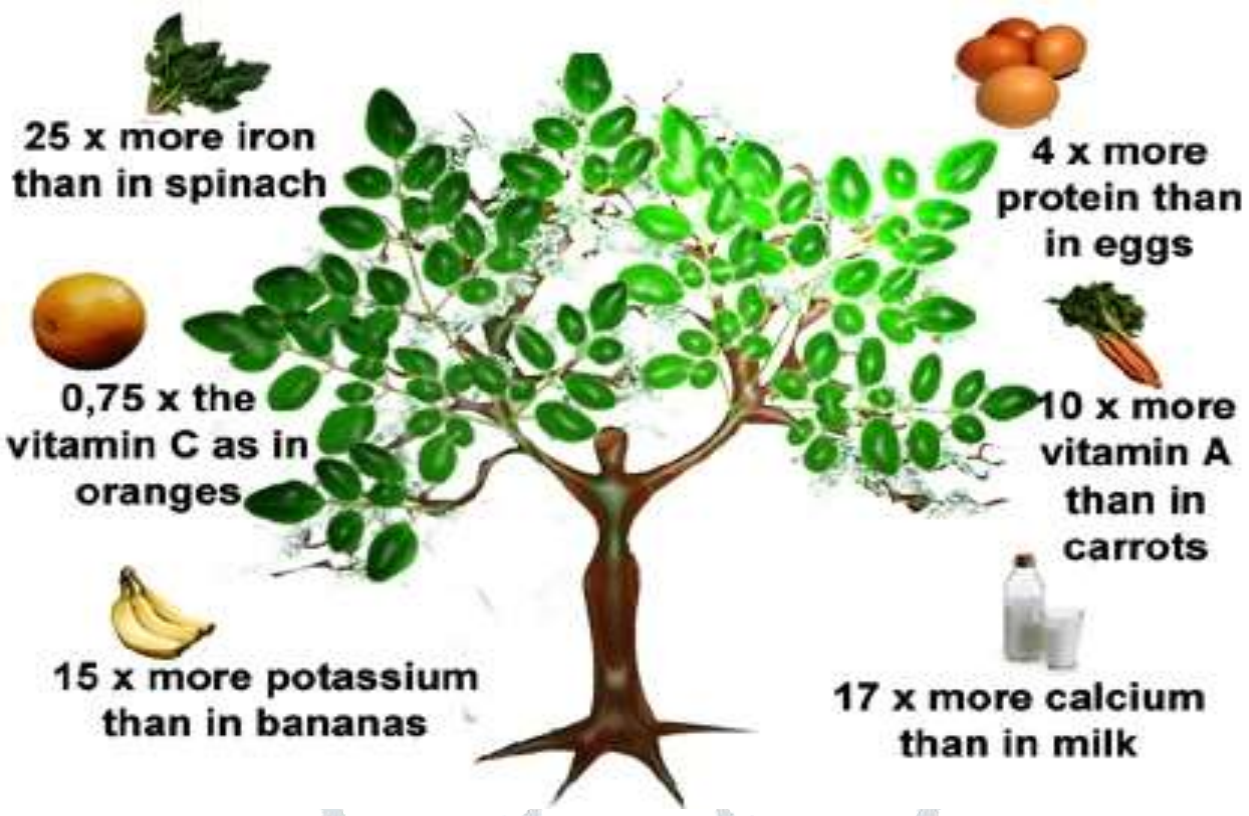

Figure 1. Nutritional Comparison of the Moringa Plant from Different Sources

Numerous research have demonstrated the anti-diabetic properties of moringa. According to a study, *M. oleifera's* aqueous extracts can treat rats with both insulin-resistant Type 2 diabetes and Type 1 diabetes caused by streptozotocin [18]. In a different study, the researchers observed a decrease in fasting blood glucose levels after feeding *Moringa* seed powder to STZ-induced diabetes rats [19]. The antioxidants in moringa can reduce the ROS that STZ induction causes in beta cells [20]. In Beta cells, STZ induces ATP dephosphorylation processes that aid xanthine oxidase in producing superoxide and reactive oxygen species (ROS) [21]. The beta cells in hyperglycemic individuals are destroyed (Fig. 1). As a result, when there is excessive glucose inside the mitochondria, reactive oxygen species are released. Beta cells undergo apoptosis because they produce relatively few antioxidants [22,23]. As a result, there will be less insulin secreted, which will cause hyperglycemia and eventually Type-2 diabetes.It has been suggested that flavonoids like quercitin and phenolics act as antioxidants by scavenging ROS. One theory is that the flavonoids in moringa scavenge the ROS generated from mitochondria, preserving the beta cells and, hence, preventing hyperglycemia [24,25].

6. Anticancer properties

One in seven deaths from cancer are attributable to incorrect medicine, which is a prevalent condition. While there are no known causes for cancer to grow, there are about 2.4 million instances there. The condition can be caused by a number of things, including smoking, inactivity, and radiation exposure [26]. The cost and side effects of cancer therapies like surgery, chemotherapy, and radiation are high. Because *M. oleifera* is natural, dependable, and safe at known quantities, it can be employed as an anticancer drug.Reactive oxygen species (ROS) and cell death are closely related. Numerous environmental conditions cause an excessive amount of ROS to be produced, which progresses into oxidative damage and eventually results in cell death [27].

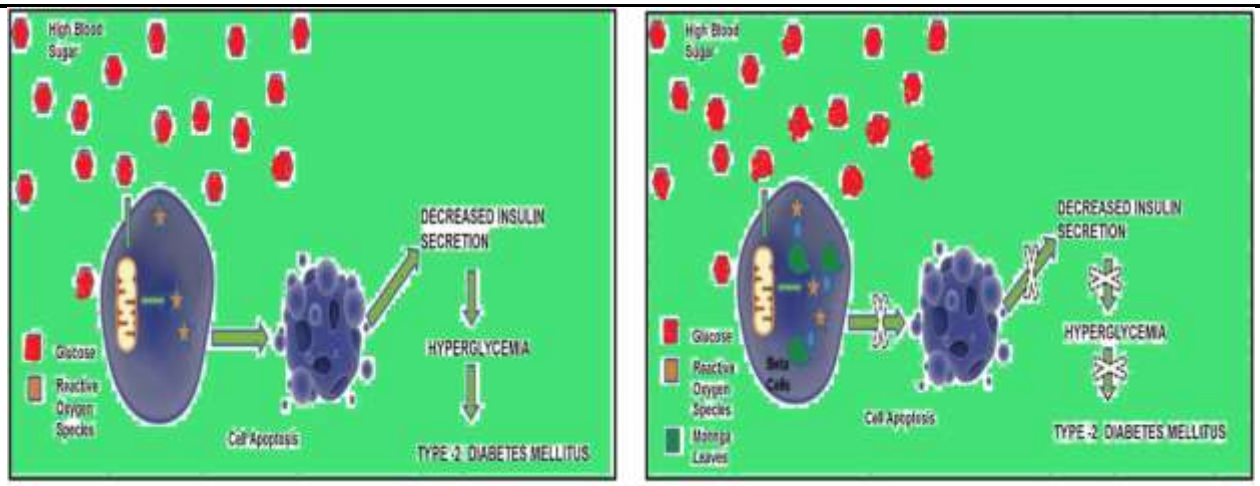

Figure 2. Shows the mechanism through which excessive blood sugar causes diabetes as well as how moringa affects the development of the disease. Reactive oxygen species are created in beta cells' mitochondria during glycolysis, which is fueled by the high blood glucose levels. Beta cell death, reduced insulin production, hyperglycemia, and ultimately Type-2 diabetes are the results of this. However, the administration of moringa can stop beta cells from going through cell death. Antioxidants in moringa work with reactive oxygen species to stop cell damage and other effects [20,17,22,25].

Glucosinolates, niazimicin, and benzyl isothiocyanate are the leaf chemicals thought to be responsible for the anticancer effects. Bioactive Moringa leaf component "Niazimicin" demonstrated potential anticancer action [28]. Seven bioactive substances, including niazimicin, 3-O-(6-oleoyl-D-glucopyranoyl)--sitosterol, -sitosterol 3-O-D-glucopyranoside, -sitosterol, and glycerol-1-(9-octadecnoate), had been extracted from the ethanol extract of the Moringa seed [29]. It has been established that benzyl isothiocyanate and cancer are related. According to research, BITC results in intracellular ROS, which kills cells. This might be one of the factors that makes moringa a potent anticancer agent [30-32].

Zeatin, a naturally occurring cytokinin [33] that has anticancer properties, is beneficial against prostate and skin malignancies, and is a potent antioxidant, is an antiaging chemical found in moringa. On human myeloma cell lines, the Moringa leaves also shown a substantial cytotoxic effect [34]. Analgesic Effects. The leaves, pods, roots, and other components of moringa plants all exhibited analgesic properties. The tail immersion method was used to detect the same analgesic effect in the alcoholic extract of Moringa leaves [35]. A methanol extract of M. oleifera was tested on frogs and guinea pigs in a different study, and the results revealed that the plant's (root bark) significant local anaesthetic activity in both animals [36].

7. Antipyretic Activity

Different extracts (ethanol, petroleum ether, and ethyl acetate, among others) were used to test the antipyretic effect of Moringa in rats, and the seed extracts (ethanol and ethyl) shown a substantial amount of activity [37]. The treatment of various forms of acute and chronic inflammations is one of the most promising applications for moringa extract.Chronic disorders like diabetes, respiratory issues, cardiovascular disease, arthritis, and obesity can all be brought on by inflammation. By inhibiting inflammatory enzymes and proteins in the body, moringa decreases inflammation, and leaf concentrate can considerably lessen inflammation in cells [38].

8. Other Medicinal Uses

The bioactive chemicals in *M. oleifera* pod components exhibit anti-inflammatory activity, which may help to lessen the aetiology of chronic disorders linked to inflammation [39].In guinea pigs administered with nbutanol extract from *M. oleifera* seeds, ovaalbumin-induced airway inflammation was successfully alleviated [40]. It was discovered that

moringa benefits and enhances the state against viral contagiousness. Leaf extracts demonstrated a powerful and selective suppression of the initial stages of HIV-1 infectivity [41]. Fruits from M. oleifera exhibited antihepatitis B virus (HBV) action in hydroalcoholic extract [42]. *Moringa* is a potential source of vitamin A [43] and has the ability to significantly reduce the lack of foods containing vitamin A. Instead, it could aid in less childhood eye issues.

9. Relevance of Moringa oleifera to Socioeconomics

M. oleifera has a variety of intriguing features in addition to being nutritious and therapeutic, making it useful for industrial, agricultural, and aesthetic applications. Agricultural, industrial, and municipal wastewater treatment could all benefit from the usage of moringa oleifera to clean up household water supplies. The natural biocoagulant capabilities of M. oleifera for water were demonstrated in a study by [44]. According to the study, M. oleifera can be utilised commercially to treat wastewater by reducing turbidity, suspended particles, and bacteria. Other studies [45–51] have demonstrated that *M. oleifera* is an efficient, nontoxic, economical, sustainable, and environmentally friendly way to filter water on an aesthetic and microbial level.

Recently, its potential to cleanse industrial wastewaters has come under considerable scrutiny. Some M. oleifera treatments appear to be effective at removing organics from wastewaters. In many parts of the poor world, its usefulness in agriculture has been documented and is now being investigated. [52] It has a remarkable ability to detoxify agricultural wastes because of its coagulation, flocculation, and sedimentation capabilities. Given that it is a rich source of antioxidants, antimicrobials, and coagulating agents, Moringa has a significant potential to substitute chemicals and antibiotics in intensive animal production systems, such as aquaculture.

Moringa-based nutritional supplements, teas, herbal infusions, condiments like curries, drinks, culinary products, and infant formula are all being marketed in many wealthy nations. Although *M. oleifera's* effectiveness is well known in underdeveloped nations, there aren't many industrial uses for its parts yet, especially in Africa. The number of trademarks and industrial, pharmaceutical, medical, and food-processing patents is rising in other parts of the world, including the United States, China, and Europe. It will be impressive to see similar developments in underdeveloped nations. The developing world's involvement in this Moringa commercial development is crucial. The plant is native to this area and has several health, dietary, and economic benefits.

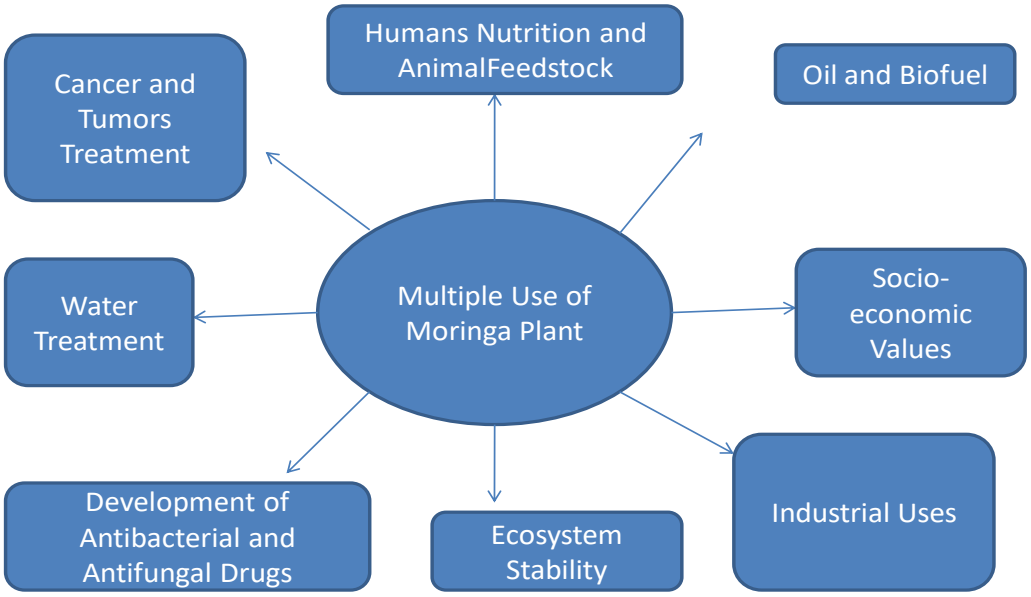

Figure 3:Multiple dimensional uses of *Moringa oleifera*

Conclusions

M. oleifera is a remarkable food crop with clear nutritional, therapeutic, and socioeconomic potentials. Its capacity to control physiological processes as well as to prevent and treat diseases has been extensively studied. The wonder tree's nutrients must be used for a number of things, thus this is crucial. Excellent anti-diabetic and anti-cancer capabilities can be found in *M. oleifera.*

Future potential

More research is required to confirm the main mechanisms of action of Moringa as an anti-diabetic and anti-cancer drug. There are many perplexing unresolved questions. The discovery of new medicinal compounds may result from further investigation into endophytic fungi and the enzymes or proteins from *M. oleifera* that are responsible for the anticancer and antidiabetic action. Evaluating *M. oleifera's* application as a bio-coagulant for commercial purposes is yet another area of focus. It might be a workable substitute for purifying water. Snacks are in high demand on the market. Hence The inclusion of Moringa in snacks to combat malnutrition has two benefits. If the potential for highly nutritious food is realised, the tree, which is native to India, might become a significant source of wealth for the country.

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