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Exploring nutritional and phytochemical potentials of a miracle tree *Moringa oleifera*: A review

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Abstract

Moringa oleifera is one of the most useful trees known in India and the World. Leaves, pods, and flower parts of the plant have excellent nutritional and phytochemicals content. This review focuses on the nutritional, phytochemical and medicinal properties of *Moringa oleifera* tree and its health-promoting properties. Moringa leaves are a dense source of nutrients like amino acids, carotenes, ascorbic acid, vitamins, and minerals with promising health benefits. Various bioactive compounds such as alkaloids, glucosinolates, isothiocyanates, carotenoids, and tannins present in different parts of the tree suggest an important role in contributing to nutritional and health benefits. Moreover, leaves contain a number of phenolic substances, including myricetin, chlorogenic acid, gallic acid, luteolin, rutin, vanillin, quercetin, and kaempferol shown to have a positive impact on health. The phytochemical properties of *Moringa oleifera* exhibit many health benefits, including anti-inflammatory, anti-fertility, anti-ulcer, hepatoprotective, cardiovascular, anti-obesity, anti-epileptic, and anti-urolithic effects. It may also have anticancer, antimicrobial, antioxidant, and anti-diabetic properties. So, by exploring the uncountable benefits of *Moringa oleifera* it could be utilized in our diet to improve nutritional value and helps to cure diseases.

Keywords: Phytochemical composition, medicinal properties, health benefits, antioxidant activity, antimicrobial activity

1. Introduction

A member of the Moringaceae family is the cruciferous plant *Moringa oleifera*, also known as *Moringa oleifera* Lam. It is a genus of quickly developing tropical deciduous plants with thick, tuberous roots, a profusion of flowers, elongated, pendulous seeds, and light green leaves. It is cultivated in various areas and is referred to by a variety of names, including drumstick tree, sajiwan, kelor, murungai, mulangay, saijhan, ben oil tree, sajna marango, and mlonge (Boopathi *et al.*, 2021) ^[1]. Although *Moringa oleifera* found in various regions of Madagascar, southwest and northwest Africa, and northern India, *Moringa oleifera* is an indigenous product to these regions. It is a native of India, Bangladesh, Afghanistan, and Pakistan sub-Himalayan regions (Chaudhary *et al.*, 2022) ^[2].

It is considered as staple vegetable all over the world and is referred to regionally as the drumstick tree and horseradish tree. In addition to their nutritional worth, drumstick trees are consumed for their therapeutic properties (Chen *et al.*, 2021) ^[3]. The ancient use of this tree as medicine has shown that it has anti-inflammatory and antioxidant properties. It was first cultivated in northern India (Peñalver *et al.*, 2022) ^[4]. *Moringa oleifera* can grow in all types of soils, but loam and clay loam soils are more suitable for its cultivation. *Moringa oleifera* tree tolerates a pH range between 6 to 8 and a rainfall of 250 to 2000 mm per year (Ruiz-Hernandez *et al.*, 2022) ^[5]. *Moringa oleifera* tree tolerates extreme pruning and has excellent regrowth capacity. It gets affected due to climate change (Chimuka *et al.*, 2021) ^[6].

When the fruit is ripe, it splits into two leaflets and contains longitudinal wings and trivalent seeds. The fruit is recognized by its long, woody pod shape (Milla *et al.*, 2021) ^[7]. It is marketed as a “superfood” in many developed nations, including Europe, for a variety of health benefits, including its high degree of antioxidant activity (Hedhili *et al.*, 2021) ^[8]. The “miracle tree” or “tree of life,” *Moringa oleifera*, is revered for its countless health benefits as well as its ability to improve water sanitation and environmental preservation (Fernandes *et al.*, 2021) ^[9]. Various parts of *Moringa oleifera* like leaves, stem, flowers, roots, and pods are excellent sources of bioactive substances as the *Moringa oleifera* contains many benefits and is used for human consumption. *Moringa oleifera* is one of the most beneficial trees that every part of Moringa contains various nutritional properties which play a vital role in our health.

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Moringa oleifera is a storehouse of nutrients as it contains all the vitamins and minerals which help to boost immunity, and enhances energy. So, in this way, *Moringa oleifera* is considered the god's precious gift to man (Tanga *et al.*, 2022) [10]. *Moringa oleifera* have numerous health benefits and medicinal properties which helps to cure various health issues in our body. It is one of the most useful plant because every part is used for several purposes. As it could be fortified in various foods like in soups, curries for nutritional and health improvement.

2. Nutritional and phytochemicals properties of different parts of *Moringa oleifera* plant

Nutritional and phytochemicals potentials of different parts of *Moringa oleifera* plant have been discussed in many studies are given below and is illustrated in Figure 1.

2.1 Leaves

The leaves of Moringa plant is considerable source of amino

acids, carotenoids, ascorbic acid, and various essential vitamins. Leaves are rich in calcium, copper, zinc, and magnesium (Osman *et al.*, 2021) [11].

Flavonoids, carotenoids, ascorbic acid, and phenolic compounds are diverse antioxidant chemicals found in *Moringa oleifera* leaves. The consumption of moringa leaf extract helps to treat arthritis, brain dysfunction, diabetes, hypertension, obesity, skin problems, etc. (Farooq *et al.*, 2021) [12]. It contains phytosterol compounds like lactagogum which helps for increasing breast milk production and provides a supplement diet to infants (Singh *et al.*, 2021) [13]. Minerals found in *Moringa oleifera* include vitamin A, vital for healthy eyes and hair, vitamin C, and other B vitamins. Rickets, bone pain, osteoporosis, and other conditions can be brought on by the minerals found in *Moringa oleifera*, such as calcium, which helps strengthen bones and teeth (Praveen *et al.*, 2021) [79].

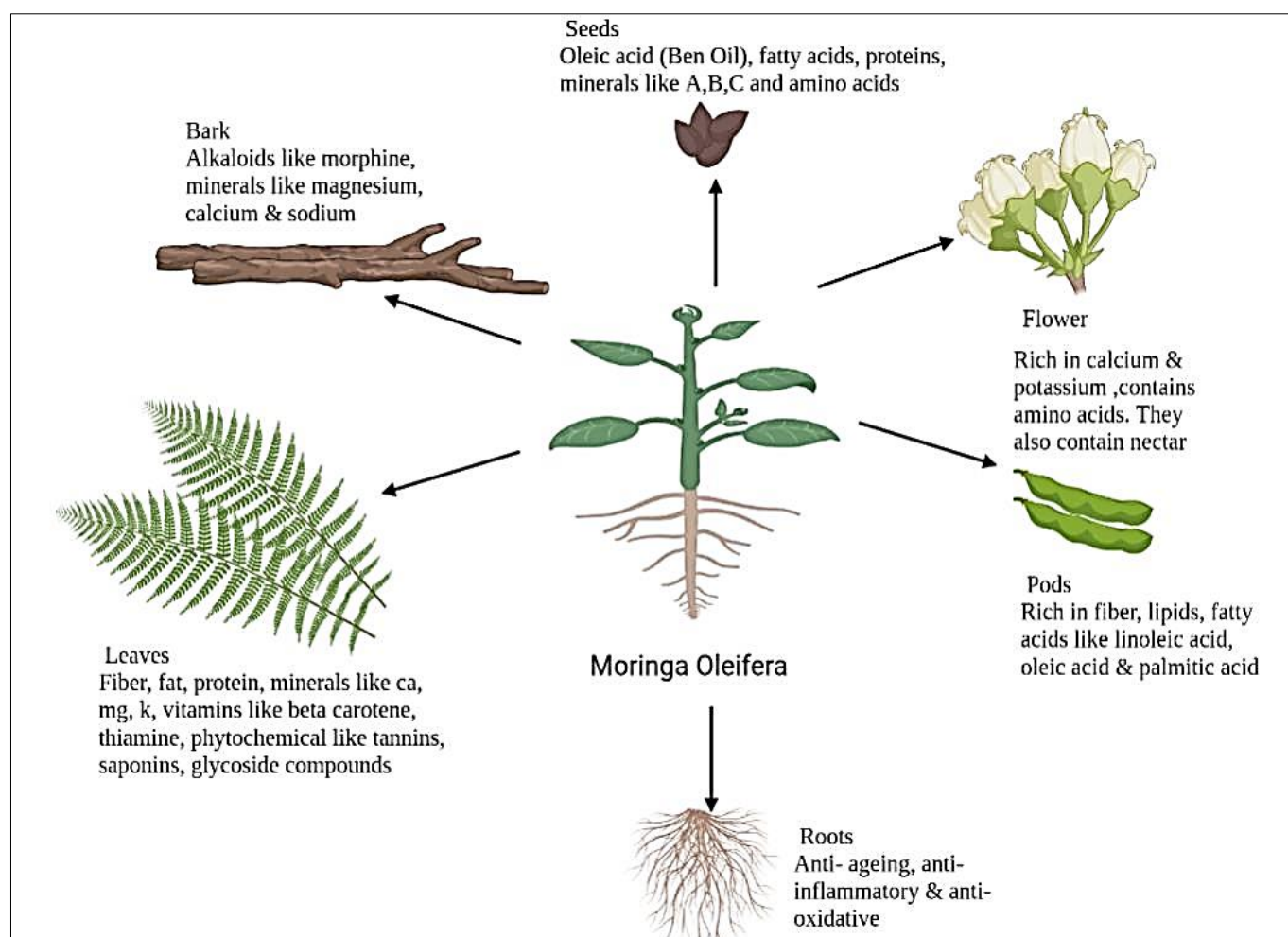


Fig 1: Nutritional and phytochemical content of different parts of *Moringa oleifera*

2.2 Seeds

Moringa seed found to contain 40% oil and is used for a variety function due to its high-quality fatty acid and also contains more than 70% oleic acid. Recent research has revealed that *Moringa oleifera* nuts are an excellent source of poly saturated fatty acids (Talath *et al.*, 2022) [15]. Protein content of seeds 31.4% and a carbohydrate content of 18.4% (Ekawati *et al.*, 2021) [16]. Seeds of *Moringa oleifera* contain vitamin E, additionally, contains essential minerals like phosphorus, sodium and potassium (Amuzu *et al.*, 2022) [75].

2.3 Flowers

Flowers contains bulk amount of high-quality protein i.e. 25.16%, ash content 6.01%, and the carbohydrate content is 53.67%. Flowers has potential to cure various problems like arthritis, urinary problems, colds, and heart problems (Jattan *et al.*, 2021) [18]. *Moringa oleifera* flowers are rich nectar sources for honey production and help to produce pure and natural honey. In some places, many peoples used flowers for tea making as it prevents us from various health issues (Kumari *et al.*, 2021) [19].

2.4 Pods

Pods of *Moringa oleifera* contain Polysaccharides d-galactose, Nitriles, isothiocyanate, and thiocarbamates (Sreeja *et al.*, 2021) [14]. *Moringa oleifera* pods contain a good amount of carbohydrates as it contains 10.4% carbohydrates, 20.66% protein content, and around 46.78% fiber. *Moringa oleifera* pods help to treat thyroid problems and help to balance the hormones. The nutritional benefits of *Moringa oleifera* are excellent, and it also has a delicious taste and aroma (Golla *et al.*, 2022) [20].

2.5 Roots

Stalk part of the *Moringa oleifera* plant contains significant amounts of minerals like iron, zinc, magnesium, calcium and copper. *Moringa oleifera* roots help to treat kidney dysfunctions and low back pain involving gout, asthma, and coughs. *Moringa oleifera* root extracts are generally applied to cure inflammatory swellings and play the role of antibiotic effect this works well for treating cholera. *Moringa oleifera* roots are also used as stimulants in paralytic afflictions and are used as a laxative, treat articular pain, and help to treat rheumatism (Zheng *et al.*, 2022) [21].

2.6 Stem and bark

The *Moringa oleifera* plant has a high carbohydrate content, 10.4% in buds, 18.5% in stem and 26.9% in bark, and bark by stem has 31.1%. The *Moringa oleifera*'s alkaloid contributes to the barks ability to be an antiulcer, which serves to prevent ulcers, as well as its ability to be a cardiac stimulant. *Moringa oleifera* stem and bark help to treat Urinary tract infections. The trunk bark of the *Moringa oleifera* plant has anti-tubercular and analgesic properties (Tanga *et al.*, 2022) [10].

3. Bioactive compounds in *Moringa oleifera*

Numerous bioactive substances, including proteins, lipids, carbs, amino acids, fats, minerals, vitamins, and dietary fibers, are found in *Moringa oleifera*. There are also other substances like carotenoids, isothiocyanates, alkaloids, glucosinolates, flavonoids, saponins, and tannins.

3.1 Phenolic compounds

Secoisolariciresinol, epipinoresinol glycosides, medioresinol, and isolariciresinol are the four main phenolic substances found in *Moringa oleifera* leaves. Other phenolic compounds present in leaves are myricetin, rutin, vanillin, gallic acid, luteolin, chlorogenic acid, quercetin, and kaempferol (Kumar *et al.*, 2022) [74]. The flavonoid concentration of the leaves of the *Moringa oleifera* is 18.75%, and the quantity of quercetin in the leaves is 43.75%. Quercetin, with a concentration of 1362.6 mg/Kg, has the highest percentage of phenolic compounds found in *Moringa oleifera* leaves. The kaempferol phenolic compound present in the leaves of *Moringa oleifera* is 1933.7 mg/kg. In recent studies, it is concluded that more phenolic compounds are present in the *Moringa oleifera* leaves as compared to the other parts of *Moringa oleifera* (Hassan *et al.*, 2021) [23].

3.2 Alkaloids, glucosinolates, and iso-thiocyanates

Moringa oleifera includes alkaloids called moringinine present in its stem and bark. The N-benzyl carbamic acid, 3-dibenzyl urea, N, L-rhamnopyranosyl vincosamide, aurantiamide acetate and deoxy-niazimicin are the compounds found in *Moringa oleifera*. The glucosinolates present in the

Moringa oleifera is (α -L-rhamnopyranosiloxy) benzyl glucosinolate which is called glucomoringin (Maldini *et al.*, 2021) [76]. Glucosinolates which are present in the *Moringa oleifera* are metabolized into isothiocyanates, which could lengthen people's lives by preventing a number of chronic illnesses. The Alkaloids, Glucosinolates, and Iso-Thiocyanates present in the *Moringa oleifera* help to make our body fit and protect us from various diseases (Sodvadiya *et al.*, 2020) [25].

3.4 Tannins

Different plants contain tannins that can attach to proteins. Consequently, plant protease enzymes may not be able to degrade the proteins found in plants. Tannins are thought to be significant quantitative protective substances offering protection against stress. Recent research have determined that the dried leaves of *Moringa oleifera* have a higher tannin content than the fresh leaves of the plant. *Moringa oleifera*'s crude extract ranges from 15.148 to 0.66. The mature leaves of *Moringa oleifera* that were dark and well-developed had the greatest tannin content (Wahyuni *et al.*, 2020) [26].

3.5 Carotenoids

Carotenoids are present in *Moringa oleifera* leaves in quantities ranging from 44.30 to 80.48 mg/100 g, which is a significant quantity. The *Moringa oleifera* leaves contain six distinct kinds of carotenoids. All- β -zeaxanthin, 13-Z-lutein, 15-Z carotene, All-E-lutein, Luteoxanthin, all- β -carotene and β -carotene are some examples of carotenoids (Baniwal *et al.*, 2022) [27]. β -lutein is primarily found in *Moringa oleifera* foliage and fruits, respectively, in amounts of 53.6 and 52.0%. As carotenoids are the primary source of vitamin-A, *Moringa oleifera* leaves are an abundant source of carotenoids that help treat malnutrition and reduce Vitamin A deficiency (Saini *et al.*, 2014) [28].

3.6 Flavonoids

The flavonoids found in the leaf, root, blossom, and seed coat of *Moringa oleifera* make up the plant. The *Moringa oleifera* leaves contain large amounts of the flavonoids isorhamnetin, apigenin, quercetin and kaempferol (Lin *et al.*, 2018) [77]. The existence of a significant amount of flavonoids in the *Moringa oleifera* is primarily responsible for its high antioxidant activity. Quercetin, rhamnetin, rutin, myricetin, kaempferol, and apigenin are the flavonoids that are frequently found in *Moringa oleifera* (Abd Rani *et al.*, 2018) [30].

4. Nutritional composition of *Moringa oleifera*

A number of different micronutrients are present in the leaves and pods of the *Moringa oleifera* shrub. *Moringa oleifera* has ten times as much vitamin A as carrots and seven times as much vitamin C as oranges. It also has 17 times more calcium than milk and nine times more protein than yogurt. *Moringa oleifera* has fifteen times the potassium of bananas. *Moringa oleifera* contains vitamins A, vitamin B1, vitamin B2, vitamin B3, vitamin E and contains a rich amount of vitamins (Mgbojikwe *et al.*, 2022) [31]. *Moringa oleifera* leaves contain large amounts of minerals like copper, zinc, magnesium, calcium, sodium, iron and potassium. According to current studies, the dried leaves of *Moringa oleifera* contain a number of minerals, including zinc in the amount of 31.10 mg and potassium in the amount of 2.18 gm, as well as calcium

present in the amount of 3.081 gm, and magnesium present in the amount of 6.727 gm. The iron concentration is abundant (16.9 mg) compared to the other minerals (Kumari *et al.*, 2022)^[75].

Crude protein and crude lipids are abundant in *Moringa oleifera* seeds, which have a protein concentration of up to 40.34% (Fernandes *et al.*, 2021)^[9]. Recent study have investigated that *Moringa oleifera* fresh leaves have a protein content of about 6.7 g, and the dried leaves contain a protein amount of about 27.1 g. As shown in recent studies, the dried leaves have more protein amount as compared to the fresh leaves of the *Moringa oleifera* (Kumar *et al.*, 2016)^[78]. *Moringa oleifera* leaves contain carbohydrates which represent the energy source for our body. Fresh leaves of *Moringa oleifera* contain the 5% carbohydrates while the dried leaves of *Moringa oleifera* contain 38.2% Carbohydrates (Doriya *et al.*, 2016)^[33]. The *Moringa oleifera* seed powder contains Arabinogalactan present in the amount 1.29%, xylan type polysaccharides present in the amount of 1.45% and cellulose also present. The carbohydrates present in the *Moringa oleifera* in good amount helps to provide energy to our body (Anudeep *et al.*, 2018)^[34].

4.1 Medicinal properties and health benefits

A number of health benefits are associated with *Moringa oleifera*. Along with having positive effects on the heart, it also has analgesic, local anesthetic, gastroprotective, hepatoprotective, anticancer, anti-urolithiasis, antimicrobial, anti-epileptic, anti-inflammatory, wound healing, immunomodulatory properties, diuretic, antioxidant, anti-allergic, Antipyretic, antihelmintic and anti-ulcer. Numerous potential medicinal properties of *Moringa oleifera* are represented in figure 2.

4.2 Anti-inflammatory activity

The anti-inflammatory properties of the compounds found in *Moringa oleifera*, including Quercetin 3-O-glucoside, crypto

chlorogenic, 4 [(3, O-acetyl rhamnosyloxy) benzyl isothiocyanate, 4 [(Lrhamnosyloxy) benzyl] isothiocyanate, 4 [(2O-acetyl Lrhamnosyloxy) benzyl isothiocyanate and quercetin, (Chirania *et al.*, 2022)^[35]. Existing antioxidants like lectins, mono palmitic acid, oleic acid, tocopherols, and tri-oleic triglycerides have been linked to the capacity of *Moringa oleifera* seeds and oil extracted from the seeds to prevent the synthesis of reactive oxygen species. (Dzuvor *et al.*, 2022)^[17]. The most effective anti-inflammatory action is found in *Moringa oleifera* leaf extract. Because *Moringa oleifera* seeds contain lectins and carbohydrate-binding proteins that can decrease water turbidity due to their coagulant activity, seed extract is used to treat drinking water (Anzano *et al.*, 2021)^[36]. Thus, the seed extract aids in the purification of water and ensures that it is suitable for ingesting. Recent research has revealed that the 4- [(2'-O-acetyl-alpha-1 rhamnosyloxy) benzyl] isothiocyanates, which are isolated from the roots extract of *Moringa oleifera*, have anti-inflammatory effects. (Sultana *et al.*, 2018)^[37].

Moringa oleifera seeds are the main source of anti-inflammatory activity. It helps to treat various chronic diseases. The seeds have a toxicity risk on different organ systems when used in conjunction with conventional steroidal and non-steroidal anti-inflammatory drugs to treat inflammation. One of the most beneficial herbal plants, *Moringa oleifera*, is thought to be successful in treating a variety of inflammatory conditions (Sayed *et al.*, 2022)^[38]. Additionally, the leaves of the *Moringa oleifera* are crucial in inflammation. As the leaves assist in treating the various illnesses that develop within our bodies. It has been discovered that *Moringa oleifera* is a potent radical scavenger and is the finest natural antioxidant source for the treatment of diseases linked to inflammation. By preventing RAW264.7 cells from producing nitric oxide and other pro-inflammatory mediators in response to lipopolysaccharide (LPS), *Moringa oleifera* leaves exhibit anti-inflammatory properties. (Luetrogon *et al.*, 2020)^[39].

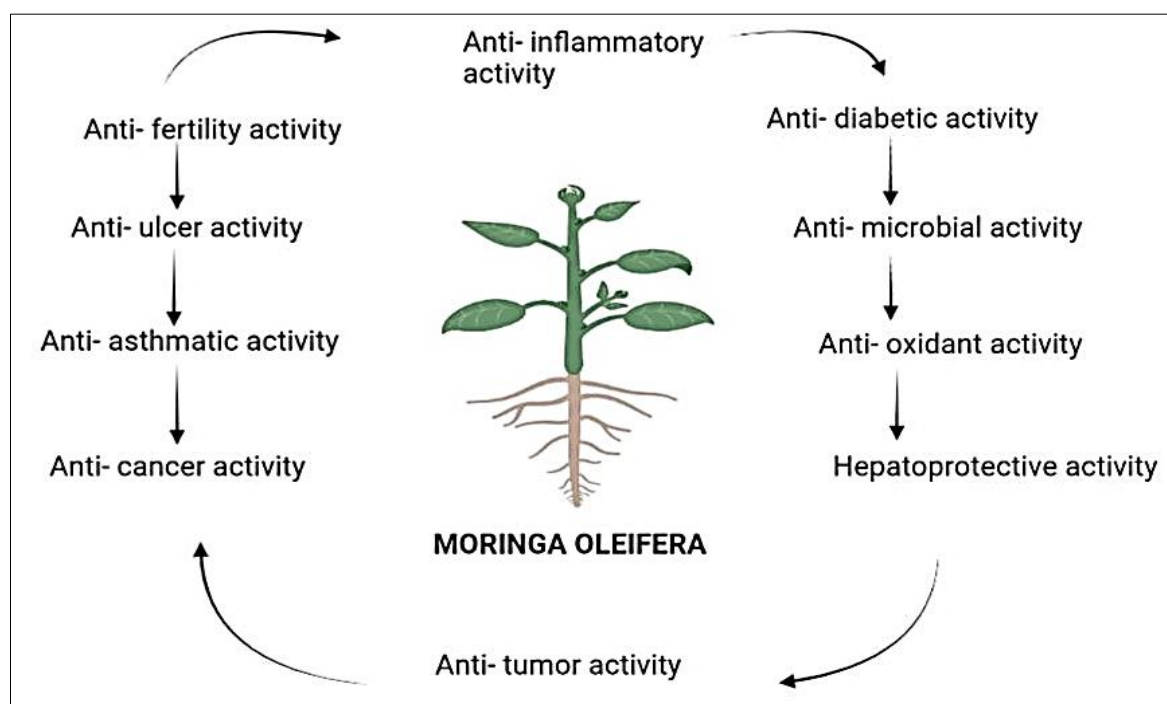


Fig 2: Potential medicinal properties of *Moringa oleifera*

In mice with healthy immune systems and immune systems that are suppressed, *Moringa oleifera* leaf extracts have been shown to activate both cellular and humoral immunity in a dose-dependent manner. The *Moringa oleifera* ethanolic seed extract reduced the amount of white blood cells and macrophage phagocytosis, both of which show immunosuppressive activity (Prithiviraj *et al.*, 2021) ^[40]. *Moringa oleifera* herbal plant is the best anti-inflammatory properties which help to treat inflammation and protects the body from several problems.

4.3 Anti-diabetic activity

For diabetic patients, *Moringa oleifera* leaves are a good supply of green leafy vegetables that lessen diabetic complications (Fatoumata *et al.*, 2020) ^[41]. The herbal plant *Moringa oleifera* has potent anti-diabetic properties because it can block ATP-sensitive potassium channels in pancreatic beta cells. This causes cell membrane depolarization and the opening of voltage-dependent calcium channels, which raises intracellular calcium in the beta cell and enhances insulin release.

Glucosinolates, flavonoids along with them as chlorogenic acid, are capable of processing hypoglycemic action. Terpenes and flavonoids, which are abundant in *Moringa oleifera*, are crucial in stimulating pancreatic cells and resulting in the production of insulin hormone, which is particularly helpful in the treatment of diabetes mellitus (Chirania *et al.*, 2022) ^[35]. Increased insulin action, improved glucose uptake and utilization, as well as prevention and restoration of cell integrity and function are just a few of the effects of *Moringa oleifera* on carbohydrate metabolism (Keshri *et al.*, 2021) ^[42]. The anti-diabetic plant *Moringa oleifera* is very effective. Type 1 diabetes brought on by streptozotocin as well as Type 2 diabetes brought on by insulin resistance can both be cured by *Moringa oleifera*'s aqueous preparations. Therefore, both Type-1 and Type 2 diabetes can be cured with *Moringa oleifera* (Rajbhar *et al.*, 2018) ^[43].

Both Type-1 and Type-2 diabetes can benefit greatly from *Moringa oleifera*. Since insulin, a hormone that keeps blood sugar levels within typical range, is not produced by the patient's body, they have type 1 diabetes. One condition connected to insulin intolerance is type 2 diabetes. Beta-cell dysfunction may also contribute to type 2 diabetes because it impairs insulin signalling because the beta cells are unable to detect glucose levels. This leads to high blood sugar levels (Alhassan *et al.*, 2022) ^[45].

A significant supply of polyphenols with hypoglycemic activity can be found in *Moringa oleifera* Leaves. The quercetin-3-glucoside and fibers found in the powdered leaves of *Moringa oleifera* have the potential to mediate the plant's enhancing impact on glucose intolerance. As a result, diabetes can be effectively treated using *Moringa oleifera* leaves (Jacques *et al.*, 2020) ^[46].

4.4 Antimicrobial activity

The moringa tree The Pterygospermin plays the most significant part in the antimicrobial and anthelmintic properties of the extract that we obtain from the *Moringa oleifera* leaves, flowers, root bark, and stem bark (Islam *et al.*, 2021) ^[47]. *E. coli*, *Enterobacter aerogenes*, *Pseudomonas aeruginosa*, and *Staph. Aureus* have all been successfully eradicated by an extract of *Moringa oleifera* leaves. The

Moringa oleifera seed chlorophyll extracts have been found to have an adverse effect on *Salmonella Typhimurium* and *E. coli*. The *Moringa oleifera*'s isothiocyanates work well against the *Helicobacter pylori* microbe (Yadav *et al.*, 2023) ^[48]. The antibacterial properties of benzyl isothiocyanate and benzyl glucosinolate are found in *Moringa oleifera* leaves. Additionally, the protein in *Moringa oleifera* is effective against certain strains of *Staphylococcus*, *Streptococcus* and *Legionella* (Abdulkadir *et al.*, 2018) ^[49]. Both the juice extracted from the stem bark of *Moringa oleifera* and the extract of its root bark has antifungal and antibacterial effects on *S. aureus*. Gram-positive species *Enterococcus faecalis* and *Staphylococcus aureus* are significantly inhibited by the aqueous and ethanolic preparations from the leaves of *Moringa oleifera*, in contrast to Gram-negative species like *Vibrio parahaemolyticus*, *Escherichia coli*, *Aeromonas caviae* and *Salmonella* (Kou *et al.*, 2018) ^[50]. The antibacterial properties of the *Moringa oleifera* root extract are aided by the presence of 4-L-rhamnosyloxybenzyl isothiocyanate. The aglycone deoxy-niazimicine, which is N-benzyl, S-ethyl orthoformate and was isolated from the chloroform part of an ethanol extract of the bark of the *Moringa oleifera* Root, is responsible for the antifungal & anti-bacterial properties (Neupane *et al.*, 2022) ^[51].

The leaves of the *Moringa oleifera* plant contain vital amino acids as well as calcium, iron, and potassium elements. Recent research has found that *Moringa oleifera* leaves are highly effective against a variety of harmful bacterial species (Saad *et al.*, 2021) ^[52]. In comparison to aqueous extracts and penicillin, the ethanol extract of *Moringa oleifera* leaves, stems, and seeds exhibits a greater level of antimicrobial action. This demonstrates that *S. aureus* infections can be controlled by *Moringa oleifera* seeds, leaves and stems (Kabiru *et al.*, 2023) ^[53]. An ethanolic and aqueous extract of the leaves of *Moringa oleifera* can be used to treat a number of bacterial illnesses. In recent studies, it was discovered that the antibacterial activity of the *Moringa oleifera* leaf extract was stronger against Gram-positive species like *Enterococcus faecalis* and *S. aureus* than it was against Gram-negative species like *Vibrio parahaemolyticus*, *Salmonella*, *Aeromonas caviae*, *P. aeruginosa* and *E. coli*. (Bagheri *et al.*, 2020) ^[54].

4.5 Antioxidant activity

Ascorbic acid, carotene, quercetin, kaempferol, and flavonoids are just a few of the natural antioxidant chemicals found in *Moringa oleifera*. The remaining anti-oxidants found in *Moringa oleifera* include myricetin, tocopherols, and lectins. 8 in discovered. *Moringa oleifera*'s stalk and roots contain an excessive amount of phytosterols, 9-octadecenamide and palmitic acid. The roots and hydrophilic leaf preparations of *Moringa oleifera* have strong anti-inflammatory and radical-scavenging properties (Kaushik *et al.*, 2023) ^[55]. The extract of *Moringa oleifera* leaves has demonstrated strong antioxidant activity against free radicals, which helps to safeguard vital biomolecules from oxidative damage and prevents oxidative damage to them. Additionally, numerous phenolic substances and alkaloids are in charge of the positive health benefits (Ahmed *et al.*, 2021) ^[56]. The elimination of free radicals is the function of antioxidant action. The *Moringa oleifera* genus has high antioxidant activity because it contains a large number of bioactive polyphenols. The antioxidant properties are also illustrated in table 1 and figure 3.

Table 1: Phytochemical constituent, potential applications functions of *Moringa oleifera*

Sr. No.	Constituents	Potential application	Function	References
1.	ITC type MIC – 1 (11)	Anti-cancer activity	MIC -1 can lead to the failure of numerous transcription factors to prevent onset and development of inflammation when activated.	(Adam <i>et al.</i> , 2023) [71]
2.	Octadecanoic acid, hexadecanoic acid (palmitic acid) and Quinic acid	Anti-cancer activity	Potentially inhibits tumor development as a cancer therapeutic drug, without altering normal bodily physiology & function.	
3.	TNF- α induced nitric oxide synthase (iNOS), 1 L- 6	Anti-cancer activity	It effects found in treatment of methotrexate – induced neurotoxicity, aspirin – induced gastric ulcer and levofloxacin – induced hepatic toxicity.	
4.	Levels of nitrogen – activated protein kinases (MAPKS), Cytokine related mRIVAS	Anti- inflammatory activity	It improved the serum immunoglobulin levels and ear skin thickness	(Xiao <i>et al.</i> , 2020) [72]
5.	STZ- nicotinamide	Anti- diabetic activity	It helps to increase the blood glucose level in body.	
6.	Quercetin & kaempferol (epicatechin & catechin)	Antioxidant activity	Reduce human leukemia cells and promotes Antioxidant activity & Alzheimer's Activity.	
7.	Phenolic compounds	Antimicrobial activity	It helps to transport nutrients in the body.	
8.	b- sitosterol	Cholesterol lowering effects.	It regulates the cell cycle in the body.	
9.	Methyl thiocarbamate, niazin A, niazin B, niazimicin etc.	Helps in alzheimer's activity	It acts as a spasmolytic, hypotensive and bradycardiac.	
10.	Spirochin & Anthonine, benzyl isothiocyanate	Anti- bacterial activity	It helps to fight against food borne pathogens.	

The extracts of *Moringa oleifera* from mature and tender *Moringa oleifera* leaves show strong antioxidant action against free radicals and prevent oxidative damage because of polyphenol enrichment (Sreeja *et al.*, 2021) [14]. Recent research demonstrates that quercetin-3-O-rutinoside, 3-hydroxybenzoic acid and hydroxycinnamic acid components were abundant in the methanol extract of *Moringa oleifera*. Shows greater antioxidant action, whereas the *Moringa oleifera* aqueous extract had higher chlorogenic, syringic acid concentrations, succinic and fumaric (Dessalegn *et al.*, 2021) [57]. Studies demonstrate the antioxidant characteristics of the *Moringa oleifera* seed protein, particularly after trypsin or alcalde hydrolysis, when the hydrolysate exhibits in vitro antihypertensive and antioxidant properties (Liang *et al.*, 2019) [58]. In order to avoid active free radicals interacting with biological macromolecules and lessen tissue harm, *Moringa oleifera* ethyl extract has a higher superoxide anion radical (O₂) scavenging activity. A linear connection exists between the greater antioxidant activity of *Moringa oleifera* leaves and the phenolic compounds, which aids in the development of products that increase the oxidative stability of food products (Kashyap *et al.*, 2022) [27]. Due to their redox characteristics, phenolic substances found in *Moringa oleifera* have the ability to inactivate lipid free radicals. Free Radicals are neutralized and peroxides are broken down in part by the phenolic components of *Moringa oleifera*. The leaves of *Moringa oleifera* contain a high concentration of antioxidants that have anti-inflammatory benefits on cardiovascular diseases, cancer, and hypertension. Along with Vitamin A, *Moringa oleifera* leaves have excellent antioxidant qualities (Keshri *et al.*, 2021) [42]. The essential function of *Moringa oleifera* is to protect our bodies from various illnesses and to treat various infections. The properties of the soil have a large influence on antioxidant activity, and *Moringa oleifera* leaves have a significant impact on environmental temperature conditions. *Moringa oleifera* has greater antioxidant activity

in its leaves and roots.

4.6 Hepatoprotective activity

According to current research, *Moringa oleifera* is effective in treating liver diseases. Due to the presence of quercetin, the methanol *oleifera* extract of *Moringa oleifera* has hepatoprotective qualities (Babar *et al.*, 2022) [59]. The stem, leaves, flowers and seeds of *Moringa oleifera* have hepatoprotective properties. According to a study, antitubercular drugs like pyrazinamide, rifampicin and isoniazid cause liver damage in rats and the ethanolic extract of *Moringa oleifera* leaves exhibits a hepatoprotective effect. The extract was also found to speed up the recovery of liver damage caused by antitubercular-induced drugs (Soni *et al.*, 2022) [60]. These hepatoprotective qualities of *Moringa oleifera* are demonstrated by the flavonoids chlorogenic acid, rutin, apigenin, kaempferol, rhamnetin, and quercetin, which have antioxidant characteristics. It has been noted that *Moringa oleifera* has hepatoprotective properties. Diverse natural antioxidants have been attempted to stop oxidative stress-mediated liver injury because oxidative stress plays a major role in the onset and progression of a number of liver diseases (Muzumbukilwa *et al.*, 2019) [61]. The hepatoprotective activity is given in figure 3.

The extract from *Moringa oleifera* leaves has demonstrated liver protection against antitubercular medications and alloxan-induced liver damage in diabetic rodents. It has been discovered that taking *Moringa oleifera* as a diet supplement for 21 days significantly reduces hepatic damage. The hepatoprotective action was attributed to benzyl glucosinolate, alkaloids, quercetin, kaempferol, flavonoids, and ascorbic acid (Prithiviraj *et al.*, 2021) [40]. It was found that supplementing with a significant amount of *Moringa oleifera* extracts has a beneficial effect on lipid profile, other biochemical markers, and liver functions (Abushal *et al.*, 2020) [62].

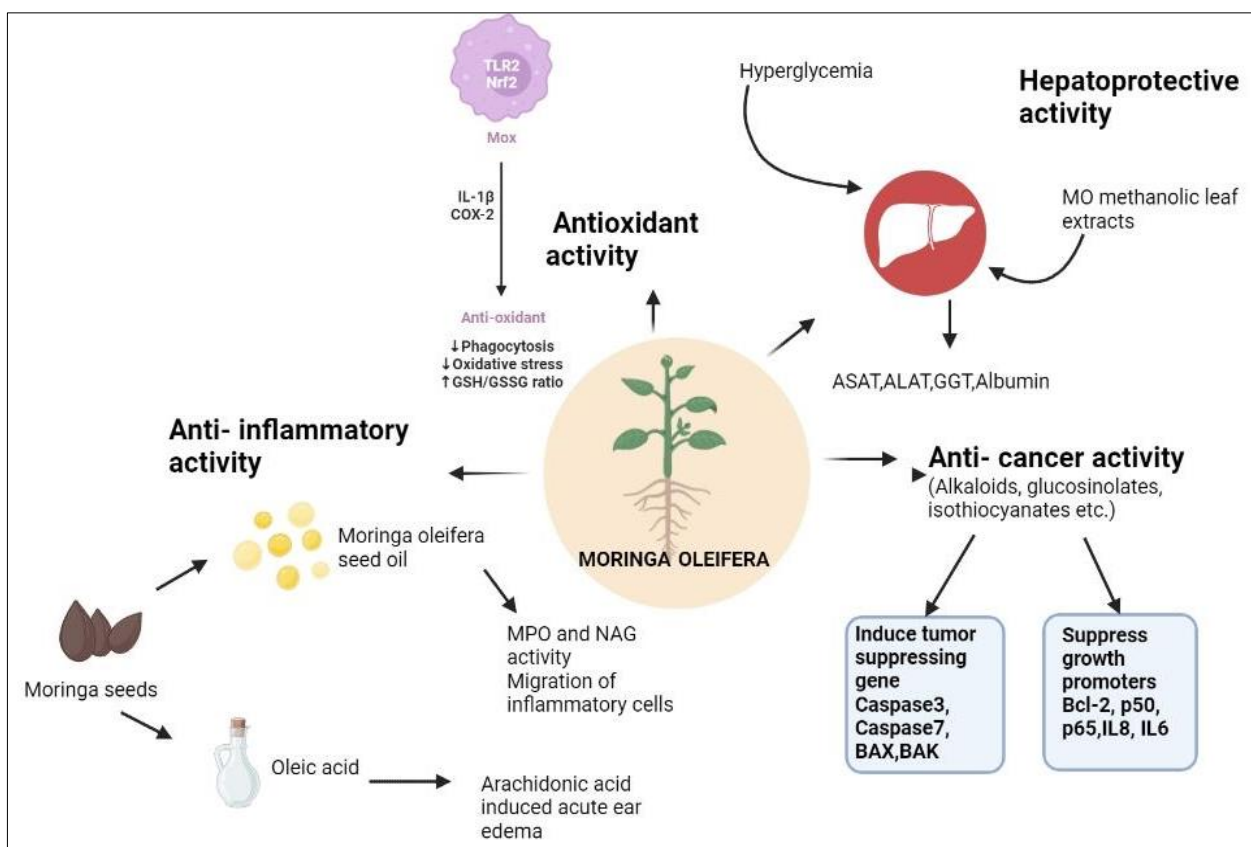


Fig 3: Illustration on health promoting properties of *Moringa oleifera*

Moringa oleifera extract lowers MDA levels and increases the activity of liver enzymes, which in turn increases the activity of antioxidant parameters. The histologically degenerative impacts of CCl₄ intoxication were also lessened following treatments with this extract. The results of the research suggest that *Moringa oleifera* leaf extract may be used as a future hepatoprotective drug because it enhances innate antioxidant activity and lessens CCl₄-induced liver damage (El-bakry *et al.*, 2016) [63]. Because *Moringa oleifera* extract has a lot of antioxidants and free radical scavenging abilities, it is thought that a high dose of this extract is used as a protective therapy with anti-tuberculosis medications and may even be taken as a dietary supplement to shield our liver from the toxic effects of many chemicals (Abdel-Daeem *et al.*, 2018) [64].

4.7 Anti-tumor activity and anti-cancer activity

It is discovered that the extract of *Moringa oleifera* leaves has cytotoxic properties against certain types of human breast cancer cell lines (Hela). In the *Moringa oleifera* leaves extract, the existence of terpenoids, tannins, glycosides, phenols, saponins, and flavonoids was identified. All kinds of cancer cell proliferation are slowed down by a *Moringa oleifera* leaf extract. So, this suggests that the *Moringa oleifera* is used for the treatment of various types of Cancer (Kinga Szlachetka *et al.*, 2020) [65]. *Moringa oleifera* leaves contain a range of phytoconstituents indicating that no single phytoconstituents may be responsible for the antitumor effect, which is instead produced by the combined, cumulative, and synergistic effects of its phytoconstituents (Kaur *et al.*, 2023) [67].

In previous studies, it is found that for mouse melanoma tumours, low nontoxic doses of a *Moringa oleifera* fruit and

leaf extract exhibit excellent antitumor activity, and leaf extract prolongs the life expectancy of cancer patients. (Jain *et al.*, 2010) [68]. Trypsin inhibitors called MoFTI, also referred to as *Moringa oleifera* floral trypsin inhibitors, are found in the flowers of the *Moringa oleifera* plant and have insecticidal properties. Vero cells and mouse macrophages were not harmed by MoFTI. According to recent research, eating a lot of *Moringa oleifera* flowers can help our bodies fight off tumors of all kinds. (de Siqueira Patriota *et al.*, 2020) [69]. Recent studies have indicated that the *Moringa oleifera* root extract effectively kills all cancer cell types, including HCT 116, Caco-2 cells, MCF7 and HepG2. Additionally, the cancer cell types that were the focus of those studies are significantly killed by this extract (Abd-Rabou *et al.*, 2017) [70]. Anti-cancer properties of *Moringa oleifera* has been represented by table 1 and figure 3.

5. Conclusion

Every component of the *Moringa oleifera* plant is considered useful due to its vitamins, minerals, and micronutrients and phytochemical potentials can have variety of uses that promote health benefits. The therapeutic benefits are brought about by a variety of bioactive substances, including sterols, glucosinolates, flavonoids, terpenes, alkaloids, phenolic acids, and numerous other fatty acids. A number of illnesses, including cancer, hypertension, obesity, diabetes, and others, have been shown to be cured by the active components of plants in prior studies. Numerous medicinal benefits include anti-fertility, anti-diabetic, and anti-inflammatory explore its worth potentials. It also helps to keep the iron levels in nursing mothers and avoid osteoporosis and other cardiovascular diseases. *Moringa oleifera*, has a variety of bioactive substances that can be found in the leaves, seeds,

stalks, and shells of various herbal parts. It is made up of bioactive substances, including phenolic compounds, lipids, fatty acids, carbohydrates, proteins, several glycosides, functional peptides, minerals, essential amino acids and vitamins are among the ingredients in this compound. It has the potential to be used in a variety of food and health product formulations.

6. Acknowledgment

Not applicable

7. Data Availability Statement

Research data are not shared.

8. Conflict of Interest

The authors have no conflict of interest to declare.

9. Ethical Guidelines

Ethics approval was not required for this research

10. List of abbreviations

ATP- Adenosine triphosphate

CCl₄- Carbon tetrachloride

LPS- Lipopolysaccharide

MDA- Malondialdehyde

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