**Review**

*Moringa oleifera*: Miracle Plant with a Plethora of Medicinal, Therapeutic, and Economic Importance

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**Abstract:** *Moringa oleifera* Lam. (*Moringaceae*) is one of the most essential medicinal plants primarily found in the rainforest area and forest ecosystem, but is now well-adapted in an organized cultivation system. *Moringa oleifera* (*M. oleifera*) is well-known as Drumstick tree, Moringa kai, color, Marengo, Moringe, mulangay, Sahjan, and Sajna, which are its native names commonly used. It has nourishing, beneficial, and preventive effects when taken as food and has an extensive scope of high restorative properties with huge dietary benefits. Different parts of the *M. oleifera* plants, such as leaves, flowers, fruits, seeds, and roots, contain a significant amount of protein, β-carotene, amino acids, important minerals, and various phenolic compounds. Because of its multifarious health benefits for its therapeutic value, it is considered an essential plant. The plant is found to be blessed with several medicinal characteristics such as antitumor, anti-inflammatory, antiulcer, antipyretic, antiepileptic, antispasmodic, diuretic, antihypertensive, antidiabetic, cholesterol-level down, cell reinforcement, and hepatoprotective. Moreover, it is used traditionally in the local curative system against cardiac problems, and the antifungal properties are efficiently utilized for the treatment of a wide range of ailments. The present review article was designed to explore the nutritional and economic benefits, medicinal and therapeutic applications, and the future biomedical prospects of *Moringa* with a view towards human wellbeing.

**Keywords:** *Moringa oleifera*; medicinal and pharmaceuticals; nutritional; economic importance; therapeutics; horticultural crops

1. Introduction

The drumstick plant is a nutrient-rich green tree of the *Moringaceae* family with many applications and is grown around many parts of the world including the United States [1,2]. In English, this plant is known as *Moringa oleifera* (*M. oleifera*), horseradish tree, or drumstick tree. It is not only used by humans and animals, but it also has many industrial uses [3]. The leaves, fruit, flowers and youthful branches of this tree are utilized as a profoundly nourishing vegetable in various nations including India, the Philippines, Hawaii, Pakistan,
and many African countries. In particular, individuals in India have been utilizing it for their day-to-day nourishment for almost 5000 years [4–6]. Starting its journey from the northern parts of India, it quickly spread to the southern portions, where ‘Murungai keerai’ (Moringa leaves) and ‘Murungaikaai’ (drumsticks) are among the most popular sources of vegetables. The moringa tree has essentially been colonized throughout the entire Asia, nearly all of Africa, South America, a tiny section of North America, and a few scars in Europe [7,8]. They essentially have versatile roles as nutritional supplement, soil quality enhancement, and use in the water purification system. Moringa plants are also a good source of oil, which is, therefore, the most popular and significant sources of revenue. The majority of the available bioactive phenolic compounds belong to flavonoid groups such as quercetin and kaempferol. Based on the reported results in several literatures, moringa leaves have a potential source of natural antioxidants due to their discernible qualities of protecting cells against free radicals [9]. Furthermore, water coagulation, proteins, and fatty acid methyl esters (FAME) from the *M. oleifera* seeds are reviewed, to explore their possible industrial applications, in biodiesel production and in the water purification system [10].

The leaves are abundant in nutrition with vitamins C and A, β-carotene, calcium, iron, potassium, and phosphorus including a protein level of 27 percent [8]. *Moringa* leaves have the same calcium content as four glasses of milk, the same amount of vitamin C as found in seven oranges, and three times the potassium found in bananas [11,12]. They further contain three times as much iron as spinach, four times as much vitamin A as in carrots, and half the protein of milk, according to research reported [13,14].

2. Methodology: Literature Search

Several electronic databases such as Pubmed, Medline, Embase, and Google Scholar were accessed for retrieving the available relevant literatures. We thoroughly searched to identify articles published till 2021, on different aspects of antidiabetic, anticancerous, phytochemical properties and their mode of action against several cancer cell lines. The keywords and terms used for the search included single and various combinations of the following: “*Moringa oleifera*”, “medicinal” “pharmaceuticals”, “nutritional”, “economic importance” “therapeutics” and “horticultural crops”. Under each of the searches, the abstracts and titles were screened and the full text versions of articles that met the criteria were downloaded.

3. Traditional and Other Uses of *Moringa oleifera*

The *M. oleifera* tree has a wide range of therapeutic applications, including both prevention and therapy. Its bark, seeds, oil, sap, leaves, roots, and flowers are used in conventional medicine. It provides an immediate remedy for stomach, catarrh, malignancy, cancer, ulcer, blood sugar, nerve, cramps, hemorrhoids, cerebral aches, sore gums, stomach-related diseases, respiratory, gastric, and resistant frameworks [15,16]. It also boosts bone density by increasing calcium levels. Flowers act as cholagogue, stimulant, tonic, and diuretic that can help to enhance bile flow. The plant is antibacterial as well and aids in the preparation of heart circulatory tonic [17]. It strengthens the eyes, skin, cerebrum, liver, and also acts as a blood erythropoietin-stimulating agent. The leaves are used as a poultice for mid-region wounds to eradicate intestinal heat in a traditional therapy. The Indian Ayurvedic Pharmacopoeia recommended the uses of dried root bark for goitre, glycosuria, and lipid problems (together with dried seeds), and leaf, seed, root bark, and stem bark for internal abscess and piles [1]. To cure conjunctivitis, the leaves are used as eyewash while a drink made from the leaves of a drumstick tree is good for people with asthma and bronchitis when consumed regularly. A dish of soup is made from the decoction of drumstick leaves. Decoction produced with young drumstick flowers and cow milk is a fantastic tonic for male and female sexual infertility and practical failure [12,18]. Humans have long history of consuming this highly valued tree for a variety of domestic uses [19]. The powdered form of the bark works on the activity of sperm and corrects abnormalities like early discharge in males. An effective home-grown cure for cholera
is the integration of new leaf extract of moringa, one spoon of honey, and one glass drink of exquisite coconut water [20]. It is beneficial against diarrhea, jaundice, and also colitis. A typical remedy for dysuria and a high acidic rate in urine is a new leaf extract of moringa combined with carrot or cucumber juice to cure pimples and clogged pores. Aging spots can efficiently be treated with drumstick leaf extract treated with lime juice which enhances the normal brilliance of the complexion [21]. Many medicinal properties such as antitumor, anti-inflammatory, antiulcer, antipyretic, antiepileptic, antispasmodic, diuretic, antihypertensive, and antidiabetic are mentioned in Table 1. Various *M. oleifera* plant-derived bioactive compounds are shown in Figure 1.

Figure 1. Selected bioactive compounds from *Moringa oleifera*: (a) 4-(L-rhamnopyranosyloxy) benzisothiocyanate, (b) Quercetin, (c) Niazirin, (d) Kaempferol, (e) Benzyl isothiocyanate, (f) Niazimisin, (g) β-sitosterol, (h) 4-(4-O-acetyl-a-L-rhamnosyloxy) benzyl isothiocyanate, (i) 4-(α-L-rhamnopyranosyloxy) benzyl isothiocyanate, (j) Moringine.
Table 1. Various beneficial phytochemicals of *M. oleifera* and their medicinal effect.

<table>
<thead>
<tr>
<th>Phytochemicals</th>
<th>Medicinal Effects</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tannins</td>
<td>Bactericidal, anti-inflammatory, and anti-parasitic.</td>
<td>[22]</td>
</tr>
<tr>
<td>Saponins reduction and immune support.</td>
<td>Antioxidant, anticancer, cholesterol.</td>
<td>[23]</td>
</tr>
<tr>
<td>Alkaloid’s cancer, cardiac dysfunction, and pain.</td>
<td>Treatment of malaria, diabetes.</td>
<td>[23]</td>
</tr>
<tr>
<td>Glycoside’s failure and cardiac arrhythmia.</td>
<td>Anti-tumoral, anti-inflammatory, antibacterial, and antioxidants.</td>
<td>[10]</td>
</tr>
<tr>
<td>Reducing sugar’s function.</td>
<td>Treatment of congestive heart.</td>
<td>[24]</td>
</tr>
<tr>
<td>4-O-(a-L-rhamnopyranosylxy)-benzyl glucosinolate (glucomoringin)</td>
<td>Provides energy for proper body.</td>
<td>[25]</td>
</tr>
</tbody>
</table>

Several parts of the *M. oleifera* tree served as great reservoir of extraordinary glucosinolates, flavonoids and phenolic compounds [26,27], carotenoids, tocopherols, polyunsaturated fats (PUFAs), profoundly bioavailable minerals, and folate [28]. Among glucosinolates, 4-O-(a-L-rhamnopyranosylxy)-benzyl glucosinolate (glucomoringin) is the most transcendent in the stem, leaves, flowers, fruits, and seeds of *M. oleifera* [26]. In the roots, benzyl glucosinolate (glucotropaeolin) is the most prominent bioactive compound present. The most elevated substance of glucosinolate belonging to a group of sulphur-containing glycosides is found in the leaves and seeds. Among the flavonoids group, flavonol glycosides (glucosides, rutinosides, and malonyl glucosides) of quercetin > kaempferol > isorhamnetin are mostly found in different parts of the tree, along with the roots and seeds. In the roots, benzyl glucosinolate (glucotropaeolin) is the most prominent. The highest level of glucosinolate is found in the leaves and seeds. Almost all the parts of *M. oleifera* are beneficial for human wellness as well as having economic importance as shown in Table 2 and Figure 2.

Table 2. Various extracts of *Moringa oleifera* and their biological activities.

<table>
<thead>
<tr>
<th>Extract Type</th>
<th>Medicinal Effects</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>M. oleifera</em> leaf extract</td>
<td>Have antioxidant potential, increase the cytotoxicity in apoptosis based chemotherapy by downregulation of (nuclear factor-kappa B; NF-kB)</td>
<td>[29,30]</td>
</tr>
<tr>
<td>Flower, seed, leaf, root and bark extract of <em>M. oleifera</em></td>
<td>Increase urine production in rats.</td>
<td>[31]</td>
</tr>
<tr>
<td>Ethanolic extracts of the seeds of <em>M. oleifera</em></td>
<td>in vitro antifungal activity</td>
<td>[32]</td>
</tr>
<tr>
<td>Hydroalcoholic extracts of the <em>M. oleifera</em> leaves</td>
<td>Hypolipidemic and antioxidant activities.</td>
<td>[33]</td>
</tr>
<tr>
<td><em>M. oleifera</em> aqueous extract of foliage</td>
<td>Increase antiproliferative potential and leads to apoptosis of cancer cells</td>
<td>[34]</td>
</tr>
<tr>
<td><em>M. oleifera</em> aqueous extract of root</td>
<td>have anti-inflammatory efficacy in rats, reduce carrageenan-induced edoema</td>
<td>[35]</td>
</tr>
<tr>
<td>Hydro-alcoholic extracts of <em>M. oleifera</em> seed</td>
<td>Reduce inflammation and help in effective treatment of experimental colitis</td>
<td>[36]</td>
</tr>
<tr>
<td><em>M. oleifera</em> acetone leaf extracts</td>
<td>Antimicrobial activity</td>
<td>[37]</td>
</tr>
<tr>
<td><em>M. oleifera</em> seeds extract</td>
<td>Show anti-diabetic activity</td>
<td>[38]</td>
</tr>
</tbody>
</table>
3.1. Leaves

*M. oleifera* leaves (Figure 2b) are a good source of beta-carotene, iron, protein, vitamin C, and potassium. Cooked leaves are used in a similar way as spinach is used. Its leaves are dried and converted into powder form; sulfur-bearing methionine and cysteine are two major amino acids present in moringa leaves [39]. They are also found in lesser amounts in several green leafy vegetables.

3.2. Flowers

When cooked, the flowers are edible and have a mushroom flavor. Cough medicine is prepared from flowers soaked with honey. The picture of moringa flower is shown in Figure 2c,d.

3.3. Ben Oil

*M. oleifera* seeds provide around 38-40% oil which is transparent, odorless, and poses the concerns of rancidity similar to other plant oils. The seed cake that remains as residue after the oil has been further extracted can be used as manure or as medium to purify the contaminated water. Oil derived from the moringa seed is beneficial to treat ear infections and skin ailments in salves. Mosquitoes are supposed to be deterred by applying oil to the skin and in this way it can be used as repellant.
4. Morphology of *Moringa oleifera*

*M. oleifera* is a long-lived, evergreen tree with a straight trunk and corky, whitish bark that grows up to 6 m in height. The tree has a tuberous tap root and a weak stem. The leaves are bright green, compound, tripinnate and 30–60 cm long. The horizontal pamphlets are elliptic fit, while the terminal one is obovate. The natural product units are pendulous, green, turning to greenish-brown, three-sided, and split longwise into three sections when dry. The units are 30–120 cm long and 1.8 cm wide and tightening at the two closures. The cases contain around 10 to 20 seeds inserted in the plump essence (Figure 2a–f).

5. Cultivation

Trees developed from seeds have longer roots (which helps with stability and availability to water) than those grown from cuttings, which have much shorter roots [40,41]. It grows nicely in semi-bone-dry, hot, and moist or sandy loam soils. The range of seeds is 3000 to 9000. Seeds germinate in two weeks at a maximum depth of two centimeters. Seedlings can be transferred when they reach 30 cm (3–6 weeks after germination) when planting is scheduled in a nursery [22]. When seedlings reach 30 cm (3–6 weeks following germination), they can be transported to a nursery for planting [42]. When seeds are few and/or labor is not a constraint, cutting is the recommended method by ensuring that moringa production and growing practices are significantly improved. Plants grown from seeds generate lower-quality fruits, according to research [43]. When hard wood cuttings (1–2 m long, 4–16 cm diameter) [24,25,28,29] from mature trees are planted during the rainy season, burying one-third of them in the soil, they lead to the establishment of roots quickly and attain a significant size in a few months [26]. From June to August, it is propagated by planting 1–2 m long limb cuttings and after 6–8 months of planting, it begins to yield pods, but does not bear after the second year. Cultivation is primarily dependent on creating the correct environment for the plant. In well-draining soil, a seed is sown an inch below the surface which germinates with specified ambient parameters as mentioned in Table 3. Plant production is between 1.1 and 1.3 million tonnes per year, with a total area of 380 km² [27]. Hot temperatures are significant for germination. Seeds after sowing should be protected from mice and wooded reptiles, as the seed is nutty and considered a delicious piece by those small animals. Stem cuttings, 10–60 cm long, can likewise be planted in summer and spring.

Table 3. Different parameters for cultivation of *M. oleifera*.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>0–2000 m</td>
<td>[28,44]</td>
</tr>
<tr>
<td>Rain</td>
<td>250–3000 mm per year, if rainfall is less than 800 mm, irrigation is required for leaf formation.</td>
<td>[17]</td>
</tr>
<tr>
<td>Type of soil</td>
<td>Sandy, or sandy-loam, Loamy</td>
<td>[45]</td>
</tr>
<tr>
<td>pH of soil</td>
<td>In the rage of 5–9</td>
<td>[46]</td>
</tr>
<tr>
<td>Fruiting period</td>
<td>In South India during the summer flowers and fruit appear, and While in North India July to September and March to April fruits ripen</td>
<td>[47]</td>
</tr>
<tr>
<td>Irrigation</td>
<td>It should be administered every 2–3 days for the first few days, then once every 10–15 days after that.</td>
<td>[48]</td>
</tr>
<tr>
<td>Temperature</td>
<td>At the temperature range of 25–35 °C and even sometimes it withstands up to 48 °C for a limited time period.</td>
<td>[49]</td>
</tr>
<tr>
<td>Harvesting period</td>
<td>In Spain, between the months of August and September for pods and for leaves, due to high production yield, three to five cuts may be made per season for better productivity.</td>
<td>[15]</td>
</tr>
</tbody>
</table>
6. Industrial Applications

6.1. Treatment of Water

Seeds of the *M. oleifera* are subjected to a fine powder for treating the muddy, unclean water [1,17]. A series of electrical charges is used to purify the water. In between the sloppy particles suspended in the water and the slick particles hanging in the smashed seeds, the small particles are continuously pushed to the pond’s bottom by gravity after approximately 60 min. Examination revealed that the seed settles in the dirt and carries more than 90% of tiny organisms and illnesses with it. Moringa seeds can also be applied to a cleaning agent in the water treatment process [1]. The sloppy particles are continually drawn by gravity as the water sinks to the bottom, after around 60 min. It also carries more than 90% of germs and diseases with it and moringa seeds can also be utilized further as a source of disinfectant. This kind of drinking water treatment has also been reported by other groups of researchers [19,50,51].

6.2. Great Fodder for Cattle

Moringa served as a great feed for cows which may lead to a significantly increase in the weight of domesticated animals by 32 percent and increased the milk output of cows by 43 percent. In addition to hay, one farmer fed his cows only 2 kg of moringa dry matter per day to their regular feed with a 58 percent increase in milk production. It can further be expanded up to 3 kg each day, and milk production by 65% [21,46].

6.3. Bio-Gas

Methane could also be produced from the leaves of *Moringa*. Various reports showed that each hectare may create 4400 cubic meters of biogas per year. When bacteria decompose organic matter (biomass) in the absence of oxygen, biogas is produced [39]. Moringa plants were mashed together with water when they were around 30 days old. Filtration of the fiber via a mesh with 5 mm holes separated the liquid fraction, which was then put into a biogas reactor with an average volatile solids feed of 5.7 g and 580 L of gas was produced per kg of volatile solids. The gas had an average methane concentration of 81% [50,51].

6.4. Standard Plate Count (SPC) Method

Because of the high microbial load, drinking water can be dangerous to consume. The SPC method involves a complete bacterial count of this water determined quantitatively. It was also reported that the *M. oleifera* seed powder works as an antibacterial agent against microorganisms [52] through the process of coagulation or flocculation of produced water [53]. The *M. oleifera* seed powder treatment had the added benefit of lowering the microbial load. After treatment, the quantities of bacterial colonies significantly reduced and the SPC was found in the medium range within the permissible limit (10^2–10^5) in case of groundwater. The addition of 100 mg/L and 150 mg/L of *M. oleifera* seeds significantly reduces the colonies in the plaque. It was seen that the *M. oleifera* seed moves as an antimicrobial specialist against microorganisms [54]. The presence of active antimicrobial properties in the *M. oleifera* such as O-ethyl-4-(α-l-rhamnosylox) benzyl carbamate) oxy benzyl isothiocyanate, proved to disengage any strong matter with the elimination of a large portion of the suspended microorganisms in water. In underground and surface water samples, a pure distilled water and extract of *M. oleifera* seed powder resulted in 90 to 95 percent sedimentation of suspended particles. Duckweed-based waste water stabilization ponds for waste water treatment are a low-cost technique for small urban areas in Zimbabwe [9]. In underground and surface water samples, a pure distilled water and extract of *M. oleifera* seed powder resulted in 90 to 95 percent sedimentation of suspended particles.
6.5. Most Probable Number (MPN)

MPN method is used for counting total coliforms, which are quantifiable. The presence of coliforms indicates that the water has been gravely contaminated and is unfit for human consumption. Hence the MPN for drinking water should be zero. The value represented the coliform MPN per 100 mL of water sample [55]. MPN was found to be over the WHO groundwater standards and MPN/100 mL coliform was reduced after treatment. After treatment, MPN levels in all samples ranged from 500 to 1200 coliforms/mL, indicating that they exceeded the limit as set by WHO standards. The presence of coliforms/mL by the MPN method confirms the presence of hazardous pollutants in water, demonstrating that treated samples are bacteriologically unfit for drinking. Using chlorine with seed powder can result in a negative MPN test. The fraction of M. oleifera seed powder was 50 and 100 mg/L for reducing pH, TS, TDS, hardness, chloride, turbidity, causticity, and alkalinity, respectively 150 mg/L for SPC and MPN [56].

6.6. Other Industrial Uses

The oil is used for the modification of perfumes and hair dressings. Due to its little tendency to deteriorate and become rancid and sticky, it is also utilized as lubricating materials for watches as well as in other delicate hardwares [17]. It is a polyuronide made up of arabinose, galactose and glucoronic acid in a 10:7:2 molar ratios; rhamnose is present in trace amounts [57]. Dehulled seed (kernel) contains about 42% oil which is responsible for the yellowish color of the seed. It is utilized as a lubricant for fine machinery such as watches. After extraction of oil, it is further pressed to make a cake which can be utilized as manure. Moringa seed oil has 13 percent saturated fatty acid content and 82 percent unsaturated fatty acid content [58]. The wood of the drumstick tree is used to make paper and materials, the bark is used to make tanning, and the seeds are employed in the purification of water. Gum of the tree M. oleifera has been reported to have gel-forming potential for topical application [59].

7. Economic Potential

India is the world’s greatest producer of Moringa, with a 380 km² region producing 1.1 to 1.3 million tonnes of delicate natural products each year. Andhra Pradesh (156.65 km²) is the largest state in terms of both area and population, followed by Karnataka (102.8 km²) and Tamil Nadu (103.8 km²) which come in second and third, respectively. Its production and management are made simple by the relative simplicity with which it propagates both sexually and asexually, along with its low demand for soil nutrients and water after planting. The introduction of this plant to a farm with a biodiverse setting may benefit both the farm owner and the surrounding ecosystem [60]. Drumstick trees could be used to extract oil without hindering their water purification capabilities. Drumstick oil is a premium product with a high market worth which could be of use for cooking oil and as a fundamental ingredient in creating a cleaner one [61].

8. Toxicity Levels

Two alkaloids found in root/bark extract are related to lethal hypotensive M. oleifera. In the animal trial of alkaloids obtained from M. oleifera, nazanin A and niazaminin B isolated from the ethanol extract caused hypotension, and bradycardia. Consistent consumption of large amounts of alcohol may result in liver and kidney damage; whereas, excess and/or repeated consumption of the alkaloid spirochin leads to toxic nerve loss and morbidity.

9. Medicinal Properties and Biomedical Applications

M. oleifera has a variety of activities, including the ones to be used as a galactagogue, rubefacient, antiacorbatic, diuretic, stimulant, purgative, antimicrobial, antibacterial [62], anti-inflammatory, antitumor, antioxidant, anti-aging agent, hypoglycaemic, antipoe-ryroidism, anti-cellular [63], hypocholesterolemic, antispasmodic. Moreover, it lowers, circulatory strain, reduces cerebral pains, and lessens headaches. Various therapeutic prop-
Properties have been credited to different portions of this profoundly regarded tree as shown in Figure 3. Practically each and every part of this plant such as bark, gum, root, natural product (cases), flowers, leaf, seed, and seed oil has its own significance. They have been used to control a broad range of illnesses in the form of traditional folk medicine ailments [64]. Several phytochemicals available in *M. oleifera* and their medicinal uses are shown in Table 4.

**Table 4.** *M. oleifera* phytochemicals and their medical uses.

<table>
<thead>
<tr>
<th>Plant Parts</th>
<th>Phytochemicals Present</th>
<th>Medicinal Uses</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root</td>
<td>4-(a-L-rhamnopyranosyloxy)-benzyl glucosinolate and benzyl glucosinolate</td>
<td>Act as anti-inflammatory; stimulant in paralytic afflictions; act as a cardiac; for treatment of rheumatism, lower back or kidney pain.</td>
<td>[1,50]</td>
</tr>
<tr>
<td>Flower</td>
<td>D-glucose, D-mannose, protein, polysaccharide, ascorbic acid,</td>
<td>A stimulant; used as a cure for tumors, hysteria, muscle diseases, inflammation, and lower serum cholesterol</td>
<td>[65–68]</td>
</tr>
<tr>
<td>Gum</td>
<td>L-arabinose, D-galactose, D-gluconic acid, Exudates L-rhamnose, D-mannose, D-xylene and leucoanthocyanin</td>
<td>Used as an abortifacient and in treatment of syphilis as well as rheumatism; overcome dental caries; gum mixed with sesame oil helped to relieve pain from headache, dysentery, asthma, and intestinal problems</td>
<td>[51]</td>
</tr>
<tr>
<td>Leave</td>
<td>Glycoside niazirin, niazirinin, and three mustard oil glycosides, 4-[4′-O-acetyl-a-L-rhamnosyloxy] benzyl isothiocyanate, niaziminin A and B, vitamin A (Beta-carotene), vitamin B (choline), riboflavin, sterols, saponins, phenolics, quercetin, flavonoids, nicotinic acid, and ascorbic acid are present various amino acids like Histidine, Lysine, Tryptophan, Phenylalanine, Leucine, Methionine, Isoleucine, Valine, etc.</td>
<td>Used for eye and ear infections, piles, headache, sore throat, fever; leaf juice is used to control glucose level; treat asthma, hyperglycemia, syphilis, malaria, pneumonia, scurvy, skin diseases, reduces blood pressure and cholesterol, and act as anticancer; anti-atherosclerotic agent, antioxidant, neuroprotectant, antidiabetic</td>
<td>[69–71]</td>
</tr>
<tr>
<td>Seed</td>
<td>Crude protein, Crude fat, carbohydrate, Methionine, cysteine, 4-(a-L-rhamnopyranosyloxy) benzyl glucosinolate, benzyl glucosinolate, moringine, mono-palmitic and di-oleic triglyceride, oleic acid, antibiotic called pterygospermin, fatty acids like behenic acid, linolenic acid, linoleic acid; Phytochemicals like tannins, saponin, phytate, lectin, flavanoids. Apart from these fats, fibers, proteins, minerals, vitamins like A, B, C, and amino acids</td>
<td>The antihypertensive chemicals thiocarbamate and isothiocyanate glycosides have been identified from the acetate phase of the ethanolic extract of Moringa pods, and seed extract exerts its protective action by lowering liver lipid peroxides</td>
<td>[72,73]</td>
</tr>
<tr>
<td>Stem bark</td>
<td>4-hydroxymellein, vanillin, β-testosterone, octacosanol acid and β-sitosterol</td>
<td>The roots are used as a cure for earache and tooth cavity; antitubercular activity; prevent enlargement of spleen and formation of tuberculous glands; in ulcer treatment and also used to cure eye diseases</td>
<td>[74]</td>
</tr>
</tbody>
</table>
Table 4. Cont.

<table>
<thead>
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</tr>
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<tbody>
<tr>
<td>Seed</td>
<td>Ben oil, Thiocarbamate and isothiocyanate</td>
<td>Ben oil has the ability to show resistance against oxidative degradation. Seed powder of <em>M. oleifera</em> Ben oil can also provide a defense to the oxidative stress induced by the arsenic and prevent the accumulation of arsenic in the tissues and blood. Various compounds related to thiocarbamate and isothiocyanate exhibit antitumor potential by inhibiting the tumor promoter teleocidin B-4-induced Epstein–barr virus.</td>
<td>[75,76]</td>
</tr>
<tr>
<td>Flower</td>
<td>Flavanoid-quercetin</td>
<td><em>M. oleifera</em> flowers possess a flavanoid known as quercetin which have a significant impact on regulation of liver function due to its hepatoprotective effects.</td>
<td>[77,78]</td>
</tr>
<tr>
<td>Gum</td>
<td>Gum exudates</td>
<td>These gum exudates are non-toxic compounds that improve stability of therapeutics thereby overall efficiency of the therapeutics. These are also used to treat various chronic disorders.</td>
<td>[79]</td>
</tr>
<tr>
<td>Leave</td>
<td>Flavanoids, Carotenoids, phenols, vitamin A</td>
<td>Antioxidant activity of <em>M. oleifera</em> leaves is mostly due to the presence of flavanoids. Carotenoids are naturally occurring pigments of plant that help in the prevention of damage to photosynthetic apparatus by excessive light intensity. Carotenoids also function as antioxidants along with working as protecting agent for aging, cellular damage and provide many health benefits. Higher concentration of phenols in leaf extract can induce caspases thereby resulting in cellular apoptosis. Vitamin A present in <em>M. oleifera</em> leaves regulates various functions such as vision, growth and reproduction, immune system cellular growth and apoptosis and brain activities.</td>
<td>[80–82]</td>
</tr>
<tr>
<td>Pod</td>
<td>Methyl phydroxybenzoate and β-sitosterol</td>
<td><em>M. oleifera</em> pod contains Methyl phydroxybenzoate and β-sitosterol that play a very efficient role in the lowering of blood pressure.</td>
<td>[4]</td>
</tr>
<tr>
<td>Root bark</td>
<td>N-benzyl, S-ethyl thioformate</td>
<td>N-benzyl, S-ethyl thioformate isolated from bark of <em>M. oleifera</em> root. This compound showed antimicrobial activity.</td>
<td>[83]</td>
</tr>
<tr>
<td>Root</td>
<td>Pterygospermin, 4-α-L-rhamnosoxy benzyl isothiocyanate</td>
<td><em>M. oleifera</em> roots contain Pterygospermin, and 4-α-L-rhamnosoxy benzyl isothiocyanate components that show a very significant antimicrobial activities. These components play a very important role in antifungal and antimicrobial activities of <em>M. oleifera</em> roots.</td>
<td>[51,72,73]</td>
</tr>
</tbody>
</table>
Figure 3. Various medicinal properties of *M. oleifera*.

9.1. Analgesic, Anti-Inflammatory, and Antipyretic Activities

All aspects of this marvel tree have been found to show pain-relieving mechanisms like that of indomethacin in various animal models. Extracts from leaves, seeds, and bark showed significant pain-relieving action in both focal (hot plate technique) and fringe models (acid-induced squirming strategy), in a dose-dependent manner [84,85]. The practical application demonstrated viability against neuropathic pain caused by multiple sclerosis [17]. In a carrageenan-induced paw edema model, reducing leaf removal movement was observed [86]. Extracts of bark showed calming action comparable to diclofenac in a similar model. Root has also been found to have calming qualities [86,87]. The neutrophil guideline and the c-Jun N-terminal kinase pathway may be responsible for the moderating effect [66]. Tannins and other active fixes are involved in the mitigating effect. Some other chemical compounds including alkaloids, flavonoids, phenols, carotenoids, sitosterol, hydroxymellein, vanillin, moringine, sitostenone, moringinine, and 9-octadecenoic acid, to name a few, are reported in this regard [88]. Leaf extract showed critical antipyretic action in brewer’s yeast-induced pyrexia model [89]. Ethanol and the source of ethyl acetic acid of seeds likewise showed huge antipyretic activity [90].
9.2. Neuropharmacological Activity

Aqueous extract of *M. oleifera* leaves has been seen as assurance against Alzheimer’s disease in a colchicine-instigated Alzheimer’s disease model utilizing social testing [91]. Protected Alzheimer’s disease can be fought by controlling electrical activity and monoamine levels in the brain [92]. Another study looked at the toluene-ethyl acetic acid derivation component of the methanolic concentrate of leaf and found that it had intense nootropic action [90]. The vitamins C and E found in the extracted leaf of *M. oleifera* play a crucial part in memory formation in Alzheimer’s disease patients [70,92].

Anticonvulsant action of leaf was demonstrated in male albino mice utilizing pentylenetetrazole and maximal electric shock paradigms [93]. Penicillin-induced epileptic convulsions were reduced in adult albino rats by aqueous extract of the root [94,95]. In actophotometer and rotarod apparatuses, ethanolic extract of leaves revealed both central nervous system depressant and muscle relaxant effects respectively [96–98]. In the staircase test and elevated plus maze test, it also showed considerable anxiolytic action that was in accordance with a dose-dependent manner [99,100].

9.3. Anticancerous Activity

In mouse melanoma tumor model tests, alcoholic and hydromethanolic extracts of leaves and fruits exhibited a considerable growth delay in tumor kinetics [101,102]. *M. oleifera* leaf extract has antiproliferative action against A549 lung cancer cell line, [70,103]. The exposure of leaf extract into chick chorioallantoic membrane leads to antiangiogenic action that was in accordance with dose-dependent manner, demonstrating their strong anticancer potential [102,104–106]. Another study found that pod extract protected male Institute of Cancer Research (ICR) mice from azoxymethane and dextran sodium sulfate-induced colon damage [29]. Studies reported that Breast cancer, hepatocarcinoma, and colorectal cancer cells in vitro, as well as cisplatin-resistant ovarian cancer cells, were all killed by a root and leaf extract of *M. oleifera* [34,107–109]. These findings imply that *M. oleifera* has regeneration potential in addition to its anti-cancerous potential, since flower extract promoted cell proliferation in normal cells but not in cancer cells, while leaf extract demonstrated substantial antitumor and hepatoprotective effects [110]. The anticancerous potential of this plant is attributed to phytoconstituents such as niazimicin, carbamates, thiocarbamates, nitrile glycosides, and others such as quercetin and kaempferol [111,112].

The effect of *M. oleifera* extract on various cancer cell lines is listed in Table 5.

<table>
<thead>
<tr>
<th>Part of <em>M. oleifera</em> Tree</th>
<th>Extract Type</th>
<th>Test</th>
<th>Cell Line Type</th>
<th>Observation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaves</td>
<td>Aqueous extract</td>
<td>XTT assay</td>
<td>Human pancreatic cancer cell lines [PANC-1]</td>
<td>The experiment shows that extract reduced more significantly the presence of all three protproteins in the NF-kB signaling pathway and decreased p65 proteins in PANC-1 cells nuclei which suggests that <em>M. oleifera</em> aqueous extract attenuated PANC-1 cell’s viability.</td>
<td>[113]</td>
</tr>
<tr>
<td>Leaves and cisplantin</td>
<td>Aqueous extract</td>
<td>XTT assay</td>
<td>Human pancreatic cancer cell lines [PANC-1]</td>
<td>Combination of <em>M. oleifera</em> and cisplatin shows inhibitory effect on proliferation of Panc-1 cells, and inhibitory effect of both combined is higher than each agent alone.</td>
<td>[114]</td>
</tr>
</tbody>
</table>
Table 5. Cont.

<table>
<thead>
<tr>
<th>Part of M. oleifera Tree</th>
<th>Extract Type</th>
<th>Test</th>
<th>Cell Line Type</th>
<th>Observation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaves</td>
<td>Moringa leaves extract loaded PLGA-CS-PEG nanoparticles and Moringa leaves extract</td>
<td>MTT assay</td>
<td>Breast cancer cell line MCF-7, Human colorectal carcinoma cell line HCT 116, colorectal adenocarcinoma cells (Caco-2)</td>
<td>M. oleifera leaves extract [ML] and M. oleifera leaves extract loaded with PLGA-CS-PEG nanoparticles [ML] acts as anti-cancer agent by decreasing cell proliferation and exhibiting apoptosis-mediated cell death in liver HepG2, colon cancer HCT 116 and Caco-2 and breast cancer MCF-7 cell line.</td>
<td>[114]</td>
</tr>
<tr>
<td>Leaves</td>
<td>Aqueous extract</td>
<td>Colorimetric tetrazolium salt [XTT] assay</td>
<td>Human pancreatic cancer cell lines [PANC-1], Cellosaurus cell line p34,</td>
<td>M. oleifera leaf extract inhibits the growth of three tested cell lines. Panc-1 cells were more susceptible to the treatment (IC$<em>{50}$ = 1.1 mg/mL) compared to COL0357 (IC$</em>{50}$ = 1.8 mg/mL) and p34 cells (IC$_{50}$ = 1.5 mg/mL). There was a significant inhibition of Panc-1 cell survival at an extract concentration of 0.75 mg/mL. There was also a significant inhibitory effect at a higher concentration (1.5 mg/mL) in the two other cell lines. Moreover, treatment with 2 mg/mL M. oleifera extract resulted in a 98% reduction of Panc-1 cell survival.</td>
<td>[115]</td>
</tr>
<tr>
<td>Leaves</td>
<td>Methanolic extract</td>
<td>MTT assay</td>
<td>Breast cancer cell line MCF-7</td>
<td>Experiment conducted on MCF-7 cell lines Average range of growth inhibition has been 80–90% (mean value 87.13%) with various conditions and in optimum extraction condition at temperature 50 °C and incubation time 45 min with medium frequency, cell growth inhibition is 88.59%.</td>
<td>[116]</td>
</tr>
<tr>
<td>Leaves</td>
<td>Methanolic extract [ME] and Dichloromethane extract [DE]</td>
<td>Antiproliferative assay</td>
<td>Breast cancer cell line MCF-7, Human hepatoma cell line, colorectal adenocarcinoma cells Caco-2</td>
<td>Dichloromethane extract was more cytotoxic than ME. It showed an IC50 of 120.37 ± 2.55, 112.46 ± 3.74, and 133.58 ± 2.47 µg/mL for HepG2, Caco-2, and MCF-7, respectively, while methanolic extract exhibited less cytotoxicity to all cancer cell lines (IC$_{50}$ &gt; 250 µg/mL). M. oleifera extracts not only exhibit antiproliferative potential against cancer cells but also showed no cytotoxicity on normal cells.</td>
<td>[117]</td>
</tr>
</tbody>
</table>
### Table 5. Cont.

<table>
<thead>
<tr>
<th>Part of M. oleifera Tree</th>
<th>Extract Type</th>
<th>Test</th>
<th>Cell Line Type</th>
<th>Observation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bark, Leaves, and Seeds</td>
<td>Ethanolic extract</td>
<td>Clonogenic cell survival assay</td>
<td>MDA-MB-231 and HCT-8</td>
<td>A significant decrease in cell survival was observed in MDA-MB-231 and HCT-8 cell lines when treated with leaf extract and barks extract and did not observe a significant decrease in cell population when cell lines were exposed to the seed extract of M. oleifera. Phenotypic changes in the cells were observed in cells treated with leaf extract and bark extract.</td>
<td>[118]</td>
</tr>
<tr>
<td>Leaves</td>
<td>Aqueous extract</td>
<td>Apoptosis assay</td>
<td>Human pancreatic cancer cell lines [PANC-1]</td>
<td>Nuclear factor kappa B (NF-kB) pathway is involved in growth and proliferation of cells by the inhibition of apoptosis. Treatment of human pancreatic cells with the aqueous extract of M. oleifera showed down-regulation of p65, phospho-IκBα and IκBα proteins levels compared to untreated cells by targeting NF-kB signaling pathway thereby inhibiting survival of pancreatic cancer cell by promoting apoptosis</td>
<td>[30,119]</td>
</tr>
<tr>
<td>Leaves and cisplatin</td>
<td>Aqueous extract</td>
<td>Apoptosis assay</td>
<td>Human pancreatic cancer cell lines [PANC-1]</td>
<td>M. oleifera leaf extract in combination with cisplatin showed strong synergistic effect by targeting NF-kB signaling pathway. Cisplatin is a chemotherapeutic agent that is based on platinum and has fewer efficacies when given alone in pancreatic cancer while combination of cisplatin with M. oleifera leaf extract increases its efficacy due to role of M. oleifera leaf extract in inhibition of NF-kB signaling.</td>
<td>[30,120]</td>
</tr>
<tr>
<td>Leaves</td>
<td>Moringa leaves extract and poly D-L-lactide-co-glycolide (PLGA)-chitosan (CS) and polyethylene glycol (PEG) loaded nanoparticles</td>
<td>MTT assay</td>
<td>Breast cancer cell line MCF-7, Human colorectal carcinoma cell line HCT 116/(Caco-2)</td>
<td>PLGA is a type of FDA-approved biodegradable nanoparticles that help in the targeted delivery of various treatments. Coating with CS and PEG helps in the longevity of the treatment and improves biocompatibility. Treatment of Breast cancer cell line MCF-7, Human colorectal carcinoma cell line HCT 116/(Caco-2) with M. oleifera leaf extract loaded with PLGA-CS-PEG increases the efficiency of the extract by inducing the apoptosis of more number of cancer cells.</td>
<td>[114]</td>
</tr>
</tbody>
</table>
9.4. Antioxidant Activity

*M. oleifera* foods offer significant antioxidant properties against a variety of free radicals [28]. Prepared leaf extract showed a considerable decrease in malondialdehyde levels and a significant increase in glutathione levels in vivo studies. Several extracts prepared from natural sources showed useful in scavenging of free radicals activity of roots altogether decreased iron and FeSO4-activated microsomal lipid peroxidation in a part subordinate way [31,114,118]. Antioxidant activity of pods through the 2-diphenyl-2-picryl hydroxyl (DPPH) method has been reported by researchers [121,122]. In a male BALB/c rat model of acetaminophen-induced nephrotoxicity, *M. oleifera* leaf extract demonstrated a nephroprotective effect in addition to antiproliferative effect [123,124]. Several bioactive compounds found in the *M. oleifera* such as triterpenoids, monopalmitic moringine, di-oleic fatty acids, campesterol, avenasterol, stigmasterol, sterol, β-sitosterol, vitamin A, and its precursor beta-carotene are only a few of the compounds that have been reported which may serve as cancer prevention agent [29,125–131].

9.5. Hepatoprotective Activity

An extract of the moringa leaves had hepatoprotective effects in Sprague Dawley rats [132,133]. They had been made aware of carbon tetrachloride or acetaminophen-induced liver toxicity [134–139]. Furthermore, hepatoprotection against antitubercular medicines and liver damage caused due to alloxan treatment [140]. The *M. oleifera* plant-based daily therapy for the period of 21 days was demonstrated to have huge potential in constricting hepatic injury [65,66]. Ascorbic acid, quercetin, kaempferol, and benzyl glucosinolate have all been discovered with hepatoprotective properties [141,142].

9.6. Anti-Ulcer and Gastroprotective Properties

The extract of leaves significantly reduced ulcer biomass in a gastric ulcer model caused by ibuprofen and a pyloric ligation test [143] and in addition to a considerable decrease in duodenal ulcers and stress ulcers caused by cysteamine [144]. This property could be enhanced by flavonoids and biphenyls [145].

9.7. Cardiovascular Activity

In male Wistar rats, an extract of *M. oleifera* leaf reduced cholesterol levels and acted as a defense against hyperlipidemia caused by iron deficiency [146]. In lower chronotropic and inotropic effects in damaged frog hearts, leaf extract had an antihypertensive effect on diseased hypertensive rodents [146,147]. Nazanin B, niazinin A, and miasmic are active ingredients for hypotensive activity [148]. In Male Wistar rats model, Isoproterenol-induced myocardial infarction was also inhibited by a leaf extract. The component responsible for this cardioprotective action was cell proliferation, lipid peroxidation prevention, and protection against isoproterenol-induced ultrastructure and histopathology unsettling effects [149]. *M. oleifera* lam function in irritation and lipid build-up in several tissue frameworks [150].

9.8. Antiobesity Activity

There was a considerable weight loss as compared to the fat control grouped by using oral therapy with leaf powder extract of *M. oleifera* [151]. Treatment of hypercholesterolemia animals with methanolic *M. oleifera* leaf extract for 49 days resulted in a major reduction in cholesterol level, body weight, fatty acids, as well as blood glucose level, liver indicators, and organ weight levels [152,153]. In heavy rats, downregulation of leptin and resistant mRNA articulation and overexpression of adiponectin quality articulation are among the mechanisms [154].
9.9. Antiasthmatic Activity

Extract of seeds showed assurance significant efficacy against asthma as researched in different models; an immediate bronchodilator effect was hypothesized for this effect, together with moderating and antibacterial actions [155] and prudence of prompt, easily affected reaction [156]. In bronchoalveolar lavage, an ethanolic extract of seeds showed potent efficacy against ovalbumin-induced bronchoalveolar lavage, guinea pigs showed a significant expansion of respiratory boundaries and a decrease in interleukin release. [157].

9.10. Hematological Activity

A randomized, double-blind, placebo-controlled trial was conducted on ladies who were pallid with hemoglobin levels somewhere in the mean hemoglobin, and mean corpuscular hemoglobin concentrations increased after being treated with an aqueous extract of moringa leaf in the 8–12 g/dL range [158]. Another review uncovered the potential of moringa for healthy human volunteers for 14 days aiding in a significant increase in platelet count [159,160].

9.11. Antidiabetic Activity

In normal and abnormal circumstances alloxan-induced or cysteamine-induced duodenal and peptic ulcers, the leaf extract had a significant antihyperglycemic and hypoglycemic effect [31,161–163]. With type 1 diabetic mouse models, an extensive review was conducted to determine the impact of the elimination of lipid profile, glucose, oral glucose resilience, body weight, and plasma insulin. The homeostatic model evaluation by different experiments on mice showing antidiabetic activity is described in Table 6.

Table 6. Antidiabetic activity of M. oleifera plant extracts.

<table>
<thead>
<tr>
<th>Tree Part [Extract]</th>
<th>Model Animal</th>
<th>Treatment and Time Duration</th>
<th>Results</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf powder</td>
<td>Alloxan-induced diabetic Sprague-Dawley rats</td>
<td>Time: 8 h Conc.: 50 mg/kg</td>
<td>At the second week, a significant reduction was observed in BG in diabetic rats treated with M. oleifera, from 300 mg/dL to 100 mg/dL as compared with controls.</td>
<td>No change in numbers of lactic acid bacteria</td>
</tr>
<tr>
<td>Leaf powder</td>
<td>Alloxan-induced diabetic mice</td>
<td>Treatment time: 1, 3 and 5 h Diabetic Con: Untreated Diabetic positive Con: Insulin 0.7IU/kg Diabetic MO: 100, 300, and 500 mg/kg MO</td>
<td>Reduction in diabetic rats at 5 h with 300 and 500 mg/kg M. oleifera (p &lt; 0.01); 500 mg/kg dose dependent significant reductions in Blood glucose level by 34.3%, 60.9%, and 66.4% after 1, 3, and 5 h, time points respectively.</td>
<td>No changes in diabetic mice Significant increase in catalase, no changes in superoxide dismutase, and significant reduction in MDA</td>
</tr>
<tr>
<td>Tree Part [Extract]</td>
<td>Model Animal</td>
<td>Treatment and Time Duration</td>
<td>Results</td>
<td>Insulin Level and Other Effect</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------</td>
<td>-----------------------------</td>
<td>---------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Aqueous leaf extract</td>
<td>STZ-induced diabetic Wistar rats</td>
<td>Treatment time: 3 weeks Con: Untreated Con M. oleifera: 100, 200, and 300 mg/kg M. oleifera Diabetic M. oleifera: 100, 200, and 300 mg/kg M. oleifera Diabetic positive Con: Glipizide 2.5 mg/kg</td>
<td>Significant reduction in fasting BG of diabetic rats treated with MO. Reduction after 1, 2, and 3 weeks with 200 mg was 25.9%, 53.5%, and 69.2%, respectively.</td>
<td>Insulin level not measured Increase in Hb and total protein levels.</td>
</tr>
<tr>
<td>Methanolic leaf extract</td>
<td>STZ-induced diabetic Wistar rats</td>
<td>Treatment time: 6 weeks Con: Untreated Con M. oleifera: 250 mg/kg M. oleifera Diabetic Con: Untreated Diabetic M. oleifera: 250 mg/kg M. oleifera</td>
<td>Reduction in diabetic rats from 30.96 to 27.6 mmol/L, ( p &lt; 0.05 )</td>
<td>Insulin level not measured, Reduction in the activities of hepatic enzymes. Significant reduction of cholesterol, LDL, IL-6, TNF-( \alpha ) and MCP-1. Significant increase in HDL</td>
</tr>
<tr>
<td>Methanolic leaf extract</td>
<td>STZ-induced diabetic Wistar rats</td>
<td>Treatment time: 3 weeks Con: Untreated Diabetic M. oleifera: 200 mg/kg/day M. oleifera</td>
<td>Reduction in BG levels in diabetic rats from 229 ± 9.05 mg/dL to 86 ± 4.2 mg/dL, ( p &lt; 0.05 )</td>
<td>Oxidative stress attenuation and normalization of mitochondrial function in liver.</td>
</tr>
<tr>
<td>Methanolic leaf extract</td>
<td>Alloxan-induced diabetic Wistar rats</td>
<td>Treatment time: 6 weeks Con: Untreated Diabetic Con: Untreated Diabetic M. oleifera: 300 or 600 mg/kg Diabetic positive Con: metformin 100 mg/kg</td>
<td>Reduction in diabetic rats. Blood glucose was reduced by 76% at 300 mg/kg and 84% at 600 mg/kg, ( p &lt; 0.001 ). In addition, glucose tolerance was improved by 56% and 57% with 300 or 600 mg/kg of M. oleifera, respectively, ( p &lt; 0.001 ).</td>
<td>Significant increase in diabetic rats. Serum insulin levels increased 1.3–1.7-fold, ( p &lt; 0.01 ). Significant reductions in triglycerides, total cholesterol, and LDL. Significant increase in HDL.</td>
</tr>
</tbody>
</table>
Table 6. Cont.

<table>
<thead>
<tr>
<th>Tree Part [Extract]</th>
<th>Model Animal</th>
<th>Treatment and Time Duration</th>
<th>Results</th>
<th>Insulin Level and Other Effect</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separate ethanolic extracts from leaves, seeds, and stem</td>
<td>C57BLKS/J Iar- + Leprdb/+ Ledprdb and C57BLKS/J Iar-m +/Leprdb mice</td>
<td>Treatment time: 5 weeks Con: Untreated M. oleifera: 150 mg/kg M. oleifera Metformin: 150 mg/kg</td>
<td>Reduction in diabetic mice (only studied in leaves extract). Reduction in fasting blood glucose from 483 to 312 mg/dL, $p &lt; 0.05$.</td>
<td>Significant increase in diabetic mice (only studied in leaves extract). Increased insulin levels from $946 \pm 92$ to $1678 \pm 268$ pg/mL, $p &lt; 0.05$. Significant decrease in triglycerides and LDL. Decreased expression of inflammatory markers in the kidneys.</td>
<td>[168]</td>
</tr>
<tr>
<td>Compounds extracted from seeds</td>
<td>STZ-induced diabetic ICR mice</td>
<td>Treatment time 2 weeks Con: Untreated Diabetic Con: Untreated Diabetic M. oleifera: 20 mg/kg per M. oleifera compound</td>
<td>Reduction in diabetic mice ($p &lt; 0.05$).</td>
<td>Insulin level not measured and no other effect</td>
<td>[169]</td>
</tr>
<tr>
<td>Seed powder</td>
<td>STZ-induced diabetic Albino rats</td>
<td>Treatment time: 4 weeks Con: Untreated Diabetic Con: Untreated Diabetic M. oleifera: 50 or 100 mg/kg M. oleifera for 4 weeks</td>
<td>Reduction in diabetic rats from 266 to 148 mg/dL, $p &lt; 0.05$.</td>
<td>Increase in body weight</td>
<td>[170]</td>
</tr>
<tr>
<td>Leaf powder</td>
<td>Male Sprague Dawley rats</td>
<td>Treatment time: Hyperglycemia was induced by applying 150 mg/kg alloxan monohydrate 50 mg/mL for 8 weeks</td>
<td>In second week, glucose levels in the diabetic group treated with M. oleifera diminished in comparison to the untreated diabetic group. The healthy group treated with M. oleifera showed lower values (24 mg/dL) in comparison to the control group (53 mg/dL).</td>
<td>Increase in body weight The doses of M. oleifera powder leaf tested revealed no adverse effects in experimental animals.</td>
<td>[163]</td>
</tr>
</tbody>
</table>
9.12. Anti-Urolithic Activity

In a hyperoxaluria-induced mouse model [171,172] and ethylene glycol-induced urolithiasis model, aqueous and ethanolic extract of this plant showed anti-urolithiatic activity [173].

9.13. Diuretic Activity

Seeds, roots, leaves, flowers, and bark extract expanded urine yield in rodents; extract of leaf showed a portion subordinate diuretic activity more prominent than control yet not as much as hydrochlorothiazide. This activity was attributed due to the presence of campesterol, stigmasterol, β-sitosterol, and avenasterol [174].


Ethanolic extract of seeds hindered latent cutaneous hypersensitivity incited by hostile to Immunoglobulin G (IgG) and histamine release from pole cells; the mechanism is hidden, yet its activity could be harmful in layer settling action [175] and more decreased scratching recurrence in an ovalbumin refinement model [176].

9.15. Anthelmintic Activity

It took a very less effort to incapacitate Indians because the plant had great anthelmintic activity [177]. Ethanolic extract and aqueous extract, separately and in larvicidal measure, showed 95.89 percent and 81.72 percent egg incubates hindrance, respectively, in ovicidal examination. They were deemed adequate for 56.94 percent of the time and 92.50 percent of the time [178].

9.16. Antidiarrheal Activity

In male Wister rats, extract of moringa seeds demonstrated a considerable decrease in gastrointestinal motility and were considered viable in castor oil mediated loose bowels [179–181]. Tannins, saponins, and flavonoids are phytochemical compounds that have antidiarrheal properties [168].

9.17. Diabetes and Diverse Effects

Leaf extract shows a decrease in undesirable sebum secretion from sebaceous organs during winter in humans [158]. This herb has unambiguously been identified as a source of “galactagogue” derived from the Greek word “galacta” which means milk—is a kind of herb and drug or food, which enhances the production of breast milk [159]. Diabetes is defined by metabolic dysregulation, especially of carbohydrate metabolism, as seen by hyperglycemia due to insulin secretion and action due to abnormal Insulin levels were not analyzed [166–168]. There was no change in the number of lactic acid bacteria counted as described in Table 5. In frog models, methanolic root concentrate demonstrated local sedative action; whereas, in guinea pig model [160], M. oleifera leaf extract has a significant inhibitory effect on CYP3A4 [161]. Thus, M. oleifera has an extraordinary potential for herb-drug formulations.

10. Summary and Future Research

Drumstick plant is a tropical tree with a diverse range of applications and is attracting increasing international attention for exploring more therapeutic interventions. It should be broadly developed in the great majority of places where climatic conditions are difficult to predict for its ideal development. Various studies on M. oleifera have been conducted so far. The primary goal of this research was to uncover and analyze the pharmacological and healing benefits of M. oleifera. This plant has been shown to be effective in preclinical studies and found to have pain-relieving, calming, anthelmintic, anticancer, local sedative, nootropic, hepatoprotective, gastroprotective, anti-hypersensitivity, anti-ulcer, cancer preventive, asthmatic, diuretic, cardiovascular, anti-stoutness, antidiabetic, antiepileptic, anti-urolithiasis, injury-repairing potentialities.
Moringa plant being a rich source of phytoconstituents, have the prospects to develop functional food and nutraceuticals. However, detailed in vitro and in vivo evaluations of bioavailability and biological activities are compulsory to permit reasonable and appropriate recommendations of phytoconstituents for future drug development. Proper attention is required to be devoted to developing cultivars with higher foliage yield by means of specific breeding works, as the foliage is the richest source of carotenoids, ascorbic acids, glucosinolate, and other bioactives, compared to other edible parts. Elicitors (abiotic and biotic) and signaling molecules, such as, methyl jasmonate and salicylic acid were studied for the augmentation of carotenoids and tocopherols in the foliage of *M. oleifera*. Overall, *M. oleifera* is emerging as one of the prospective industrial crops in tropical and subtropical countries.


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