Applications of *Moringa oleifera*

Subjects: Horticulture

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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, ß-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.

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][5][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. Industrial Applications

2.1. Treatment of Water

Seeds of the *M. oleifera* are subjected to a fine powder for treating the muddy, unclean water [1][15]. 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 [16][17][18].

2.2. 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% [19][20].

2.3. 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 [21]. 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% [17][18].

2.4. 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 [22] through the process of coagulation or flocculation of produced water [23]. 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 [24]. 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.

2.5. 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 [25]. 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 [26].

2.6. 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 [15]. 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 [27]. 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 [28]. 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 [29].

3. Economic Potential

India is the world's greatest producer of *Moringa*, with a 380 km^2 region producing 1.1 to 1.3 million tonnes of delicate natural products each year. Andhra Pradesh (156.65 km^2) is the largest state in terms of both area and population, followed by Karnataka (102.8 km^2) and Tamil Nadu (103.8 km^2) 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 [30]. 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 [31].

4. 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 niaziminin 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.

5. Medicinal Properties and Biomedical Applications

M. oleifera has a variety of activities, including the ones to be used as a galactagogue, rubefacient, antiscorbutic, diuretic, stimulant, purgative, antimicrobial, antibacterial [32], anti-inflammatory, antitumor, antioxidant, anti-aging agent, hypoglycaemic, antipoetryroidism, anti-cellular [33], hypocholesterolemic, antispasmodic. Moreover, it lowers, circulatory strain, reduces cerebral pains, and lessens headaches. Various therapeutic properties have been credited to different portions of this profoundly regarded tree as shown in **Figure 1**. Practically each and every part of this plant such as bark, gum, root, natural product (cases), flowers, leaf, seed, and seed oil has their own significance. They have been used to control a broad range of illnesses in the form of traditional folk medicine ailments [34].

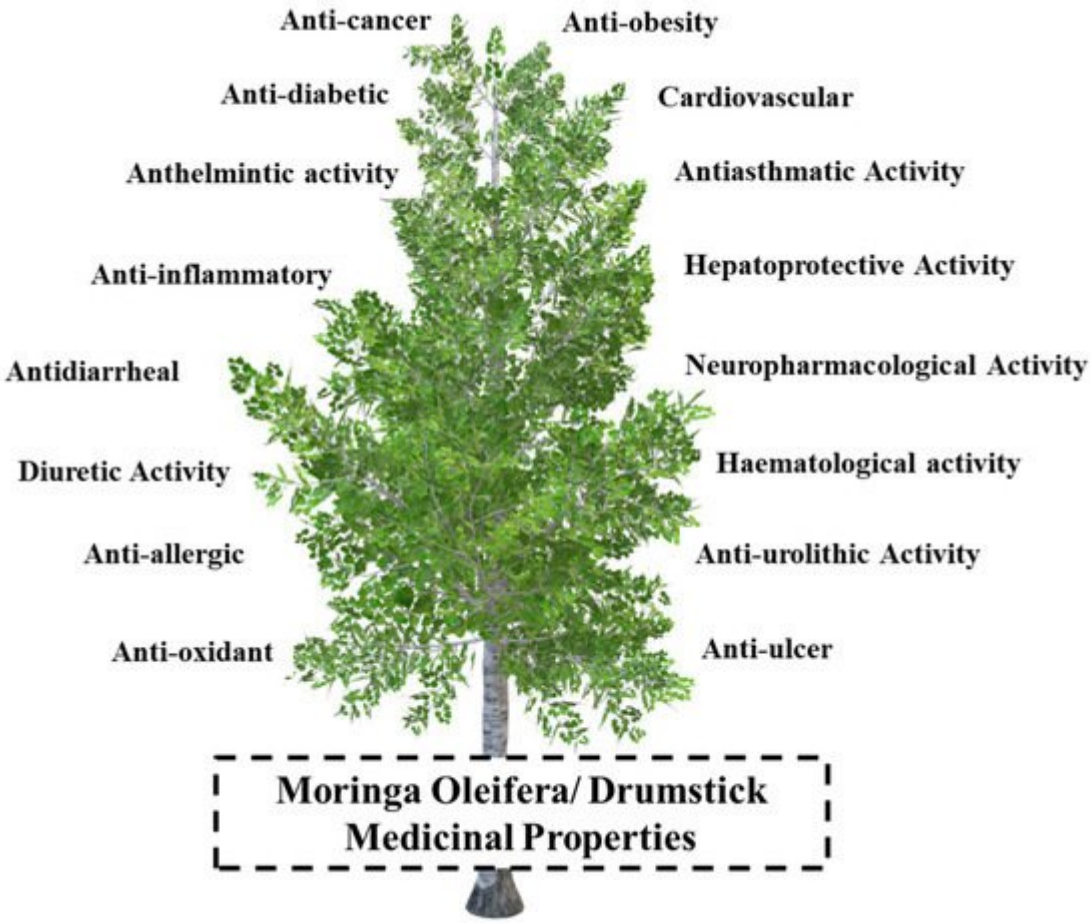

Figure 1. Various medicinal properties of *M. oleifera*.

5.1. 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 [35][36]. The practical application demonstrated viability against neuropathic pain caused by multiple sclerosis [15]. In a carrageenan-induced paw edema model, reducing leaf removal movement was observed [37]. Extracts of bark showed calming action comparable to diclofenac in a similar model. Root has also been found to have calming qualities [37][38]. The neutrophil guideline and the c-Jun N-terminal kinase pathway may be responsible for the moderating effect [39]. 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 [40]. Leaf extract showed critical antipyretic action in brewer's yeast-induced pyrexia model [41]. Ethanol and the source of ethyl acetic acid of seeds likewise showed huge antipyretic activity [42].

5.2. 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 [43]. Protected Alzheimer's disease can be fought by controlling electrical activity and monoamine levels in the brain [44]. 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 [42]. 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 [44][45].

Anticonvulsant action of leaf was demonstrated in male albino mice utilizing pentylenetetrazole and maximal electric shock paradigms [46]. Penicillin-induced epileptic convulsions were reduced in adult albino rats by aqueous extract of the root [47][48]. In actophotometer and rotarod apparatuses, ethanolic extract of leaves revealed both central nervous system depressant and muscle relaxant effects respectively [49][50][51]. In the staircase test and elevated plus maze test, it also showed considerable anxiolytic action that was in accordance with a dose-dependent manner [52][53].

5.3. Anticancerous Activity

In mouse melanoma tumor model tests, alcoholic and hydromethanolic extracts of leaves and fruits exhibited a considerable growth delay in tumor kinetics [54][55]. *M. oleifera* leaf extract has antiproliferative action against A549 lung cancer cell line, [45][56]. 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 [55][57][58][59]. Another study found that pod extract protected male Institute of Cancer Research (ICR) mice from azoxymethane and dextran sodium sulfate-induced colon damage [60]. 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* [61][62][63][64]. 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 [65]. The anticancerous potential of this plant is attributed to phytoconstituents such as niazimicin, carbamates, thiocarbamates, nitrile glycosides, and others such as quercetin and kaempferol [66][67].

5.4. Antioxidant Activity

M. oleifera foods offer significant antioxidant properties against a variety of free radicals [68]. 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 [69][70][71]. Antioxidant activity of pods through the 2-diphenyl-2-picryl hydroxyl (DPPH) method has been reported by researchers [72][73]. In a male BALB/c rat model of acetaminophen-induced nephrotoxicity, *M. oleifera* leaf extract demonstrated a nephroprotective effect in addition to antiproliferative effect [74][75]. 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 [60][76][77][78][79][80][81][82].

5.5. Hepatoprotective Activity

An extract of the moringa leaves had hepatoprotective effects in Sprague Dawley rats [83][84]. They had been made aware of carbon tetrachloride or acetaminophen-induced liver toxicity [85][86][87][88][89][90]. Furthermore, hepatoprotection against antitubercular medicines and liver damage caused due to alloxan treatment [91]. The *M. oleifera* plant-based daily therapy for the period of 21 days was demonstrated to have huge potential in constricting hepatic injury [39][92]. Ascorbic acid, quercetin, kaempferol, and benzyl glucosinolate have all been discovered with hepatoprotective properties [93][94].

5.6. 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 [95] and in addition to a considerable decrease in duodenal ulcers and stress ulcers caused by cysteamine [96]. This property could be enhanced by flavonoids and biphenyls [97].

5.7. 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 [98]. In lower chronotropic and inotropic effects in damaged frog hearts, leaf extract had an antihypertensive effect on diseased hypertensive rodents [98][99]. Nazanin B, niazinin A, and miasmic are active ingredients for hypotensive activity [100]. 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 [101]. *M. oleifera* lam function in irritation and lipid build-up in several tissue frameworks [102].

5.8. 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* [103]. 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 [104][105]. In heavy rats, downregulation of leptin and resistant mRNA articulation and overexpression of adiponectin quality articulation are among the mechanisms [106].

5.9. 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

[107] and prudence of prompt, easily affected reaction [108]. 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. [109].

5.10. 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 [110]. Another review uncovered the potential of moringa for healthy human volunteers for 14 days aiding in a significant increase in platelet count [111] [112].

5.11. 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 [69][113][114][115]. 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.

5.12. Anti-Urolithic Activity

In a hyperoxaluria-induced mouse model [116][117] and ethylene glycol-induced urolithiasis model, aqueous and ethanolic extract of this plant showed anti-urolithiatic activity [118].

5.13. 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 [119].

5.14. Anti-Allergic Activity

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 [120] and more decreased scratching recurrence in an ovalbumin refinement model [121].

5.15. Anthelmintic Activity

It took a very less effort to incapacitate Indians because the plant had great anthelmintic activity [122]. 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 [123].

5.16. 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 [124][125][126]. Tannins, saponins, and flavonoids are phytochemical compounds that have antidiarrheal properties [127].

5.17. Diabetes and Diverse Effects

Leaf extract shows a decrease in undesirable sebum secretion from sebaceous organs during winter in humans [110]. 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 [111]. 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 [127][128][129]. There was no change in the number of lactic acid bacteria counted. In frog models, methanolic root concentrate demonstrated local sedative action; whereas, in guinea pig model [112], *M. oleifera* leaf extract has a significant inhibitory effect on CYP3A4 [113]. Thus, *M. oleifera* has an extraordinary potential for herb-drug formulations.

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