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REVIEW ARTICLE

Pharmacological Investigation and Health Benefits of *Moringa oleifera* Lam: A Comprehensive Review and Future Perspectives

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Abstract

Moringa oleifera Lam, referred to as the horseradish or drumstick tree, has attracted much interest for its diverse pharmacological properties and traditional uses across various cultures. This review provides an in-depth analysis of the pharmacological properties of *M. oleifera*, focusing on its phytochemical composition, therapeutic potential, and safety profile. This study discusses various pharmacological characteristics, including antidiabetic, anticancer, antimicrobial, anti-inflammatory, antioxidant, hepatoprotective, and neuroprotective activities. This review also investigates the mechanisms of action responsible for the observed pharmacological effects and provides insights into the molecular pathways involved. The safety and potentially harmful effects of *M. oleifera* supplements are evaluated through preclinical and clinical trials. This review summarises the current understanding of *M. oleifera*'s pharmacological properties and offers valuable insights for researchers, healthcare professionals, and policymakers seeking to utilise the therapeutic potential of this plant. Overall, *M. oleifera* shows great promise as a natural source of bioactive compounds with therapeutic applications. Future research should focus on *M. oleifera* therapeutic applications of *M. oleifera*, including clinical trials, structure-activity relationships, and novel formulations to improve bioavailability and efficacy.

Major Findings: *Moringa oleifera* exhibits diverse pharmacological properties, including antidiabetic, anticancer, anti-inflammatory, antioxidant, antimicrobial, hepatoprotective, and neuroprotective effects. Various plant parts have demonstrated therapeutic potential with a favourable safety profile, though further research is needed to optimise formulations and validate clinical efficacy. Future studies should focus on clinical trials, synergistic effects, and standardization to enhance its therapeutic applications.

Keywords: *Moringa oleifera*, Pharmacological Activities, Pharmacological Properties, Prevention

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1. Introduction

A significant activity now utilising the potential properties of bioactive compounds naturally found in plants is the application of plant-derived products in medicine. Numerous studies have explored the potential properties of incorporating plant ingredients into safe medications through synthetic methodologies, as well as incorporating them into a daily diet. The *M. oleifera* plant, sometimes known as a horseradish or drumstick tree, is a member of the *Moringaceae* family and is widely referred to as "*pokok kelor*" in Malaysia. Numerous bioactive components are present in it, which give the plant extract its pharmacological properties and bolster its positive consequences on humans[1-3]. The leaves of *M. oleifera* are rich in bioactive compounds such as carotenoids and polyphenols, making them a valuable source of natural medicinal benefits[4]. Several investigations have been conducted to explore the potential medical benefits of bioactive chemicals, which exhibit multiple biological activities including antioxidant, anti-inflammatory, and anti-microbe properties. Furthermore, the development of an efficient extraction technique has changed the game because it allows the extraction of useful substances while preserving their original structure and content. Thus, it has been demonstrated that real substances work better than synthetic substances, which are frequently hazardous and have a higher cancer risk. However, even before its nutritional value and possible medical benefits were identified, *M. oleifera* was utilised practically and historically for a variety of reasons, including food preparation, cosmetic value, and traditional treatments for a wide range of ailments[5,6]. The perennial tree, *M. oleifera* is widely grown in many tropical countries and can withstand difficult growing environments. *M. oleifera*, sometimes referred to as the miracle tree, has been used in traditional medicine for several generations. Different portions of *M. oleifera* are used to treat a variety of diseases, including malnutrition, diabetes, blindness, anaemia, hypertension, stress, depression, skin, arthritis, joints, and kidney stones, with no documented adverse effects at doses that can be consumed. Additionally, this plant demonstrated the ability to support blood glucose management and cardiovascular system health and provided anti-oxidant, anti-inflammatory, and anti-cancer activities. It also demonstrated the ability to support breastfeeding and urinary tract regulation[7]. Its nutritional, therapeutic, and bioremediation qualities allow its use in many culinary applications. Tree seeds have historically been employed in wastewater treatment as natural coagulants and flocculants. The bark and leaves function as biosorbents to remove dyes and heavy metals from the environment. Because of the tree's unique blend of different phytochemicals, it offers treatments for various diseases and conditions. Tree gum exudates are used in biodegradable drug delivery systems, as well as treatments for intestinal cancer, asthma, and diarrhoea. These applications make them extremely valuable in medicine. The multifaceted benefits of *M. oleifera* could lead to the overuse of this tree, which may soon threaten the current state of natural variability. The species must be conserved for reasons related to ethnobotany, pharmacology, nutraceuticals, and biodiversity[8]. Because the components of *M. oleifera* are directly linked to its safety, more researchers are concentrating on identifying the active compounds to investigate their pharmacological effects and potential mechanisms, which are essential for the development of *M. oleifera*-based medications and food products. Investigating the relationship between the product's components and efficacy, identifying the essential constituents, choosing various dose forms, and assessing *M. oleifera* toxicity in humans are essential and valuable tasks. These discoveries have led to the development of new preparation techniques, pharmacological benefits, and toxicological consequences for *M. oleifera*[9]. This review provides an overview of the current understanding of *M. oleifera*'s pharmacological properties, offering valuable insights for researchers and healthcare professionals to utilise the therapeutic potential of this plant. To recognise the significance of *M. oleifera*'s medicinal properties, it is important to first analyze its botanical classification.

2. Plant Profile and Taxonomical Classification

The plant *M. oleifera* belongs to the Kingdom *Plantae*; Subkingdom: *Tracheobionta*; Super Division: Spermatophyta; Division: *Magnoliophyta*; Class: *Magnoliopsida*; Subclass: Dilleniidae; Order:

Capparales; Family: *Moringaceae*; Genus: *Moringa*; Species: *oleifera*[10-12].

3. Morphology

Moringa oleifera biomass yield and quality in Southwest China valleys using different planting densities and cutting heights[13]. A typical tree has modest to moderate dimensions, with naturally trifoliate leaves, flowers that are born on an inflorescence that is 10 to 25 cm long[12], and fruits that are typically trifoliate and called "pods"[10]. The canopy has an umbrella form, the branches are normally disorderly, the trunk develops straight but occasionally becomes poorly formed, the brown seeds possess a somewhat porous shell, and the tree can produce between 15,000 and 25,000 seeds annually[14].

4. Phytochemical Constituents and Phytochemistry

Simple sugars, rhamnose, glucosinolates, and isothiocyanates, a rather uncommon class of chemicals, are among several substances found in *M. oleifera*[15]. The stem of *M. oleifera* has been used for the isolation of octacosanoic acid, 4-hydroxymellin, β-sitosterol, β-sitosterol 14, and vanillin[16]. Xylose, mannose, L-rhamnose, glucuronic acid, galactose, and L-arabinose were present in the cleansed whole-gum exudate from *M. oleifera*. Mild acid hydrolysis of the entire gum produced a homogenous, degraded gum polysaccharide that included galactose, l-mannose, glucuronic acid, quercetin, wax, D-glucose, sucrose, nine amino acids, kaempferol, and traces of alkaloids present in flowers. The ash contained a significant amount of calcium and potassium. Certain flavonoid pigments, including alkaloids, kaempferol, rhamnetin, isoquercitrin, and kaempferitrin, have also been reported present in them[16,17]. A novel O-ethyl-4-(ά-Lrhamnosyloxy)benzyl carbamate 11 has been separated from the *Moringa* seed's ethanol extract[18], together with seven recognised bioactive compounds 3-O-(6'-O-oleoyl-β-D-glucopyranosyl)-β-sitosterol[19], such as niazimicin[20], and 4-(ά- Lrhamnosyloxy)-benzyl isothiocyanate[21].

5. Traditional Uses

Although *M. oleifera* has historically been employed for several reasons (Figure 1), its leaves are typically the most utilised component of the plant[22,23]. They are specifically utilised in traditional medicine and animal and human nutrition. Proteins, minerals, beta-carotene, and antioxidant compounds, all of which are frequently deficient in populations in developing or undeveloped nations, are abundant in leaves. *Moringa* leaves are added to food preparations as dietary integrators. These leaves are employed in conventional medicine to cure various conditions, such as genitourinary disorders, diabetes, arthritic conditions, typhoid fever, parasitic diseases, swollen areas, wounds, and skin conditions. Along with cardiac stimulants and contraceptive methods, they are also utilised for lactation and strengthening immunity (for managing complications associated with HIV/AIDS)[22-26]. Raw, the extract from water-based infusions, or dried leaves can be consumed immediately. In a similar vein, the utilization of seeds affects both traditional medicine and human nutrition. Barks are simmered in water and steeped in alcohol to form beverages and remedies for toothache, diabetes, anaemia, hypertension, impaired vision, joint pain, and stomach disorders (such as ulcers and stomach pain)[22]. *Moringa* seeds are a well-known method to filter out water pollutants[22]. Finally, flowers are used to make aphrodisiacs and to cure tumours, hysteria, enlargement of the spleen, inflammation, and muscle diseases[24,26].

6. Pharmacological Activities

Moringa oleifera has various pharmacological activities (Table 1).

6.1 Anti-diabetic Effects

Diabetes Mellitus (DM) is a condition related to metabolism characterised by higher levels of blood glucose because the organ system is insufficient to produce an adequate amount of insulin, which is necessary to control blood glucose levels. Many studies have shown that *M. oleifera* has a high polyphenol content, which helps lower blood sugar and improve erectile dysfunction, making it a promising anti-diabetic

medication[32,33]. It was discovered that *M. oleifera* leaf powder contained fibres and quercetin-3-glucoside, which have a moderating impact on impaired glucose metabolism[34]. The leaves contain a lot of unique *Moringa* Isothiocyanate (MIC) compounds, which indicate significant biological activity and suggest potential health advantages[35]. Additionally, a potential formulation for a wound dressing containing *M. oleifera* extracts may help manage wounds that could exacerbate diabetic symptoms[36]. Using glucometer and spectrophotometric techniques, oral administration of *M. oleifera* leaf ethanolic extract has been studied for its hypoglycemic and hepatic functionality parameters in rats treated with alloxan[37]. The glycemic concentration in the rats that received treatment significantly decreased, and the hepatic parameters ALT, AST, and ALP increased in a manner that varied according to dosage. Additionally, it was shown that the levels of bilirubin and albumin varied with dosage; for instance, an increase in albumin level was observed at 200 mg/kg, but a reduction in albumin levels was observed at higher doses. It can be concluded that the extracts have anti-diabetic properties in addition to protecting against liver damage; the safest dose was found to be 400 mg/kg. In a different study, rats in the experiment were administered *M. oleifera* leaves extracted in a mixture of ethanol and 95%, 75%, 50%, 25% v/v, and 100% water to explore the hypoglycemic activities and how it affected the results of the Intraperitoneal Glucose Tolerance Test (IPGTT)[38]. To further screen for strong anti-diabetic effects, a 95% (v/v) ethanolic extract (at 1000 mg/kg) that showed the highest activity was presented for liquid-liquid separation into water, butanol, ethyl acetate, chloroform, and hexane[38]. Following delivery to diabetic rats, the 95% ethanolic extract and butanol fraction were the only ones that demonstrated an impact on blood glucose concentration. However, in normal rats, no hyperglycemic effects were observed. The extracts with antihyperglycemic potential were found to contain cryptochlorogenic acid, kaempferol-3-O-glucoside, and quercetin 3-β-D-glucoside, as established by TLC and HPLC analysis. In addition to the leaves, *M. oleifera* seed extracts have been investigated for their possible anti-diabetic properties. In streptozotocin-induced diabetic albino rats, the oil and aqueous extracts of *M. oleifera* seeds showed

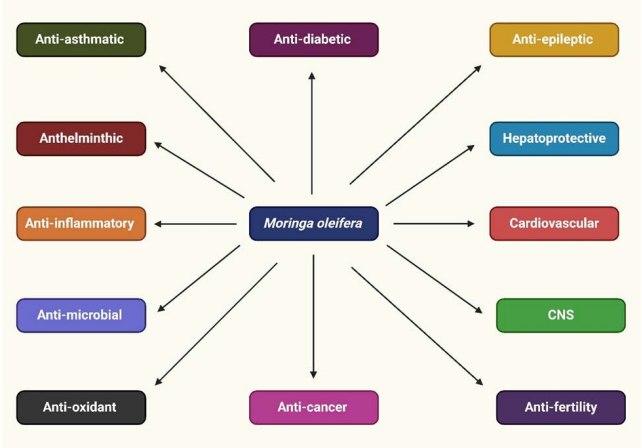

Figure 1. Pharmacological properties of *M. oleifera*.

Table 1. Pharmacological action of *M. oleifera*-derived chemical compounds or extracts

Plant part	Study model	Disease	Observed effect	References
Leaves	Beta-carotene-linoleic acid system, liposome peroxidation, and liver microsomes	Metabolic disease and diabetes	Antioxidant	17
Leaves	Cancer breast cells	Cancer	Inhibition of NF-κB signaling	27
Leaves	RAW Macrophages	Cardiovascular	Reduced expression of inflammatory markers	28
Seeds	Raw264.7 cells	Anti-inflammatory	Reduced the levels of TNF-α, IL-6, and IL-1β	29
Seeds	Rats	Anti-inflammatory, and anti-diabetic	Using the TNO Intestinal Model (TIM-1), bio-accessibility of 1 was found to be 61% and 62% in the fed and fasted phases, respectively.	30
Leaves	High-fat-induced obesity rats	Obesity	Anti-obesity properties	31

potential against many biochemical markers[39]. Serum levels of electrolytes (Cl^-, K^+ and Na^+), creatinine, albumin, urea, body weight, blood glucose, and enzyme indicators of hepatic injury (ALT and AST) were measured. A substantial drop in blood glucose was seen in rats with diabetes treated with aqueous extract at dosages of 100 mg/kg and 200 mg/kg[39].

6.2 Anti-cancer Activity

The fruits, leaves, flowers, and stems of *Moringa* plants are effective in preventing cancer, a fatal illness. Tumor cell growth is inhibited by the extracted *Moringa* chemicals, isothiocyanate and thiocarbamate[18,40]. The dichloromethane fraction was cytotoxic to breast cancer MCF7 cells[41]. Niazimincin can effectively prevent chemical carcinogenesis through chemoprevention[42]. In a melanoma mouse model, hydromethanolic and alcoholic leaf and fruit extracts significantly inhibited tumor expansion[43]. In cancer cells, Reactive Oxygen Species (ROS) are decreased and tumour cell development is prevented by *Moringa* extract, which is water-soluble at low temperatures[44]. According to a recent computer modelling study, *M. oleifera* contains rutin, which exhibits the greatest propensity for binding with breast cancer gene-1 (BRAC-1)[45].

6.3 Anti-Inflammatory Activity

Several sections of *M. oleifera* (roots, flowers, pods, and leaves) have shown notable anti-inflammatory activity. Nitric oxide inhibitory action was reported for the separated chemical (4-[2-o-Acetyl-alpha -l-rahamnoslyloxy) benzyl] thiocynate from *Moringa*, and it was later discovered efficacious in Raw264.7 cell lines[46]. A substance obtained from the roots of *M. oleifera*, aurnatiamide acetate and 1,3-dibenzyl-urea, prevented the generation of TNF-α[47]. Anti-inflammatory effects are mediated by active substances such as vanillin, moringin, β-sitosterol, alkaloids, flavonoids, tannins, and phenols[43]. NF-κB translocation was impeded by the fruit extract of *M. oleifera*, whereas large amounts (500–1000 µg/mL) of the chloroform extract were cytotoxic[48]. Decreasing the levels of thymic stromal lymphopoietin, mannose receptor mRNA, and retinoic acid-related orphan receptor γT in ear tissues was reported to be an effective treatment for atopic dermatitis in human keratinocytes using *M. oleifera* leaf extract in mice[49].

6.4 Cardiovascular Activity

A study that looked at both the cardiotoxicity and lipid profile of *M. oleifera* leaf aqueous extract in Wistar albino rats assessed the cardioprotective function[50]. This study included the administration of potassium bromate to rats to induce cardiac tissue poisoning and, subsequently, to examine the detoxifying properties of *Moringa* extracts. Strong cardio-toxins and potassium bromate lowered heart antioxidant activity and increased lipid peroxidation. Increased enzyme levels of cardiac biomarkers (AST, ALT, ALP, and others) showed cardiac dysfunction solely in potassium-bromate-induced rats. *M. oleifera* extract exhibited cardioprotective capability against potassium bromate-induced cardiac oxidative injury in rats by reducing the loss of antioxidants and restoring heart complications[50]. The possibilities of powdered *M. oleifera* seeds have been assessed in Spontaneously Hypertensive Rats (SHRs) by administering chow containing the seed powder orally to the SHRs and observing the effects on their hearts[51]. A higher risk of cardiac issues is associated with hypertension. The rats' blood pressure did not change after oral administration of *Moringa* seed powder; however, their nocturnal heart rate decreased and their cardiac diastolic function improved. Additionally, scientists hypothesised that the application of seed powder would have an impact

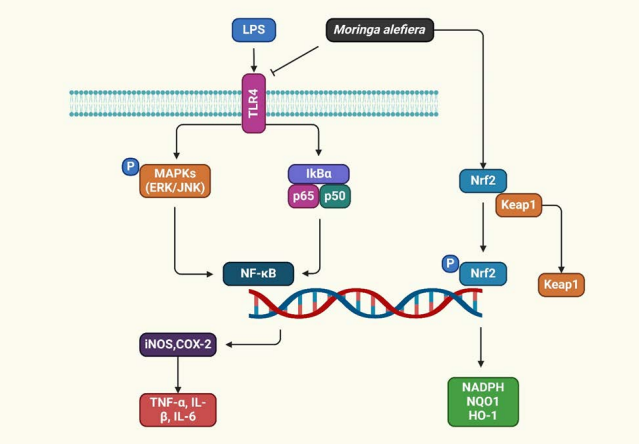

Figure 2. Interactions between bioactive compounds of *Moringa oleifera* and their signalling pathways.

on the calcium-regulated mechanism and other signalling pathways linked to pressure overload-induced left ventricular hypertrophy. To clarify the precise mechanism underlying the cardioprotective properties of *Moringa*, more research is necessary. An investigation into the impact of powdered *M. oleifera* seeds on nitrosative and oxidative vascular stressors in SHRs was conducted[52]. Vascular p47phox and p22phox expression, the elevation of SOD2, and a decrease in the free 8-isoprostane circulating level were all linked to the reduction in vascular strains in the SHR aortas treated with *Moringa*. Decreased C-reactive proteins and circulating nitrites, which are frequently increased in normal SHRs, were observed following treatment due to lower NF-κB and iNOS protein expression (Figure 2). Additionally, the study discovered that the arteries' resistance to the endothelium-dependent carbachol-induced relaxation functional test increased in the treated SHR group. In a supplemental diet, this study demonstrated the potential of *M. oleifera* seed powder as an overall vascular antioxidant, anti-inflammatory, and endothelial protective agent against cardiovascular problems indicated by inflammation and oxidative stress[52]. Furthermore, the cardioprotective properties of methanolic *M. oleifera* seed extract have been investigated in Wistar albino rats that have experienced isoproterenol-induced Myocardial Infarction (MI)[53]. The potential of *M. oleifera* seeds for the treatment of ischemic heart disorders was also assessed. Male C57/BL6 wild-type mice were orally administered *M. oleifera* seed powder by feeding a meal containing the powdered seed. A study discovered that MI mice treated with *M. oleifera* had less cardiac dysfunction and a lower MI-related death rate[54].

6.5 Anti-Oxidant Activity

Strong free radical scavengers against free radicals are present in aqueous extracts[44]. Previous research indicates that Kaempferol, which is mostly present in plant leaves, maybe a source of antioxidant potential[55]. In Wistar rats exposed to beryllium poisoning, the combined effects of piperine and curcumin with *Moringa* were found to have a synergistic effect[56]. By regulating GSH levels, the plant's alcoholic extract prevented glucose-induced cataractogenesis in separated goat eye lenses[57]. Myricetin, which is extracted from *Moringa* seeds, is a more potent antioxidant than alpha-tocopherol and Butylated Hydroxytoluene (BHT). In HEK-293 cells, the leaf extract of *M. oleifera* and its constituents, including crypto-chlorogenic acid, astragalin, and isoquercetin, helped reduce ROS[58]. In addition, compared to those given warm water, *Moringa* helps lower plasma Monoaldehyde (MDA) levels in the Fasting Plasma Glucose (FPG) in normal adults. With the alcoholic extract of the plant, there was a dose-dependent decrease in MDA levels and an increase in GSH, with no harmful effects up to 100 mg/kg[59].

6.6 Anti-Fertility Activity

Testis, seminal vesicles, and epididymis weights all significantly increased in response to leaf extract, which also increased seminiferous tubule diameter and scored higher on measures of epididymal maturity and lumen development[60]. A potential underlying mechanism for the cyclophosphamide-induced damage model in the ethanolic extract of prepubertal spermatogonial cells protected by leaves in Swiss male albino mice could be the increase in c-Kit and Oct4 transcript expression, which occurs independently of the p53-mediated pathway[61]. There have been reports on the impact of leaf extract on rats treated for ten days following fertilization[62]. The extract demonstrated an inhibitory effect on progesterone and a synergistic effect with estradiol[63]. Approximately 11,300–23,000 IU of vitamin A can be found in fresh MO leaves. Vitamin A is important for several anatomical processes including cell differentiation, immune development, growth and development of the embryo, and reproduction[5,64].

6.7 Antiepileptic Activity

After intraperitoneal administration of 200 and 400 mg/kg, *M. oleifera* leaves extracted with methanol demonstrated maximum electroshock-induced convulsions and strong anti-convulsant action against pentylenetetrazole. Phenytoin and diazepam served as reference standards. At both dosage levels, the methanolic extract dramatically decreased the amount of hind limb extension in the MES test and markedly delayed the onset of seizures in Ptz-induced convulsions. This could be a result of the alkaloids, flavonoids, and tannins in the extract[65]. The research was conducted to determine how well an *Moringa concanensis* leaves administered intraperitoneally at a dose of 200 mg/kg prevented seizures in Swiss albino

mice caused by PTZ and MES. MES seizures and inhibition of tonic hindlimb extension were observed. It was observed that convulsions in PTZ seizures stopped. Since the ethanolic extract of *M. concanensis* leaves abolishes both seizures caused by PTZ and hind limb extension generated by MES, the extract may have numerous mechanisms underlying its anti-convulsant properties[66].

6.8 Anti-Asthmatic Activity

Test rats with intestinal spasms caused by acetylcholine hydrochloride showed anti-spasmodic action with a median effective dose of 65.6 mg/ml bath concentration in *M. oleifera* seeds[67]. This offers a rationale for the science behind the conventional management of gastrointestinal issues. *M. oleifera* has been used in *Ayurveda* medicine to treat chronic rheumatism and asthma[68]. The alkaloid moringine is responsible for its pharmacological action as it relaxes bronchioles[69]. Furthermore, the ethanolic extract of *M. oleifera* seed kernel displayed an anti-asthma effect in rats, based on its capacity to block histamine release. Reduced inflammatory cell infiltration has been observed in lung sections according to histopathological investigations[70]. Clinical research has recently supported the use of *M. oleifera* as a pharmacological agent and further validated its anti-asthma action, providing *Ayurveda*, a traditional Indian medicine, as a scientific foundation[71]. However, further research is required to establish *M. oleifera*'s anti-asthma effectiveness of *M. oleifera* and define the ideal dosage due to the limited sample size of 20 patients.

6.9 CNS Activity

M. oleifera has considerable central nervous system activity, including antidepressant, neuroprotective, and memory-enhancing benefits, principally due to its antioxidant and cholinergic characteristics. Research indicates its capacity to diminish neurodegeneration, enhance spatial memory, and alleviate neurotoxicity. Extracts from the leaves of *M. oleifera* increase the brain levels of monoamines, which may help treat Alzheimer's disease. The norepinephrine levels, dopamine, brain serotonin (5-HT), locomotor behaviour, and penicillin-induced convulsions were all studied in relation to the in vitro anticonvulsant effects of the ethanolic and aqueous *Moringa oleifera* root and leaf extracts[72].

6.10 Anti-microbial Activity

Global scientific interest in plant-based sources of less expensive, more dependable, and efficient antibiotics to treat a wide range of infectious diseases in humans and agriculture is growing. *M. oleifera* is a plant species with a wealth of information that supports its antibacterial potential[11]. The anti-microbial characteristics of *M. oleifera* seeds, leaves, bark, and roots were determined by investigating the plant's resistance to a variety of microbes. The antibacterial properties of the plant have been linked to the presence of 4-(4'-O-acetyl-alpha-L-rhamnosyloxy)-benzyl isothiocyanate and 4-(alpha-L-rhamnosyloxy) benzyl isothiocyanate[73-75]. For example, the bioactive complexes (isothiocyanates 1 and 2) evaluated for antibacterial properties against some microorganisms were found to impede the development of gram-positive and other microorganisms[74]. The antibacterial activity of all the retained items was attributed to isothiocyanate complexes. It was also shown that *M. oleifera* leaf extracts are effective against gram-negative bacteria that are resistant to multiple drugs that cause infectious diseases[76]. The research carried out by Moura *et al,*[77] demonstrated the antibacterial properties of *M. oleifera* seed lectins, which were discovered to impede bacterial growth and reduce *S. marcescens*' ability to produce biofilms. In addition, lectin inhibits the growth of Bacillus species.

6.11 Anthelminthic Activity

The anthelmintic activity of *M. oleifera* leaves is dose-dependent and superior to *Vitex negundo* leaves[78]. In addition, an in vitro investigation revealed that the leaf extracts caused death in the L1 and L2 larvae of *Haemonchus contortus* and prevented egg embryonation and highlighting[79]. *M. oleifera* exhibits anthelminthic activity. The biologically active components, however, are neglected because these investigations can also be used to form natural medications based on this feature for toxicity and associated pharmacokinetic testing.

6.12 Hepatoprotective Activity

The *in vivo* hepatoprotective effects of *M. oleifera* ethanolic leaf extract and alcoholic seed extract were assessed in relation to liver damage caused by isoniazid, rifampicin, and pyrazinamide. Reports on the impact of the crude extract on the functioning of

the kidneys and liver were provided as well, in addition to the hepatorenal and haematological activities of the methanolic extract of *M. oleifera* roots[55].

6.13 Anti-hypertensive Activity

The consumption of extracts of *M. oleifera* or raw leaves has been linked positively to lowered blood pressure in test animals, according to articles that have investigated the plant's anti-hypertensive properties. Elevated blood pressure increases the risk of cardiovascular problems, stroke, and mortality and is a common indication of hypertension with serious complications[51,80]. According to data from several health interventions conducted by the University College Hospital (UCH) located in Ibadan, Nigeria, hypertension is the most prevalent disease in individuals over 40[81]. Heart arrest and hypertension are difficult to treat and cure, often requiring synthetic medications with unpleasant side effects. Therefore, natural medicines can alleviate hypertension and reduce high blood pressure as potentially investigated. Scientific evidence supporting *M. oleifera* as an antihypertensive herb with potent heart-protective properties has also been reported[52,82]. Cheraghi *et al*,[83] studied the cardioprotective effects of *M. oleifera* isolated magnetic hydrogel nanocomposites loaded with N,α-Lrhamnopyranosyl vincosamide (VR) isolated from *M. oleifera*. It was demonstrated that heart failure biomarkers were suppressed and that the VR levels of Superoxide Dismutase (SOD) and Malondialdehyde (MDA) were decreased in cardiac tissues. The *M. oleifera*'s cardioprotective properties of *M. oleifera* in an Isoproterenol (ISP)-induced myocardial infarction model were also highlighted in previous studies[84].

6.14 Cholesterol-lowering Activity

In contrast to the obese control group, there was a noteworthy decrease in body mass index following oral administration of leaf powder[85]. Rats with hypercholesterolemia treated for 49 days with MO leaf methanolic extract of MO leaf had a significant decrease in body weight, triglycerides, liver biomarkers, and blood glucose levels, as well as a reduction in total cholesterol and body weight[31,86]. Among these mechanisms are the increase in adiponectin gene expression and downregulation of leptin mRNA expression in obese rats[87].

6.15 Diuretic Activity

Urine production in rats was enhanced by extracts from leaves, flowers, seeds, roots, and bark, and the leaf extract had a dose-dependent diuretic activity that was higher than that of the control, but lower than that of hydrochlorothiazide. This action is caused by campesterol, stigmasterol, β-sitosterol, and avenasterol[73].

6.16 Antispasmodic Activity

Antispasmodic ethanol extracts from the leaves and roots exhibit antispasmodic properties, potentially via calcium channel blockage. The plant's traditional use in gastrointestinal motility complications is scientifically supported by the spasmolytic activity displayed by its ingredients[67,88].

6.17 Antiulcer Activity

Millions of people worldwide are afflicted with ulcers, an overlooked tropical sickness[89]. *Mycobacterium ulcerans* infection was the reason for this finding. Using *M. oleifera* ethanolic extract of bark root, cytoprotective, anti-secretory, and anti-ulcer effects were demonstrated in albino Wistar rats. These results are consistent with the majority of ethnobotanical literature available on the plant[22,90]. The anti-ulcerative qualities of *M. oleifera* leaves and roots in alkaline solutions with medicinal value have been reaffirmed[91]. The utility of *Moringa oleifera* as an anti-ulcer medication was further validated by testing a polyherbal mixture of *Amaranthus tricolor*, *Raphanus sativus*, and *Moringa oleifera* leaf extracts in a male albino Wistar rat experimental model of stomach ulcer[92]. Their research revealed that the polyherbal mixture had strong anti-ulcerative properties and was effective in preventing stomach ulcers caused by ischemia, reperfusion, ethanol, and indomethacin. In a different study, the free acidity and total acidity of gastric juice were reported to be greatly decreased by both *M. oleifera* extract and famotidine, a medication frequently used to treat ulcers[93]. Therefore, *M. oleifera* formulations, especially in the alkaline form, are safe and effective in treating and curing ulcers. *M. oleifera*'s antiulcer properties have been linked to the presence of both flavonoids and tannins[67,73,93].

6.18 Antibacterial Activity

Numerous bacterial species, including drug-resistant bacteria, water-borne infections, and bacteria that cause diarrhoea, have been tested against the powerful *M. oleifera*. According to research, water-borne pathogens such as *Escherichia coli*, *Vibrio cholera*, and *Salmonella typhii* were inhibited by hexane and methanol seed extracts of the plant[94]. As a result, the antibacterial properties of *M. oleifera* could be used to treat water-borne diseases caused by bacteria as a natural antibacterial agent. A second study was conducted to examine the antibacterial qualities of various *M. oleifera* components to use the plant for natural dental care. The ethanol extract of leaves demonstrated the strongest antibacterial properties against Streptococcus and *S. aureus* mutans development among the numerous activities to form suitable components for a prototype mouthwash and toothpaste, with the toothpaste showing more efficacy than the mouthwash[95]. Methanol and ethanol extracts of *M. oleifera* leaves were found to exhibit a substantially stronger ($p < 0.05$) inhibitory action against *Pseudomonas aeruginosa*, *S. aureus*, and *E. coli* at an elevated dosage of 120 mg/mL compared to an aqueous extract[96]. *Moringa* leaves have antibacterial characteristics that are effective against both gram-negative (*E. coli* and *P. aeruginosa*) and gram-positive (*S. aureus*) bacteria. In another study, the agar disc diffusion method was used to test an *M. oleifera* leaf extract against isolated Multidrug-Resistant (MDR) *P. aeruginosa*, *S. aureus*, and *E. coli*. The aqueous extract had the lowest bactericidal activity (0.27 ± 0.27 mm), whereas the chloroform extract had the highest (9.32 ± 1.45 mm)[97].

6.19 Antifungal Activity

It has been demonstrated that some plant parts, such as the seeds and leaves, have antifungal properties against fungi, such as *Penicillium*, *Aspergillus flavus*, and *Trichophyton interdigitale*. The ethanolic leaf extract showed antifungal activity against a range of dermatophytes, including *Microsporum canis*, *Trichophyton rubrum*, *Cladosporium cladosporioides*, *Penicillium sclerotigenum*, *R. izoctonia*, *Aspergillus terreus*, *Aspergillus oryzae*, and *Aspergillus niger*. The ethyl acetate-based methanolic and MO leaf extracts were highly effective against both fungi. The study found that MO extract worked well against the test fungus. For this, both microorganisms and solvents are required. MO extracts may have antifungal action against dermatophytic fungi such as *Gypsum microsporum*. As a result, MO is employed in the conventional treatment of dermatological disorders and infectious diseases[98,99].

7. Phytopharmaceutical Formulations

Researchers have always been interested in plant extracts because they can be used to produce various therapeutic properties. Usually, this process produces pharmaceuticals that can be distinguished by two attributes: patient compliance and the formation of a stable product. The benefit of extracts from the *Moringa* plant is that, at the quantities and volumes often used for medicinal efficacy, they seem to be extremely safe[100]. *M. oleifera* has gained widespread acceptance in the field of research, and scientists have developed a variety of formulations using various techniques. Phytopharmaceutical preparations of *M. oleifera* employ its bioactive constituents, such as flavonoids, phenolic acids, and glucosinolates, for therapeutic and nutritional purposes. These compositions comprise capsules, teas, oils, syrups, and topical treatments, providing antioxidant, anti-inflammatory, and antibacterial advantages. Standardisation, increase of bioavailability, and clinical validation are essential for optimising its therapeutic potential.

8. Toxicological Studies

Studies on humans conducted, so far have not revealed any negative consequences. Additionally, many preparations have been used as food and medication for a long time without any negative consequences. There was no mortality in rats administered aqueous leaf extract (400–2000 mg/kg body weight). Nonetheless, during the three weeks of the trial, a dose-dependent decrease in the rats' body weight was noted[101]. In another study, oral dosages of *M. oleifera* leaf extract up to 6400 mg/kg did not result in mortality in albino Wistar mice. However, an increase in the extract dosage leads to dullness and reduced movement[102].

9. Conclusion

In conclusion, this review highlights the extensive pharmacological properties and therapeutic potential of *M. oleifera*. The plant contains a wide array of bioactive compounds that contribute to its diverse medicinal effects, including anti-diabetic, anti-cancer, anti-inflammatory, cardioprotective, antioxidant, antimicrobial, and hepatoprotective activities. Various parts of the plant, including the leaves, seeds, roots, and bark, have demonstrated beneficial effects in both *in vitro* and *in vivo* studies. The safety profile of *M. oleifera* appears favourable based on toxicological assessments. However, further research is still needed to fully elucidate the mechanisms of action, optimal dosing, and long-term effects in humans. Overall, *M. oleifera* shows great promise as a natural source of bioactive compounds with therapeutic applications. Its multifaceted pharmacological properties make it a valuable plant for developing novel phytopharmaceuticals and functional food products to address various health conditions. Continued scientific investigation of *M. oleifera* will likely uncover additional medicinal uses and lead to evidence-based applications in modern healthcare.

10. Future Perspectives

Future research on *M. oleifera* includes more clinical trials to validate its therapeutic effects, studies on synergistic effects with conventional therapies, standardised extracts and formulations, optimization of cultivation, harvesting, and processing techniques, and raising awareness about its health benefits. Addressing these research gaps and challenges could lead to *M. oleifera* becoming a versatile therapeutic agent for health promotion and disease combating.

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12. Author's Contribution

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13. References

1. Luetragoon T, Sranujit RP, Noysang C, Thongsri Y, Potup P, Suphrom N, *et al.* Bioactive compounds in *Moringa oleifera* Lam. leaves inhibit the pro-inflammatory mediators in lipopolysaccharide-induced human monocyte-derived macrophages. Molecules. 2020; 25(1):191. https://doi.org/10.3390/molecules25010191 PMid:31906558 PMCid:PMC6982846
2. Aliyah AN, Ardianto C, Samirah S, Nurhan AD, Marhaeny HD, Ming LC, et al. In silico molecular docking study from *Moringa oleifera* and *Caesalpinia sappan* L. secondary metabolites as antagonist TRPV1. J Med Pharm Chem Res. 2023; 5(10):885–94. https://doi.org/10.48309/jmpcr.2023.177582
3. Padayachee B, Baijnath H. An updated comprehensive review of the medicinal, phytochemical and pharmacological properties of *Moringa oleifera*. South African J Bot. 2020; 129:304-316. https://doi.org/10.1016/j.sajb.2019.08.021
4. Proestos C, Varzakas T. Aromatic plants: Antioxidant capacity and polyphenol characterisation. Foods. 2017; 6(4):28. https://doi.org/10.3390/foods6040028 PMid:28375185 PMCid:PMC5409316
5. Leone A, Spada A, Battezzati A, Schiraldi A, Aristil J, Bertoli S. Cultivation, genetic, ethnopharmacology, phytochemistry and pharmacology of *Moringa oleifera* leaves: An overview. Int J Mol Sci. 2015; 16(6):12791-12835. https://doi.org/10.3390/ijms160612791 PMid:26057747 PMCid:PMC4490473
6. Abdelkader Dilmi, Abdelfateh Benmakhlouf, Oualid Dairi. Application of response surface methodology for optimizing process parameters for water treatment using blend of plant-based naturel bio-floculant and synthetic coagulant : (*Moringa oleifera*-alum blend). Asian J Green Chem. 2025; 9:494–510. https://doi.org/10.48309/AJGC.2025.508931.1696
7. Meireles D, Gomes J, Lopes L, Hinzmann M, Machado J. A review of properties, nutritional and pharmaceutical applications of *Moringa oleifera*: Integrative approach on conventional and traditional Asian medicine. Adv Tradit Med. 2020; 20(4):495-515. https://doi.org/10.1007/s13596-020-00468-0 PMCid:PMC7430547

8. Gupta S, Jain R, Kachhwaha S, Kothari S. Nutritional and medicinal applications of *Moringa oleifera* Lam. — Review of current status and future possibilities. J. Herb. Med. 2018; 11:1-11. https://doi.org/10.1016/j.hermed.2017.07.003
9. Su X, Lu G, Ye L, Shi R, Zhu M, Yu X, *et al. Moringa oleifera* Lam.: A comprehensive review on active components, health benefits and application. RSC Adv. 2023; 13(35):24353-24384. https://doi.org/10.1039/D3RA03584K PMid:37588981 PMCid:PMC10425832
10. Chaudhary K, Chaurasia S. Neutraceutical properties of *Moringa oleifera*: A review. Eur J Pharm Med Res. 2017; 4:646-655.
11. Paikra BK, Gidwani B. Phytochemistry and pharmacology of *Moringa oleifera* Lam. J Pharmacopuncture. 2017; 20(3):194. https://doi.org/10.3831/KPI.2017.20.022 PMid: 30087795 PMCid:PMC5633671
12. Mallenakuppe R, Homabalegowda H, Gouri M, Basavaraju PS, Chandrashekharaiah UB. History, taxonomy and propagation of *Moringa oleifera* – A review. SSR Inst Int J Life Sci. 2019; 3(3.28):3.15.
13. Zheng Y, Zhang Y, Wu J. Yield and quality of *Moringa oleifera* under different planting densities and cutting heights in southwest China. Ind Crops Prod. 2016; 91:88-96. https://doi.org/10.1016/j.indcrop.2016.06.032
14. Aekthammarat D, Pannangpetch P, Tangsucharit P. *Moringa oleifera* leaf extract lowers high blood pressure by alleviating vascular dysfunction and decreasing oxidative stress in L-NAME hypertensive rats. Phytomedicine. 2019; 54:9-16. https://doi.org/10.1016/j.phymed.2018.10.023 PMid:30668387
15. Fahey JW, Zalcmann AT, Talalay P. The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. Phytochemistry. 2001; 56(1):5-51. https://doi.org/10.1016/S0031-9422(00)00316-2 PMid:11198818
16. Faizi S, Siddiqui BS, Saleem R, Siddiqui S, Aftab K, Gilani A-ulH. Isolation and structure elucidation of new nitrile and mustard oil glycosides from *Moringa oleifera* and their effect on blood pressure. J Nat Prod. 1994; 57(9):1256-1261. https://doi.org/10.1021/np50111a011 PMid:7798960
17. Morah EJ, Eboagu NC, Nwakife NC, Chinelo Ezeonu C. Characterization and Phytochemical Evaluation of the Seed, Seed Oil and Leaves of *Moringa oleifera*. Adv J Chem Sect B Nat Prod Med Chem. 2024;6(2):147–65. https://doi.org/10.48309/ajcb.2023.394689.1166
18. Prajoko YW, Pramono S, Hartanto A, Prakoso MA. The Effect of *Moringa* Oleifera Extract on CPK and Quality of Life of Breast Cancer Hpatinnts Reseiving Aromatase Inhibitor Therapy. J Med Chem Sci. 2023; 6(6):2750–2755. https://doi.org/10.26655/JMCHEMSCI.2023.11.19
19. Faizi S, Siddiqui BS, Saleem R, Siddiqui S, Aftab K, Gilani A-ulH. Novel hypotensive agents, niazimin A, niazimin B, niazicin A and niazicin B from *Moringa oleifera*: Isolation of first naturally occurring carbamates. J Chem Soc Perkin Trans. 1994; (20):3035-3040. https://doi.org/10.1039/p19940003035
20. Dillard CJ, German JB. Phytochemicals: Nutraceuticals and human health. J Sci Food Agric. 2000; 80(12):1744-1756. https://doi.org/10.1002/1097-0010(20000915)80:12<1744::AID-JSFA725>3.0.CO;2-W
21. Toma A, Deyno S. Phytochemistry and pharmacological activities of *Moringa oleifera*. Int J Pharmacogn. 2014; 1(4):222-231.
22. Popoola JO, Obembe OO. Local knowledge, use pattern and geographical distribution of *Moringa oleifera* Lam. (*Moringaceae*) in Nigeria. J Ethnopharmacol. 2013; 150(2):682-691. https://doi.org/10.1016/j.jep.2013.09.043 PMid:24096203
23. Sivasankari B, Anandharaj M, Gunasekaran P. An ethnobotanical study of indigenous knowledge on medicinal plants used by the village peoples of Thoppampatti, Dindigul district, Tamil Nadu, India. J Ethnopharmacol. 2014; 153(2):408-423. https://doi.org/10.1016/j.jep.2014.02.040 PMid:24583241
24. Anwar F, Latif S, Ashraf M, Gilani AH. *Moringa oleifera*: A food plant with multiple medicinal uses. Phyther. Res. 2007; 21(1):17-25. https://doi.org/10.1002/ptr.2023 PMid:17089328
25. Abe R, Ohtani K. An ethnobotanical study of medicinal plants and traditional therapies on Batan Island, the Philippines. J Ethnopharmacol. 2013; 145(2):554-565. https://doi.org/10.1016/j.jep.2012.11.029 PMid:23183086
26. Yabesh JM, Prabhu S, Vijayakumar S. An ethnobotanical study of medicinal plants used by traditional healers in the Silent Valley of Kerala, India. J Ethnopharmacol. 2014; 154(3):774-789. https://doi.org/10.1016/j.jep.2014.05.004 PMid:24832113
27. Khalafalla MM, Abdellatef E, Dafalla HM, Nassrallah AA, Aboul-Enein KM, Lightfoot DA, *et al.* Active principle from *Moringa oleifera* Lam leaves effective against two leukemias and a hepatocarcinoma. African J Biotechnol. 2010; 9(49):8467-8471.
28. Kooltheat N, Sranujit RP, Chumark P, Potup P, Laytragoon-Lewin N, Usuwanthim K. An ethyl acetate fraction of *Moringa oleifera* Lam. inhibits human macrophage cytokine production induced by cigarette smoke. Nutrients. 2014; 6(2):697-710. https://doi.org/10.3390/nu6020697 PMid:24553063 PMCid:PMC3942728
29. Xiong Y, Rajoka MSR, Zhang M, He Z. Isolation and identification of two new compounds from the seeds of *Moringa oleifera* and their antiviral and anti-inflammatory activities. Nat Prod Res. 2022; 36(4):974-983. https://doi.org/10.1080/14786419.2020.1851218 PMid:33251874
30. Richter N, Siddhuraju P, Becker K. Evaluation of nutritional quality of *Moringa* (*Moringa oleifera* Lam.) leaves as an

alternative protein source for Nile tilapia (*Oreochromis niloticus* L.). Aquaculture. 2003; 217(1-4):599-611. https://doi.org/10.1016/S0044-8486(02)00497-0

31. Bais S, Singh GS, Sharma R. Antiobesity and hypolipidemic activity of *Moringa oleifera* leaves against high fat diet-induced obesity in rats. Adv Biol. 2014. https://doi.org/10.1155/2014/162914
32. Jacques AS, Arnaud SS, Jacques DT. Review on biological and immunomodulatory properties of *Moringa oleifera* in animal and human nutrition. J Pharmacogn Phyther. 2020; 12(1):1-9. https://doi.org/10.5897/JPP2019.0551
33. Bashah NAK, Noor MM. Antihyperglycemic and androgenic properties of *Moringa oleifera* leaves aqueous extract attenuate sexual dysfunction in diabetes-induced male rats. Malaysian Appl Biol. 2021; 50(2):99-105. https://doi.org/10.55230/mabjournal.v50i2.1977
34. Ndong M, Uehara M, Katsumata S-i, Suzuki K. Effects of oral administration of *Moringa oleifera* Lam on glucose tolerance in Goto-Kakizaki and Wistar rats. J Clin Biochem Nutr. 2007; 40(3):229-233. https://doi.org/10.3164/jcbn.40.229 PMid:18398501 PMCid:PMC2275769
35. Waterman C, Rojas-Silva P, Tumer TB, Kuhn P, Richard AJ, Wicks S, *et al.* Isothiocyanate-rich *Moringa oleifera* extract reduces weight gain, insulin resistance, and hepatic gluconeogenesis in mice. Mol Nutr Food Res. 2015; 59(6):1013-1024. https://doi.org/10.1002/mnfr.201400679 PMid:25620073 PMCid:PMC4456298
36. Chin C-Y, Jalil J, Ng PY, Ng S-F. Development and formulation of *Moringa oleifera* standardised leaf extract film dressing for wound healing application. J Ethnopharmacol. 2018; 212:188-199. https://doi.org/10.1016/j.jep.2017.10.016 PMid:29080829
37. Aja P, Igwenyi I, Okechukwu P, Orji O, Alum E. Evaluation of anti-diabetic effect and liver function indices of ethanol extracts of *Moringa oleifera* and Cajanus cajan leaves in alloxan induced diabetic albino rats. Glob Vet. 2015; 14(3):439-447.
38. Irfan HM, Asmawi MZ, Khan NAK, Sadikun A, Mordi MN. Anti-diabetic activity-guided screening of aqueous-ethanol *Moringa oleifera* extracts and fractions: Identification of marker compounds. Trop. J Pharm Res. 2017; 16(3):543-552. https://doi.org/10.4314/tjpr.v16i3.7
39. Nadro M, Audu A, Glen E. Anti-diabetic effects of aqueous extract and oil of *Moringa oleifera* seed on liver and kidney functions in streptozotocin-induced diabetes in rat. Am J Biochem. 2018; 8:69-74.
40. Parvathy M, Umamaheshwari A. Cytotoxic effect of *Moringa oleifera* leaf extracts on human multiple myeloma cell lines. Trends Med Res. 2007; 2(1):44-50. https://doi.org/10.3923/tmr.2007.44.50
41. Fisall UFM, Ismail NZ, Adebayo IA, Arsad H. Dichloromethane fraction of *Moringa oleifera* leaf methanolic extract selectively inhibits breast cancer cells (MCF7) by induction of apoptosis via upregulation of Bax, p53 and caspase 8 expressions. Mol Biol Rep. 2021; 48(5):4465-4475. https://doi.org/10.1007/s11033-021-06466-y PMid:34086162
42. Upadhyay P, Yadav MK, Mishra S, Sharma P, Purohit S. *Moringa oleifera*: A review of the medical evidence for its nutritional and pharmacological properties. Int J Res Pharm Sci. 2015; 5(2):12-16.
43. Bhattacharya A, Tiwari P, Sahu PK, Kumar S. A review of the phytochemical and pharmacological characteristics of *Moringa oleifera*. J Pharm Bioallied Sci. 2018; 10(4):181-191. https://doi.org/10.4103/JPBS.JPBS_126_18 PMid:30568375 PMCid:PMC6266645
44. Singh A, Navneet X. Ethnomedicinal, pharmacological and antimicrobial aspects of *Moringa oleifera* Lam. A review. J Phytopharm. 2018; 7(1):45-50. https://doi.org/10.31254/phyto.2018.7110
45. Balogun TA, Buliaminu KD, Chukwudozie OS, Tiamiyu ZA, Idowu TJ. Anticancer potential of *Moringa oleifera* on BRCA-1 gene: Systems biology. Bioinform Biol Insights. 2021; 15:1-7. https://doi.org/10.1177/11779322211010703 PMid:35173424 PMCid:PMC8842389
46. Tan WS, Arulselvan P, Karthivashan G, Fakurazi S. *Moringa oleifera* flower extract suppresses the activation of inflammatory mediators in lipopolysaccharide-stimulated RAW 264.7 macrophages via NF-κB pathway. Mediators Inflamm. 2015. https://doi.org/10.1155/2015/720171 PMid:26609199 PMCid:PMC4644847
47. Cuellar-Núñez M, De Mejia EG, Loarca-Piña G. *Moringa oleifera* leaves alleviated inflammation through downregulation of IL-2, IL-6, and TNF-α in a colitis-associated colorectal cancer model. Food Res Int. 2021; 144:110318. https://doi.org/10.1016/j.foodres.2021.110318 PMid:34053523
48. Abdel-Daim MM, Khalil SR, Awad A, Zeid EHA, El-Aziz RA, El-Serehy HA. Ethanolic extract of *Moringa oleifera* leaves influences NF-κB signaling pathway to restore kidney tissue from cobalt-mediated oxidative injury and inflammation in rats. Nutrients. 2020; 12(4):1031. https://doi.org/10.3390/nu12041031 PMid:32283757 PMCid:PMC7230732
49. Choi E-J, Debnath T, Tang Y, Ryu Y-B, Moon S-H, Kim E-K. Topical application of *Moringa oleifera* leaf extract ameliorates experimentally induced atopic dermatitis by the regulation of Th1/Th2/Th17 balance. Biomed Pharmacother. 2016; 84:870-877. https://doi.org/10.1016/j.biopha.2016.09.085 PMid:27744247
50. Oseni O, Ogunmoyole T, Idowu K. Lipid profile and cardio-protective effects of aqueous extract of *Moringa oleifera* (Lam) leaf on bromate-induced cardiotoxicity on Wistar albino rats. Eur J Adv Res Biol Life Sci. 2015; 3(2):52-66.

51. Randriamboavonjy JI, Loirand G, Vaillant N, Lauzier B, Derbré S, Michalet S, *et al.* Cardiac protective effects of *Moringa oleifera* seeds in spontaneous hypertensive rats. Am J Hypertens. 2016; 29(7):873-881. https://doi.org/10.1093/ajh/hpw001 PMid:26864583
52. Randriamboavonjy JI, Rio M, Pacaud P, Loirand G, Tesse A. *Moringa oleifera* seeds attenuate vascular oxidative and nitrosative stresses in spontaneously hypertensive rats. Oxid Med Cell Longev. 2017; 2017:4129459. https://doi.org/10.1155/2017/4129459 PMid:28713487 PMCid:PMC5496124
53. Hugar S, Shivapraksha S, Biradar S, Shivakumar B. Evaluation of *Moringa oleifera* seeds for the cardio protective efficacy. World J Pharm Res. 2018; 7:1461-1473.
54. Li Y-J, Ji Q-Q, Wang Z, Shen L-H, He B. *Moringa oleifera* seeds mitigate myocardial injury and prevent ventricular failure induced by myocardial infarction. Am J Transl Res. 2020; 12(8):4511-4521.
55. Ibadi EA, Yousef MI, El-Nabi Kamel MA, El-Banna S. Hepatotoxicity of polyethylene glycol and possible protection using *Moringa oleifera* leaves extract (MOLE). J Med Chem Sci. 2023; 6(4):907–19. https://doi.org/10.26655/JMCHEMSCI.2023.4.23
56. Agrawal ND, Nirala SK, Shukla S, Mathur R. Co-administration of adjuvants along with *Moringa oleifera* attenuates beryllium-induced oxidative stress and histopathological alterations in rats. Pharm Biol. 2015; 53(10):1465-1473. https://doi.org/10.3109/13880209.2014.986685 PMid:25853973
57. Sasikala V, Rooban B, Priya SS, Sahasranamam V, Abraham A. *Moringa oleifera* prevents selenite-induced cataractogenesis in rat pups. J Ocul Pharmacol Ther. 2010; 26(5):441-447. https://doi.org/10.1089/jop.2010.0049 PMid:20879807
58. Vongsak B, Mangmool S, Gritsanapan W. Antioxidant activity and induction of mRNA expressions of antioxidant enzymes in HEK-293 cells of *Moringa oleifera* leaf extract. Planta Med. 2015; 81(12/13):1084-1089. https://doi.org/10.1055/s-0035-1546168 PMid:26166137
59. Banik S, Biswas S, Karmakar S. Extraction, purification, and activity of protease from the leaves of *Moringa oleifera*. F1000Research. 2018; 7:1151. https://doi.org/10.12688/f1000research.15642.1 PMid:30345026 PMCid:PMC6171725
60. Cajuday LA, Pocsidio GL. Effects of *Moringa oleifera* Lam. (*Moringaceae*) on the reproduction of male mice (*Mus musculus*). J Med Plants Res. 2010; 4(12):1115-1121.
61. Nayak G, Honguntikar SD, Kalthur SG, D'souza AS, Mutalik S, Setty MM, *et al.* Ethanolic extract of *Moringa oleifera* Lam. leaves protect the pre-pubertal spermatogonial cells from cyclophosphamide-induced damage. J Ethnopharmacol. 2016; 182:101-109. https://doi.org/10.1016/j.jep.2016.02.003 PMid:26875643
62. Nath D, Sethi N, Singh R, Jain A. Commonly used Indian abortifacient plants with special reference to their teratologic effects in rats. J Ethnopharmacol. 1992; 36(2):147-154. https://doi.org/10.1016/0378-8741(92)90015-J PMid:1608272
63. Shukla S, Mathur R, Prakash AO. Histoarchitecture of the genital tract of ovariectomized rats treated with an aqueous extract of *Moringa oleifera* roots. J Ethnopharmacol. 1989; 25(3):249-261. https://doi.org/10.1016/0378-8741(89)90031-7 PMid:2747260
64. Vergara-Jimenez M, Almatrafi MM, Fernandez ML. Bioactive components in *Moringa oleifera* leaves protect against chronic disease. Antioxidants. 2017; 6(4):91. https://doi.org/10.3390/antiox6040091 PMid:29144438 PMCid:PMC5745501
65. Amrutia J, Lala M, Srinivasa U, Shabaraya A, Semuel MR. Anticonvulsant activity of *Moringa oleifera* leaf. Int Res J Pharm. 2011; 2(7):160-162.
66. Joy AE, Kunhikatta SB, Manikkoth S. Anti-convulsant activity of ethanolic extract of *Moringa concanensis* leaves in Swiss albino mice. Arch Med Heal Sci. 2013; 1(1):6-9. https://doi.org/10.4103/2321-4848.113548
67. Cáceres A, Saravia A, Rizzo S, Zabala L, De Leon E, Nave F. Pharmacologie properties of *Moringa oleifera*. 2: Screening for antispasmodic, antiinflammatory and diuretic activity. J Ethnopharmacol. 1992; 36(3):233-237. https://doi.org/10.1016/0378-8741(92)90049-W PMid:1434682
68. Fahey JW. *Moringa oleifera*: A review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Part 1. Trees Life J. 2005; 1(5):1-15.
69. Kirtikar KR, Basu BD. Indian medicinal plants. Facsimile Publisher; 1918. https://doi.org/10.5962/bhl.title.137025
70. Goyal BR, Goyal RK, Mehta AA. Investigation into the mechanism of anti-asthmatic action of *Moringa oleifera*. J Diet Suppl. 2009; 6(4):313-327. https://doi.org/10.3109/19390210903280199 PMid:22435513
71. Agrawal B, Mehta A. Antiasthmatic activity of *Moringa oleifera* Lam: A clinical study. Indian J Pharmacol. 2008; 40(1):28-31. https://doi.org/10.4103/0253-7613.40486 PMid:21264158 PMCid:PMC3023118
72. Chintalapati M, Margesan T. Investigation of In-vitro antioxidant and neuroprotective effects of *Moringa oleifera* root extract on SH-SY5Y neuroblastoma cell line. J Med Pharm Chem Res. 2025; 7(3):516–33. https://doi.org/10.48309/jmpcr.2025.464055.1299.
73. Caceres A, Cabrera O, Morales O, Mollinedo P, Mendia P. Pharmacological properties of *Moringa oleifera*. 1: Preliminary screening for antimicrobial activity.

J Ethnopharmacol. 1991; 33(3):213-216. https://doi.org/10.1016/0378-8741(91)90078-R PMid:1921416

74. Padla EP, Solis LT, Levida RM, Shen C-C, Ragasa CY. Antimicrobial isothiocyanates from the seeds of *Moringa oleifera* Lam. Zeitschrift fur Naturforsch. - Sect. 2012; 67(11-12):557-564. https://doi.org/10.1515/znc-2012-11-1205 PMid:23413749
75. Neto JX, Pereira ML, Oliveira JT, Rocha-Bezerra LC, Lopes TD, Costa HP, *et al.* A chitin-binding protein purified from *Moringa oleifera* seeds presents anticandidal activity by increasing cell membrane permeability and reactive oxygen species production. Front Microbiol. 2017; 8:980. https://doi.org/10.3389/fmicb.2017.00980 PMid:28634471 PMCid:PMC5459921
76. Dzotam JK, Touani FK, Kuete V. Antibacterial and antibiotic-modifying activities of three food plants (*Xanthosoma mafaffa* Lam., *Moringa oleifera* (L.) Schott and *Passiflora edulis* Sims) against Multidrug-Resistant (MDR) gram-negative bacteria. BMC Complement. Altern Med. 2015; 16:1-8. https://doi.org/10.1186/s12906-016-0990-7 PMid:26753836 PMCid:PMC4709887
77. Moura M, Trentin D, Napoleão T, Primon-Barros M, Xavier A, Carneiro N, *et al.* Multi-effect of the water-soluble *Moringa oleifera* lectin against Serratia marcescens and Bacillus sp.: Antibacterial, antibiofilm and anti-adhesive properties. J Appl Microbiol. 2017; 123(4):861-874. https://doi.org/10.1111/jam.13556 PMid:28792661.
78. Rastogi T, Bhutda V, Moon K, Aswar P, Khadabadi S. Comparative studies on anthelmintic activity of *Moringa oleifera* and *Vitex negundo*. Asian J Res Chem. 2009; 2(2):181-182.
79. Tayo GM, Poné JW, Komtangi MC, Yondo J, Ngangout AM, Mbida M. Anthelminthic activity of *Moringa oleifera* leaf extracts evaluated *in vitro* on four developmental stages of *Haemonchus contortus* from goats. Am J Plant Sci. 2014; 5(11):1702-1710.
80. Chen K-H, Chen Y-J, Yang C-H, Liu K-W, Chang J-L, Pan S-F, *et al.* Attenuation of the extract from *Moringa oleifera* on monocrotaline-induced pulmonary hypertension in rats. Chin J Physiol. 2012; 55(1):22-30. https://doi.org/10.4077/CJP.2012.AMM104 PMid:22242951
81. Azeez I, Yusuf B. Case finding of hypertension at a secondary health care facility in south-west Nigeria. Ann. Ibadan Postgrad. Med. 2018; 16(1):44-51.
82. Attakpa ES, Bertin G, Chabi N, Ategbo J-M, Seri B, Khan N. *Moringa oleifera*-rich diet and T cell calcium signaling in spontaneously hypertensive rats. Physiol Res. 2017; 66(5):753-767. https://doi.org/10.33549/physiolres.933397 PMid:28406707
83. Cheraghi M, Namdari M, Daraee H, Negahdari B. Cardioprotective effect of magnetic hydrogel nanocomposite loaded N, α-L-rhamnopyranosyl vincosamide isolated from *Moringa oleifera* leaves against doxorubicin-induced cardiac toxicity in rats: *In vitro* and *in vivo* studies. J Microencapsul. 2017; 34(4):335-341. https://doi.org/10.1080/02652048.2017.1311955 PMid:28406043
84. Nandave M, Ojha SK, Joshi S, Kumari S, Arya DS. *Moringa oleifera* leaf extract prevents isoproterenol-induced myocardial damage in rats: Evidence for an antioxidant, antiperoxidative, and cardioprotective intervention. J Med Food. 2009; 12(1):47-55. https://doi.org/10.1089/jmf.2007.0563 PMid:19298195
85. Nahar S, Faisal FM, Iqbal J, Rahman MM, Yusuf MA. Antiobesity activity of *Moringa oleifera* leaves against high fat diet-induced obesity in rats. Int J Basic Clin Pharmacol. 2016; 5(4):1263-1268. https://doi.org/10.18203/2319-2003.ijbcp20162427
86. Pare D, Hilou A, Ouedraogo N, Guenne S. Ethnobotanical study of medicinal plants used as anti-obesity remedies in the nomad and hunter communities of Burkina Faso. Medicines. 2016; 3(2):9. https://doi.org/10.3390/medicines3020009 PMid:28930119 PMCid:PMC5456226
87. Metwally FM, Rashad HM, Ahmed HH, Mahmoud AA, Raouf ERA, Abdalla AM. Molecular mechanisms of the anti-obesity potential effect of *Moringa oleifera* in the experimental model. Asian Pac J Trop Biomed. 2017; 7(3):214-221. https://doi.org/10.1016/j.apjtb.2016.12.007
88. Gilani AH, Aftab K, Suria A, Siddiqui S, Salem R, Siddiqui BS, *et al.* Pharmacological studies on hypotensive and spasmolytic activities of pure compounds from *Moringa oleifera*. Phyther Res. 1994; 8(2):87-91. https://doi.org/10.1002/ptr.2650080207
89. Organization WH. Investing to overcome the global impact of neglected tropical diseases: Third WHO report on neglected tropical diseases 2015: World Health Organization; 2015.
90. Choudhary MK, Bodakhe SH, Gupta SK. Assessment of the antiulcer potential of *Moringa oleifera* root-bark extract in rats. JAMS J Acupunct Meridian Stud. 2013; 6(4):214-220. https://doi.org/10.1016/j.jams.2013.07.003 PMid:23972244
91. Ruckmani K, Kavimani S, Jayakar B, Anandan R. Anti-ulcer activity of the alkali preparation of the root and fresh leaf juice of *Moringa oleifera* Lam. Anc Sci Life. 1998; 17(3):220-223.
92. Devaraj V, Krishna BG. Antiulcer activity of a Polyherbal Formulation (PHF) from Indian medicinal plants. Chin J Nat Med. 2013; 11(2):145-148. https://doi.org/10.1016/S1875-5364(13)60041-2 PMid:23787181
93. Das D, Dash D, Mandal T, Kishore A, Bairy K. Protective effects of *Moringa oleifera* on experimentally induced gastric ulcers in rats. Res J Pharm Biol Chem Sci. 2011; 2(2):50-55.

94. Peter A, Walter A, Wagai S, Joseph O. Antibacterial activity of *Moringa oleifera* and *Moringa stenopetala* methanol and n-hexane seed extracts on bacteria implicated in water borne diseases. Afrcan J Microbiol Res. 2011; 5(2):153-157.
95. Elgamily H, Moussa A, Elboraey A, Hoda E-S, Al-Moghazy M, Abdalla A. Microbiological assessment of *Moringa oleifera* extracts and its incorporation in novel dental remedies against some oral pathogens. Open Access Maced. J Med Sci. 2016; 4(4):585-590. https://doi.org/10.3889/oamjms.2016.132 PMid:28028395 PMCid: PMC5175503
96. Singh K, Tafida GM. Antibacterial activity of *Moringa oleifera* (Lam) leaves extracts against some selected bacteria. Pak J Pharm Sci. 2014; 6(9):52-54.
97. Eremwanarue O, Shittu H. Antimicrobial activity of *Moringa oleifera* leaf extracts on multiple drug resistant bacterial isolates from urine samples in Benin City. Niger J Biotechnol. 2018; 35(2):16-26. https://doi.org/10.4314/njb.v35i2.3
98. Kumar GK, Ramamurthy S, Ulaganathan A, Varghese S, Praveen AA, Saranya V. *Moringa oleifera* Mouthwash reinforced with silver nanoparticles – Preparation, characterization and its efficacy against oral aerobic microorganisms – *In vitro* study. Biomed Pharmacol J. 2022; 15(4):2051-2059. https://doi.org/10.13005/bpj/2542
99. Ugwoke C, Eze K, Tchimene K, Anze S. Pharmacognostic evaluation and antimicrobial studies on *Moringa oleifera* Lam (*moringaceae*). Int J Pharm Sci Res. 2017; 8(1):88-94.
100. Stohs SJ, Hartman MJ. Review of the safety and efficacy of *Moringa oleifera*. Phytotherapy Research. 2015; 29(6):796-804. https://doi.org/10.1002/ptr.5325 PMid:25808883 PMCid:PMC6680322
101. Adedapo A, Mogbojuri O, Emikpe B. Safety evaluations of the aqueous extract of the leaves of *Moringa oleifera* in rats. J Med Plants Res. 2009; 3(8):586-591.
102. Awodele O, Oreagba IA, Odoma S, da Silva JAT, Osunkalu VO. Toxicological evaluation of the aqueous leaf extract of *Moringa oleifera* Lam (*Moringaceae*). J Ethnopharmacol. 2012; 139(2):330-336. https://doi.org/10.1016/j.jep.2011.10.008 -PMid:22138517.