Review Article

Moringa oleifera Lam: A versatile medicinal tree in tropical and subtropical countries

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Abstract

Moringa oleifera Lam (Moringaceae), with several common names such as "sahajan", "drumstick", "super food", "miracle tree", "horseradish" and "ben oil tree", is distributed throughout in tropical and subtropical regions of the world. This plant is a panacea, since different parts of it have long been used in herbal medicines by Indians and Africans to cure more than 300 diseases. Moringa is one of the most nutrient-rich plants as it contains over 90 nutrients, 46 antioxidants, 18 amino acids, including 8 essential amino acids. The leaves, pods and seeds of it show presence of a variety of essential phytochemicals. With no known reports of side effects, different parts of the plant are used to treat malnutrition, diabetes, blindness, anemia, hypertension, stress, depression, skin, arthritis, joints, liver and kidney disorders. The powder from seeds and leaves is widely used in water and effluent treatment to improve water quality, which has special applicability in intensive animal production systems, such as aquaculture. The plant possesses many pharmacological attributes such as hypoglycemic, anti-diabetic anti-oxidant, hepato-protective, neuro-protective, cardio-protective, chemo-preventive, anti-cancer, anti-ulcer, cytotoxic, anti-inflammatory, anti-microbial, herbicidal, anti-hypertensive, enzyme inhibition, uterotonic, and fertility stimulator. Due to high nutritional value and several medicinal properties, the plant may act as a nutritional and medical alternative for socially neglected populations. This review will present an updated compilation of the published research on the medicinal characteristics, phytochemical composition, and pharmacological properties along with recent advances in pharmacognosy of moringa.

***Keywords*:** Moringa, phytochemical, anti-inflammatory, pharmacological

Introduction

In the last few decades there has been an exponential growth in the field of herbal medicines because of their popularity for both historical and cultural reasons. A bulk of the population still in many developing countries depends on medicinal plants for health care (Gupta, 2017). *Moringa oleifera* (family Moringaceae) is a very common medicinal tree in the tropical and subtropical regions of the world including India, Pakistan, Afghanistan, Bangladesh, Sri Lanka, North Eastern and South Western Africa and Madagascar. The popular names of *Moringa oleifera (M. oleifera)* are "drumstick", "super food", "miracle tree", "horseradish" and "ben oil tree" *etc* (Gopalakrishnan et al., 2016). In addition, it is known as Haritashaaka, Raktaka and Akshiva in Ayurveda, and as "sahajan" in Unani system of medicine. Moringa is a plant of choice in the Ayurveda and the Chinese ancient systems of medicine. Ayurveda advocates its use for pain relief and rapid expulsion of worms (Biswas et al., 2020). Moringa is one of the most nutrient-rich plants as it contains more than 90 nutrients, 46 antioxidants, 18 amino acids, including 8 essential amino acids (William et al., 2014). Further, Moringa is the cheapest source of nutrients, proteins, enzymes and essential vitamins i.e. A, C and E, and hence an effective remedy to treat malnutrition. It is reported that moringa provides 7 times more vitamin C than oranges, 10 times more vitamin A than carrots, 17 times more calcium than milk, 9 times more protein than yoghurt, 15 times more potassium than bananas and 25 times more iron than spinach (Gopalakrishnan et al., 2016). The leaves, pods and seeds of moringa show presence of a variety of essential phytochemicals. The plant is known to be used in many traditional medicines and pharmacopeias against an array of health conditions that include malaria, diabetes, skin infection, tuberculosis, anemia, headaches, epilepsy,

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sexually transmitted diseases and so on. Some of the pharmacological activities of *M. oleifera* include hypoglycemic, anti-diabetic anti-oxidant, hepato-protective, neuro-protective, cardio-protective, chemo-preventive, anti-cancer, anti-ulcer, cytotoxic, anti-inflammatory, anti-microbial, herbicidal, anti-hypertensive, enzyme inhibition, uterotonic, and fertility stimulator. The present review article is an attempt to critically review the phytochemical, pharmacological and medicinal properties as well as various applications of *M. oleifera*, so that to evaluate the potential of the plant.

Systematic position

Moringa is the most extensively distributed species of the monogenic plant family Moringaceae, with taxonomic classification as below (Bhattacharya et al., 2018). The *Moringa* genus comprises of fourteen deciduous species including trees and shrubs: *M. arborea; M. longituba; M. borziana, M. pygmaea; M. hildebrandtii; M. drouhardii; M. longituba; M. peregrina; M. stenopetala; M. rivae; M. ruspoliana; M. Ovalifolia; M. Concanensis and M. oleifera* (Jeffrey and Mabberley, 1988; Meireles et al., 2020) in sub-Himalayan ranges of India, Pakistan, Afghanistan, Bangladesh, Sri Lanka, North Eastern and South Western Africa and Madagascar.

Kingdom	Plantae
Subkingdom	Tracheobionta
Super division	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Dilleniidae
Order	Capparales
Family	Moringaceae
Genus	*Moringa*

Botanical description

Moringa is a small to medium, soft wooded deciduous perennial tree with sparse foliage cover. It is a very fast growing tree that can reach up to 4 m height in a year and at final stage, it can attain 6-15 m height with 20-40 cm diameter at breast height (Figure 1a). The tripinnate compound leaf consists of many small leaflets with a pale green to dark green colour (Figure 1c). The flower is heteromorphic, bisexual, oblique, axillary, and stalked, consisting of five pale green sepals; five unequal white petals; slender style; five anther stamens (Figure 1b). The fruit is trilobed capsule grow up to 90 cm in length and 12 mm broad in width (Figure 1d) and the seeds are covered with 3 papery wings (Figure 1e) The chromosome number of true diploid (2n) *M. oleifera* is 28 (Tomar et al., 2020).

Propagation, cultivation and harvesting

Moringa can be easily propagated in tropical and subtropical regions across the world due to its better adaptability to different soils types and climatic conditions. It prefers to grow in well drained, fertile and slightly acidic soil (Afzal et al., 2020). It requires sandy or loamy soil with a slightly acidic to alkaline soils (pH range 5-9). However, it will not grow well in soils with very high clay content (cotton soils) (Sagona et al., 2020). With respect to climatic conditions, it grows well in average annual temperature of 18.7-28.5^{0}C, however, it also have the potential to survive in severe temperature up to 48 ^{0}C. It can tolerate light frosts, water scarcity and grows in the

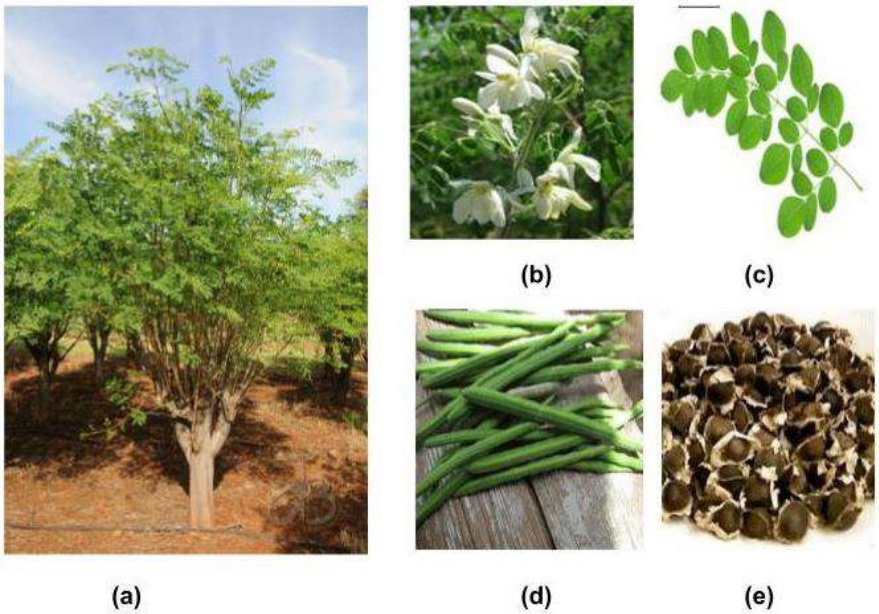

Figure 1. *Moringa oleifera* (a) Tree (b) Flowers, (c) Leaves, (d) Fruits, (e) Seeds

regions with annual rainfall of 250-3000 mm.

Moringa can be propagated by seeds and stem cuttings of 1 to 2 m length (Palada and Chang, 2002). The direct seeding method has high germination rates. The seeds of the plant normally germinate within 5–12 days after seeding when implanted at a depth of 2 cm in the soil. The saplings are placed in plastic bags containing sandy or loamy soil. After it grows to about 30 cm, it can be transplanted. The tree can also be cultivated from cuttings with 1-2 m length and 4–5 cm in diameter, but with poorly developed root system. Further, such plants tend to be sensitive to drought and winds. In commercial cultivation, spacing between saplings is important as it helps in plant management and harvest. In India, moringa sheds its leaves in December-January; flowers in January-March with tender pods in April-June. The tree developed from seeds start bloom after 2 years but the tree produced from stem cuttings yields fruits after 6-12 months after planting (Tomar et al., 2020).

Phytochemical constituents

The medicinal significance of *M. oleifera* is because of the presence of a variety of bioactive components in all parts of the plant (Alegbeleye, 2018; Liang et al., 2019). Several specific bioactive secondary metabolites, such as alkaloids, glycosides, flavonoids, saponins, glucosinolates, resins, volatile oils, gums and tannins have been isolated and

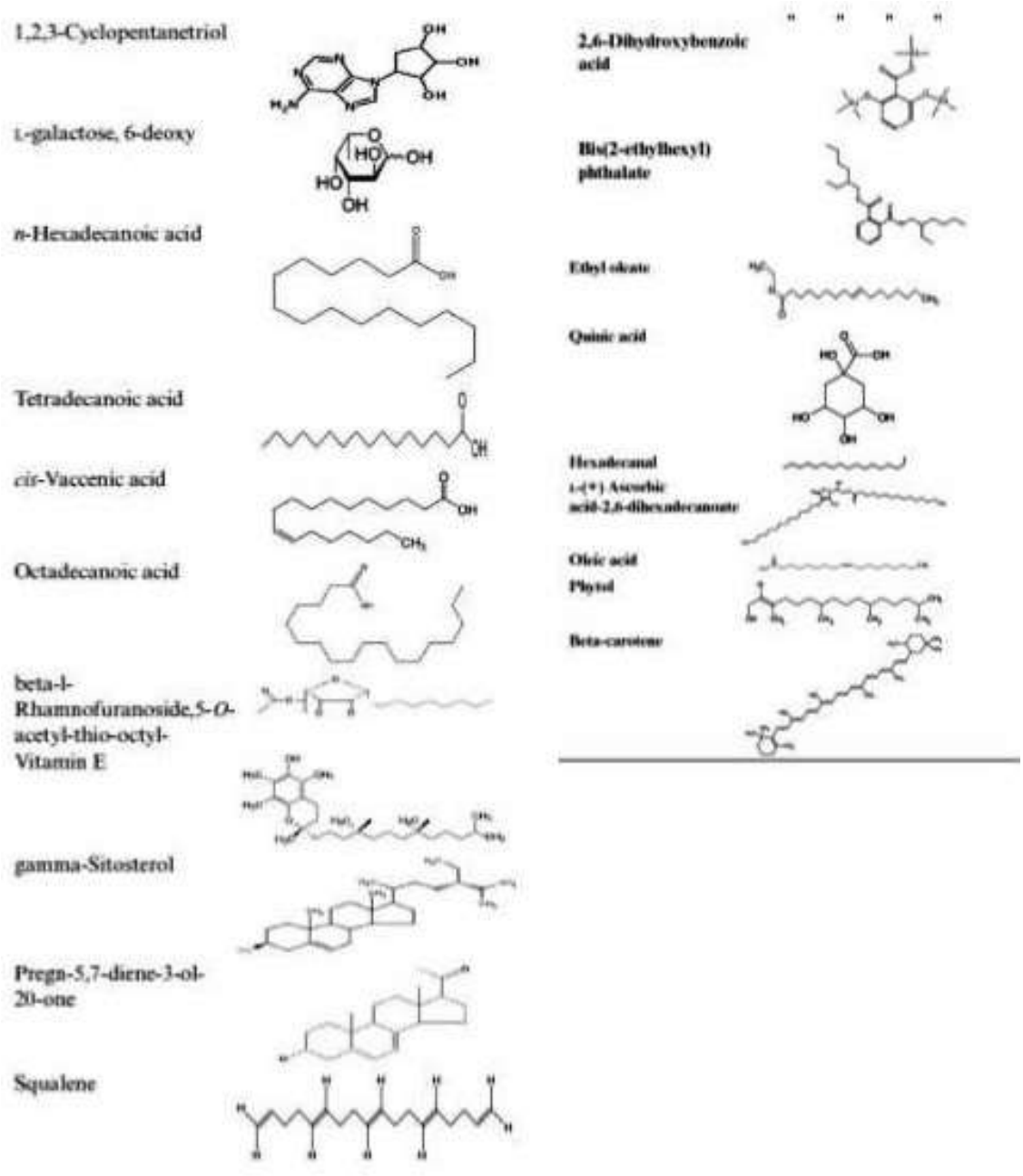

Figure 2. Structures of some important phytoconstituents of *Moringa oleifera* (Bhattacharya et al., 2018)

characterized (Bhattacharya et al., 2018) and many of them are of chemotaxonomic relevance (Alegbeleye, 2018; Dzuvor et al., 2022). The structure of some of the important phytoconstituents have been shown in Figure 2 (Bhattacharya et al., 2018). The phytochemicals isolated from moringa include flavonoids (mainly in the leaves), glucosinolate and isothiocyanate (mainly in the leaves), phenolic acid (mainly in the leaves), alkaloids and sterols (in the leaves, roots, and seeds), and terpene (mainly in the pods) (Dhakad et al., 2019; Dzuvor et al., 2022; Abdel-Latif et al., 2022). The phenols and alkaloids are more abundant in the leaves than in the seeds, while flavonoids, saponins, and anthocyanins are more abundant in the seeds (Gupta et al., 2018). Further, moringa provides a rich mixture of zeatin, quercetin, beta-sitosterol, caffeoylquinic acid and kaempferol (Anwar et al., 2007).

A number of compounds isolated and characterized in methanolic leaf extracts of *M. oleifera*, are kaempferide 3-O-(2″,3″-diacetylglucoside), kaempferide 3-O-(2″-O-galloylrhamnoside), kaempferide 3-O-(2″-O-galloylrutinoside)-7-O-alpha-rhamnoside, kaempferol 3-O-[beta-glucosyl-(1-2)]-[alpha-rhamnosyl-(1-6)]-beta- glucoside-7-O-alpha-rhamnoside and kaempferol 3-O-[alpha- rhamnosyl-(1-2)]-[alpha-rhamnosyl-(1-4)]-beta-glucoside-7-O alpha- rhamnoside together with benzoic acid 4-O-beta-glucoside, benzoic acid 4-O-alpha-rhamnosyl-(1-2)-beta-glucoside and benzaldehyde 4-O-beta-glucoside (Manguro and Lemmen, 2007; Prabu et al., 2019; Padayachee and Baijnath, 2020; Abdel-Latif et al., 2022).

Multiple applications of Moringa

There are a lots of literature about the nutritional, medicinal, environmental, agricultural and socio-economic applications of *M. oleifera* (Alegbeleye, 2018; Abdel-Latif et al., 2022). Moringa is cultivated as a multipurpose tree for food and health management (leaves, seeds, flowers and fruits), water purification and as a softening agent (crushed leaves), blue dye (wood), insecticide for other plants, green manure (seed-cake, leaves), biogas and biodiesel production (leaves and seeds), plant growth promoter (Zeatin growth hormone from leaves), oil seed crop and vegetables, livestock feed (leaves and treated seedpod-cake), extraction of various enzymes as well as treatment of human herpesvirus-4 (Gopalakrishnan et al., 2016) (Brilhante et al., 2017; Gandji et al., 2020).

As a human food and animal fodder

Fresh leaves of moringa are widely consumed by humans as a vegetable in salad, soups and sauces (Sagona et al., 2020). The leaves are more nutritious than other vegetables as these contain as much vitamin A as carrots and are richer in vitamin C than tomatoes, radishes, carrots and peas. The leaves and stems of moringa have fodder potential since grow quickly, require little water, and are good source of protein and minerals with excellent palatability and 79 and 57% digestibility. Studies show that milk production and weight was increased in ruminants when moringa was added as part of their diet (Tomar et al., 2020). Moringa leaves are readily eaten by cattle, sheep, goats, pigs and rabbits. Moringa leaves in poultry, pigs and various fish species is feasible. It is a promising protein source for inclusion in fish diets at low levels, and has been tested in various fish species as a potential replacement for fish meal. Feeding chickens with Moringa leaves and seeds improves egg production.

Commercial production of ben oil

Moringa seeds are the source of a high quality oil "Ben oil", which resembles olive oil, and has both nutritional and industrial application. The moringa seed oil is used as a substitute for olive oil in cooking food, in perfume manufacturing and in lubrication of fine watches. The oil is of equal value, both for cooking oil as well as main ingredient for soap manufacture. The seed cake after oil pressing though not edible and high in saponin can be used as fertilizer (Sagona et al., 2020).

As a water purifier

Moringa seeds act as natural coagulant, and can replace aluminium sulphate (Alum). The seed contains a cationic protein that can clarify turbid water, and hence can be used in water purification. Acid extract of natural polyelectrolyte moringa seeds is very effective as a is a coagulant for removal of fluoride from water (Ravikumar and Sheeja, 2013). Further, moringa seed extract has the ability to eliminate heavy metals (such as lead, copper, cadmium, chromium and arsenic) from water (Ravikumar and Sheeja, 2013; Nwagbara et al., 2022).

As a traditional medicine for health care

Though, different parts (leaves, stems, roots, flowers, seeds, and cortex) of moringa have medicinal value, the leaves are more widely used (Álvarez-Román et al., 2020). The leaf powder of moringa is used in the diet of children and pregnant and lactating women to cure malnutrition (Bancessi et al., 2020), and at the same time, young leaves may be used as cattle fodder to improve milk production (Sagona et al., 2020). In Malawi, crushed leaves are used for treating conjunctivitis, scorpion bites and diarrhea (Sagona et al., 2020). In Guinea-Bissau, the leaves of moringa are used in water to eyesight problems, sprains and fever (Bancessi et al., 2020), but across Africa as antipyretic, antibiotic, bacteriostatic, fungistatic and pain-killer. The leaf juice is used by diabetic patients to stabilize blood pressure and control blood glucose levels. The roots, leaves and flowers of moringa are used in traditional medicine for the treatment of diarrhea and hypertension in many

countries (Anwar et al., 2007). Further, moringa leaves have been used to treat a number of diseases including insulin resistance, cardiovascular disease, hepatic steatosis, cancer and others (Almatrafi et al., 2017). Further uses involve treatment of abscess, anaemia, arthritis, asthenia, convulsions, cough, dysentery, dysmenorrhea, epilepsy and spasms, flu and sinusitis, gonorrhoea, headaches and migraine, haemorrhoids, infertility, intestinal worms, icterus, indigestion, immune deficiency caused by HIV, malaria, oligospermia, otitis, paralysis, rheumatism, sexual dysfunction, skin and mucosae infections, stomach troubles, typhoid fever, varicella (Agoyi et al., 2017).

Pharmacological properties

Hypoglycemic and anti-diabetic activities

Diabetes is the cause of several complications such as retinopathy, nephropathy and atherosclerosis *etc*. Research studies have shown that moringa can act as an anti-diabetic agent to cure both Type 1 (lack of production or under secretion of insulin) and Type 2 (insulin resistance or Beta cell dysfunction) diabetes. Moringa has shown outstanding hypoglycemic activity in various diabetic animal models, or in human volunteers, because it can not only stimulate insulin secretion from pancreatic β-cells, but also directly reduce blood glucose by reacting with anti-insulin antibodies (Villarruel-López et al., 2018; Xiao et al., 2020). The aqueous extract of *M. oleifera* leaf can cure streptozotocin (STZ)-induced Type 1 diabetes and also insulin resistant Type 2 diabetes in rats (Divi et al., 2012). In a study, the anti-diabetic activity of two low doses (50 and 100 mg/kg body weight) of Moringa seed powder on STZ-induced diabetes male rats was investigated (AL-Malki and Rabey, 2015). The researchers have hypothesized that the flavonoids in moringa scavenge the ROS released from mitochondria, thereby protecting the beta cells and in turn keeping hyperglycemia under control (Kamalakkannan and Prince, 2006; Wang et al., 2022).

Hepato-protective and anti-oxidant activities

The leaves are the chief source of antioxidants due to presence of high levels of carotenoids, ascorbic acids, and glucosinolate (Saini et al., 2016). Moringa leaf is well-known for its effect on eliminating reactive oxygen species (ROS) due to presence of more than 40 natural antioxidants (Pakade et al., 2013).Three anti-oxidants caffeic acid, quercetin and gallic acid identified in leaf and stem extracts of *M. oleifera* can prevent non-alcoholic fatty liver disease (NAFLD) (Asgari-Kafrani et al., 2020), the most commonly diagnosed chronic liver disease in developed countries. The methanolic leaf extracts of moringa by HPLC-PDA-ESI/MS exhibited the highest amounts of 13 out of 19 phenolic compounds; quinic acid, gallic acid, 4-O-caffeoylquinic acid, caffeic acid, trans-ferulic acid, apigenin 7-O-glucoside, quercetrin, kaempferol, naringenin, apigenin, luteolin, cirsiliol and cirsilineol (Bennour et al., 2020). The isoquercetin is recorded to have the highest anti-oxidative activity by increasing the expression of antioxidant enzymes, such as superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase (Vongsak et al., 2015).

Neuro-protective and cardio-protective activities

Cerebral ischemia is caused due to obstruction of blood flow to the brain. This leads to reperfusion and lipid peroxidation, which in turn results in formation of ROS. Moringa can be used as a potent neuro-protectant by reducing the formation of ROS, thereby protecting the brain (Kirisattayakul et al., 2013). The isolated polyphenols and phenolic extract from moringa leaves have demonstrated strong neuroprotective activities against H2O2-induced oxidative stress in PC-12 cells (Gao et al., 2022). A cardioprotective alkaloid (*N*,α-L-rhamnopyranosyl vincosamide (VR), isolated from the leaves of *M. oleifera,* markedly reduced isoproterenol (ISO)-induced increase in the levels of serum cardiac markers (troponin-T, creatine kinase-MB, lactate dehydrogenase and glutamate pyruvate transaminase as well as cardiac lipid peroxidation) with a parallel increase in the antioxidants suggesting its cardio-protective and free radical scavenging potential (Panda et al., 2013).

Chemo-preventive activity

Chronic pathological disorders such as cancer, inflammatory diseases and immune disorders figure among the leading causes of mortality worldwide (Michl et al. 2016). Therefore, dietary chemoprevention received increased attention over the past few years as an approach to lower cancer incidence and mortality. Sulforaphane (SFN) and moringin (GMG-ITC), edible isothiocyanates, are considered ideal chemo-preventive agents due to their abundance in cruciferous vegetables including *M. oleifera*, excellent bioavailability, ability to target multiple pathways and low toxicity (Michl et al., 2016). In a study, the chemo-protective role of hydroethanolic extract of moringa and its saponin against 7, 12- dimethyl-benz[a]anthracene (DMBA)-intoxicated mice was investigated. Moringa produced protective effects in hepatic and renal tissue against DMBA-induced toxicity (Sharma and Paliwal, 2012). Further, moringa leaves and flowers help in protecting liver damage in rats given an over dosage of Acetaminophen (APAP) (Sharifudin et al., 2013), is the most common cause of drug-induced liver diseases and acute liver failure in humans and experimental animals.

Anti-cancer, anti-ulcer and cytotoxic activities

Folk medicine practitioners suggest the use of extracts from different parts of *M. oleifera* for cancer treatment. The hexane fraction of moringa seeds inhibit breast cancer (MCF7) cell proliferation at IC_{50} of 130mg/ml, though, the mechanism

remained unknown (Adebayo et al., 2020). The extracts from the leaves, on the other hand, induce apoptosis in hepatocellular, pancreatic, and alveolar cancer cells by regulating apoptotic biomarkers, such as p53, caspases, nuclear factor-kappaB, and Bcl-xL (Tiloke et al., 2013; Jung et al., 2015). In another study, Brown *et al*. used moringa leaf extracts (aqueous, butanolic, ethanolic, hydroethanolic, and methanolic) in conjunction with Vesicular stomatitis virus (VSV), and showed that the ethanolic extract inhibits the production of C4-II and HeLa cervical cancer cells. This inhibition was correlated with decreased levels of NF-kB and Bcl-xL in these cells. The results indicate that *M. oleifera* may synergize with VSV for the treatment of cervical cancers through modulation of pathways involved in cell proliferation, apoptosis and antiviral responses (Brown et al., 2020). The anti-ulcer activity of moringa leaves in swiss albino mice against aspirin induced peptic ulcer has also been reported (Jose et al., 2014). Treatments with moringa ethanol leaf extract and moringa silver nanoparticles (MO-AgNPs) had selective cytotoxicity towards leukemia cell line (Kasumi-1), being non-cytotoxic to normal myeloid cells (CD34+) cells. The two treatments successfully induced cytotoxicity, wherein each treatment caused cell cycle arrest at varying stages, with ethanol leaf extract and MO AgNPs causing cell cycle arrest at G1 and S phases, respectively (Khor et al., 2020).

Anti-inflammatory activity and immune disorders

Autoimmune diseases are primarily linked with genetic factors, immunomodulation, viral infection and antigenic differences. With the exclusion of genetic factors, moringa has shown exceptional positive effects on the other three aspects. Moringa can not only eliminate pathogens (bacteria, fungi, viruses, and parasites), but also inhibits chronic inflammatory responses, such as asthma, ulcerative colitis, and metabolic diseases (Xiao et al., 2020). Additionally, moringa can attenuate physical and chemical irritation-induced immune disorders, such as metal intoxication, drug side effects, or even the adverse effect of food additives. Autoimmune diseases, like rheumatoid arthritis, atopic dermatitis, and multiple sclerosis, can also be inhibited by moringa treatments (Xiao et al., 2020). Various parts of the plant have the traditional use in skin problem (leaves, seeds, root, gum), nervous disorder (leaves, flower, root, bark, gum), immunity imbalance (seeds) (Naidoo and Coopoosamy, 2011).

Anti-hypertensive activity

WHO reports that 1.13 billion people are affected worldwide due to hypertension that can lead to stroke, blindness, heart attack, kidney, and heart failure. Moringa leaves have traditionally been used in Ayurvedic medicines for treatment of hypertension (Dangi et al., 2002). Methanolic and ethyl acetate extracts of moringa have significantly reduced systolic blood pressure of hypertensive mice (Acuram et al., 2019). Further, Niazicin-A, Niazimin-A, and Niaziminin-B compounds from *M. oleifera* ethanolic leaf extract were reported to have potent antihypertensive activity by inhibition of angiotensin-converting enzyme [ACE] (Khan et al., 2019).

Antiviral activity

Moringa is frequently used against AIDS and secondary infections associated with HIV. It showed significant activities against viruses like HIV, HSV, HBV, EBV, FMDV and NDV. In some cases active molecules with mode of actions were documented by authors. On the other hand, there is a number of reports where neither lead compounds nor the relevant mechanisms were reported regarding the anti-viral activities of crude plant extract (Biswas et al., 2020). According to Naidoo & Coopoosamy (2011), moringa seeds and flowers were used by human society to treat small pox (caused by *Variola major* and *Variola minor*) and chicken pox (caused by *Varicella zoster*) infections in some regional culture.

Anti-bacterial activity

Moringa seed extracts is widely used in preventing waterborne diseases due to anti-bacterial activity, however, it shows a slightly higher inhibitory effect against gram-negative bacteria. The leaves and seeds appear to possess a broader spectrum of anti-microbial activity than the other parts of the plant (Xiao et al., 2020). *M. oleifera* extract promotes the healing of infected wounds in methicillin-resistant *Staphylococcus aureus* (MRSA)-infected diabetic rats but is less effective in the healing of wounds infected with *P. aeruginosa* in diabetic rats (Al-Ghanayem et al., 2022). Benzyl isothiocyanate, extracted from the seeds of moringa, can significantly reduce the pathogenicity of bacteria by inhibiting bacterial conjugation (Padla et al., 2012). This properties of *M. oleifera* seeds have wide applicability in preventing diseases and can enhance the quality of life in rural communities as it is widely located.

Anti-fungal activity

In a study, the aqueous and ethanolic extracts of *M. oleifera* were used for determination of anti-fungal activity against *Saccharomyces cerevisiae, Candida albicans, and C. tropicalis*. The ethanolic and aqueous extracts of moringa leaf were highly active against *Saccharomyces cerevisiae* and active against *C. tropicalis* and not showing activity against *C. albicans* (Patel et al., 2014).

Herbicidal activity

In a pot experiment, sunflower plants and associated *Econocloa colonum* grassy weed were sprayed with root, leaf and seeds water extracts of *M. oleifera* at the two concentrations (5 and 10%) with promising effect in

controlling weeds as well as growth enhancement of the target plant (El-Rokiek et al., 2022).

Enzyme inhibition

Alpha-glucosidase is a key enzyme in the breakdown of carbohydrates into glucose. Inhibition of α-glucosidase leading to reduction in the absorption of carbohydrates from food in the intestines is a therapeutic approach for postprandial hyperglycemia. Moringa leaf acts as an inhibitor of α-glucosidase (alpha glucosidase inhibitor, AGI), and has the potential to be developed as an alternative food therapy for diabetics (Natsir et al., 2018).

Impact on reproductive functions

The leaf of *M. oleifera* contains bioactive mini proteins and cysteine-rich peptides (Kini et al., 2017), a number of which have hormone or drug-like activity that can modulate physiological functions via binding to specific receptors on target cells. Moringa leaves are frequently used in Nigerian families for the management of several diseases including the fertility enhancement of the male and female both (Ajuogu et al., 2019). *Moringa* contains phytosterols such as stigmasterol, sitosterol and kampesterol which are precursors for many hormones including estrogen, which stimulates the proliferation of the mammary gland ducts to produce milk. Lactogogues from *Moringa* are prescribed to lactating Nigerian mothers to boost milk production. This may partly account for the reason why many of these lactating women do not get pregnant during this period of accelerated intake of the leaves despite unprotected sexual activity (Attah et al., 2020). The aqueous extract of moringa flower possesses promising uterotonic potential and the effect seems to be mediated through excitatory muscarinic, histaminergic H1 and α1 adrenergic receptors (Singh et al., 2008). Mice fed with dietary moringa leaf (4% MOL) showed improved litter size, litter birth weight, and litter survivals until weaning age compared to control mice fed with normal diet. Therefore, moringa may serve as a functional feed addictive for improving animal reproductive performance (Zeng et al., 2019).

Men are exclusively responsible for nearly 20%–30% of the identifiable reasons of infertility worldwide. Deficiencies in semen quality and quantity have been identified as the prime cause of male infertility, with about 90% of cases attributed to suboptimal spermatogenesis and sperm counts (Agarwal et al., 2015). In a study conducted by a group of researchers, aqueous leaf extract of moringa maintained basic sperm functions, inhibited excess sperm free superoxide production and preserved acrosome reaction and DNA integrity (Moichela et al., 2021). Moringa leaves as a feed supplement could increase plasma testosterone concentrations, libido, and sperm motility of Bali bulls (Syarifuddin et al., 2017). In another study, feeding rabbits with moringa leaf meal up to 2.5% as a supplement improved sperm production and sperm reserves, while above this level it reduced sperm storage potential and daily sperm production (Ewuola et al., 2019). Moringa leaf (100 mg/kg, 5 doses in a week for 4 weeks) either alone or in combination intraperitoneally, ameliorated cyclophosphamide (100 mg/kg, one dose in a week for 3 weeks))-induced testicular toxicity and improved functional integrity of spermatozoa as well as spermatogenic cells in Swiss albino mice (Nayak et al., 2020). In contrast, there is a limited scientific documentation regarding the possible contraceptive or abortifacient potentials of the leaf meal of *Moringa* in wistar rats. However, leaves of *Moringa* species cultivated in a remote village in India have been reported to show abortifacient activities *in vivo* at certain doses (Nath et al., 1992).

Conclusion

In spite of the overwhelming influences and our dependence on modern medicines, a large segment of the world population still rely on plant-based drugs. Moringa is one of the most important medicinal plants used in medicines of Ayurveda, siddha, Unani and Homeopathy. It is the source of a variety of biologically active phytoconstituents which are responsible for medicinal and pharmacological properties of the plant. Based on the scientific reports, moringa seems to be an inexpensive, eco-friendly and socially beneficial alternative, especially for the socially neglected population, suffering from poverty and malnutrition, and for those who have limited access to technological resources. Therefore, there is an urgent need to investigate the biological activity of its phytoconstituents for development of easily available, effective, safe and cheap herbal drugs with lesser side-effects.

Conflict of interest

The author declares that there is no conflict of interest.

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