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REVIEW ARTICLE

Moringa oleifera: A Food Plant with Multiple Medicinal Uses

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Moringa oleifera **Lam (Moringaceae) is a highly valued plant, distributed in many countries of the tropics and subtropics. It has an impressive range of medicinal uses with high nutritional value. Different parts of this plant contain a profile of important minerals, and are a good source of protein, vitamins, β-carotene, amino acids and various phenolics. The *Moringa* plant provides a rich and rare combination of zeatin, quercetin, β-sitosterol, caffeoylquinic acid and kaempferol. In addition to its compelling water purifying powers and high nutritional value, *M. oleifera* is very important for its medicinal value. Various parts of this plant such as the leaves, roots, seed, bark, fruit, flowers and immature pods act as cardiac and circulatory stimulants, possess antitumor, antipyretic, antiepileptic, antiinflammatory, antiulcer, antispasmodic, diuretic, antihypertensive, cholesterol lowering, antioxidant, antidiabetic, hepatoprotective, antibacterial and antifungal activities, and are being employed for the treatment of different ailments in the indigenous system of medicine, particularly in South Asia. This review focuses on the detailed phytochemical composition, medicinal uses, along with pharmacological properties of different parts of this multipurpose tree.**

Keywords: Moringa oleifera; phytomedicine; food plant; medicinal uses; pharmacological properties; natural coagulant.

INTRODUCTION

Moringa oleifera Lam (syn. *M. ptreygosperma* Gaertn.) is one of the best known and most widely distributed and naturalized species of a monogeneric family *Moringaceae* (Nadkarni, 1976; Ramachandran *et al.*, 1980). The tree ranges in height from 5 to 10 m (Morton, 1991). It is found wild and cultivated throughout the plains, especially in hedges and in house yards, thrives best under the tropical insular climate, and is plentiful near the sandy beds of rivers and streams (The Wealth of India, 1962; Qaiser, 1973). It can grow well in the humid tropics or hot dry lands, can survive destitute soils, and is little affected by drought (Morton, 1991). It tolerates a wide range of rainfall with minimum annual rainfall requirements estimated at 250 mm and maximum at over 3000 mm and a pH of 5.0–9.0 (Palada and Changl, 2003).

Moringa oleifera, native of the western and sub-Himalayan tracts, India, Pakistan, Asia Minor, Africa and Arabia (Somali *et al.*, 1984; Mughal *et al.*, 1999) is now distributed in the Philippines, Cambodia, Central America, North and South America and the Caribbean Islands (Morton, 1991). In some parts of the world *M. oleifera* is referred to as the 'drumstick tree' or the 'horse radish tree', whereas in others it is known as the kelor tree (Anwar and Bhanger, 2003). While in the Nile valley, the name of the tree is 'Shagara al Rauwaq', which means 'tree for purifying' (Von Maydell, 1986). In Pakistan, *M. oleifera* is locally known as 'Sohanjna' and is grown and cultivated all over the country (Qaiser, 1973; Anwar *et al.*, 2005).

Moringa oleifera is an important food commodity which has had enormous attention as the 'natural nutrition of the tropics'. The leaves, fruit, flowers and immature pods of this tree are used as a highly nutritive vegetable in many countries, particularly in India, Pakistan, Philippines, Hawaii and many parts of Africa (D'souza and Kulkarni, 1993; Anwar and Bhanger, 2003; Anwar *et al.*, 2005). *Moringa* leaves have been reported to be a rich source of β-carotene, protein, vitamin C, calcium and potassium and act as a good source of natural antioxidants; and thus enhance the shelf-life of fat containing foods due to the presence of various types of antioxidant compounds such as ascorbic acid, flavonoids, phenolics and carotenoids (Dillard and German, 2000; Siddhuraju and Becker, 2003). In the Philippines, it is known as 'mother's best friend' because of its utilization to increase woman's milk production and is sometimes prescribed for anemia (Estrella *et al.*, 2000; Siddhuraju and Becker, 2003).

A number of medicinal properties have been ascribed to various parts of this highly esteemed tree (Table 1). Almost all the parts of this plant: root, bark, gum, leaf, fruit (pods), flowers, seed and seed oil have been used for various ailments in the indigenous medicine of South Asia, including the treatment of inflammation and infectious diseases along with cardiovascular, gastrointestinal, hematological and hepatorenal disorders

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Table 1. Some common medicinal uses of different parts of *Moringa oleifera*

Plant part	Medicinal Uses	References
Root	Antilithic, rubefacient, vesicant, carminative, antifertility, anti-inflammatory, stimulant in paralytic afflictions; act as a cardiac/circulatory tonic, used as a laxative, abortifacient, treating rheumatism, inflammations, articular pains, lower back or kidney pain and constipation,	*The Wealth of India*, 1962; Padmarao *et al.*, 1996; Dahot, 1988; Ruckmani *et al.*, 1998
Leave	Purgative, applied as poultice to sores, rubbed on the temples for headaches, used for piles, fevers, sore throat, bronchitis, eye and ear infections, scurvy and catarrh; leaf juice is believed to control glucose levels, applied to reduce glandular swelling	Morton, 1991; Fuglie, 2001; Makonnen *et al.*, 1997; *The Wealth of India*, 1962; Dahot, 1988
Stem bark	Rubefacient, vesicant and used to cure eye diseases and for the treatment of delirious patients, prevent enlargement of the spleen and formation of tuberculous glands of the neck, to destroy tumors and to heal ulcers. The juice from the root bark is put into ears to relieve earaches and also placed in a tooth cavity as a pain killer, and has anti-tubercular activity	Bhatnagar *et al.*, 1961; Siddhuraju and Becker, 2003
Gum	Used for dental caries, and is astringent and rubefacient; Gum, mixed with sesame oil, is used to relieve headaches, fevers, intestinal complaints, dysentery, asthma and sometimes used as an abortifacient, and to treat syphilis and rheumatism	Fuglie, 2001
Flower	High medicinal value as a stimulant, aphrodisiac, abortifacient, cholagogue; used to cure inflammations, muscle diseases, hysteria, tumors, and enlargement of the spleen; lower the serum cholesterol, phospholipid, triglyceride, VLDL, LDL cholesterol to phospholipid ratio and atherogenic index; decrease lipid profile of liver, heart and aorta in hypercholesterolaemic rabbits and increased the excretion of faecal cholesterol	Nair and Subramanian, 1962; Bhattacharya *et al.*, 1982; Dahot, 1998; Siddhuraju and Becker, 2003; Mehta *et al.*, 2003
Seed	Seed extract exerts its protective effect by decreasing liver lipid peroxides, antihypertensive compounds thiocarbamate and isothiocyanate glycosids have been isolated from the acetate phase of the ethanolic extract of *Moringa* pods	Faizi *et al.*, 1998; Lalas and Tsaknis, 2002

(The Wealth of India, 1962; Singh and Kumar, 1999; Morimitsu *et al.*, 2000; Siddhuraju and Becker, 2003).

The seeds of *Moringa* are considered to be antipyretic, acrid, bitter (Oliveira *et al.*, 1999) and reported to show antimicrobial activity (The Wealth of India, 1962). The seed can be consumed fresh as peas; or pounded, roasted, or pressed into sweet, non-desiccating oil, commercially known as 'Ben oil' of high quality. The unique property is the ability of its dry, crushed seed and seed press cake, which contain polypeptides, to serve as natural coagulants for water treatment (Ndabigengesere and Narasiah, 1998).

So far no comprehensive review has been compiled from the literature encompassing the efficacy of this plant in all dimensions. Its versatile utility as a medicine, functional food, nutraceutical and water purifying potential motivated us to bridge the information gap in this area, and to write a comprehensive review on the medicinal, phytochemical and pharmacological attributes of this plant of high economic value.

PHYTOCHEMISTRY

Moringa oleifera is rich in compounds containing the simple sugar, rhamnose and a fairly unique group of compounds called glucosinolates and isothiocyanates (Fahey *et al.*, 2001; Bennett *et al.*, 2003). The stem bark has been reported to contain two alkaloids, namely moringine and moringinine (Kerharo, 1969). Vanillin, β-sitosterol [**14**], β-sitostenone, 4-hydroxymellin and octacosanoic acid have been isolated from the stem of *M. oleifera* (Faizi *et al.*, 1994a).

Purified, whole-gum exudate from *M. oleifera* has been found to contain L-arabinose, -galactose, -glucuronic acid, and L-rhamnose, -mannose and -xylose, while a homogeneous, degraded-gum polysaccharide consisting of L-galactose, -glucuronic acid and L-mannose has been obtained on mild hydrolysis of the whole gum with acid (Bhattacharya *et al.*, 1982).

Flowers contain nine amino acids, sucrose, D-glucose, traces of alkaloids, wax, quercetin and kaempferat; the ash is rich in potassium and calcium (Ruckmani *et al.*, 1998). They have also been reported to contain some flavonoid pigments such as alkaloids, kaempherol, rhamnetin, isoquercitrin and kaempferitrin (Faizi *et al.*, 1994a; Siddhuraju and Becker, 2003).

Antihypertensive compounds thiocarbamate and isothiocyanate glycosides have been isolated from the acetate phase of the ethanol extract of *Moringa* pods (Faizi *et al.*, 1998). The cytokinins have been shown to be present in the fruit (Nagar *et al.*, 1982). A new *O*-ethyl-4-(α-L-rhamnosyloxy)benzyl carbamate [**11**]

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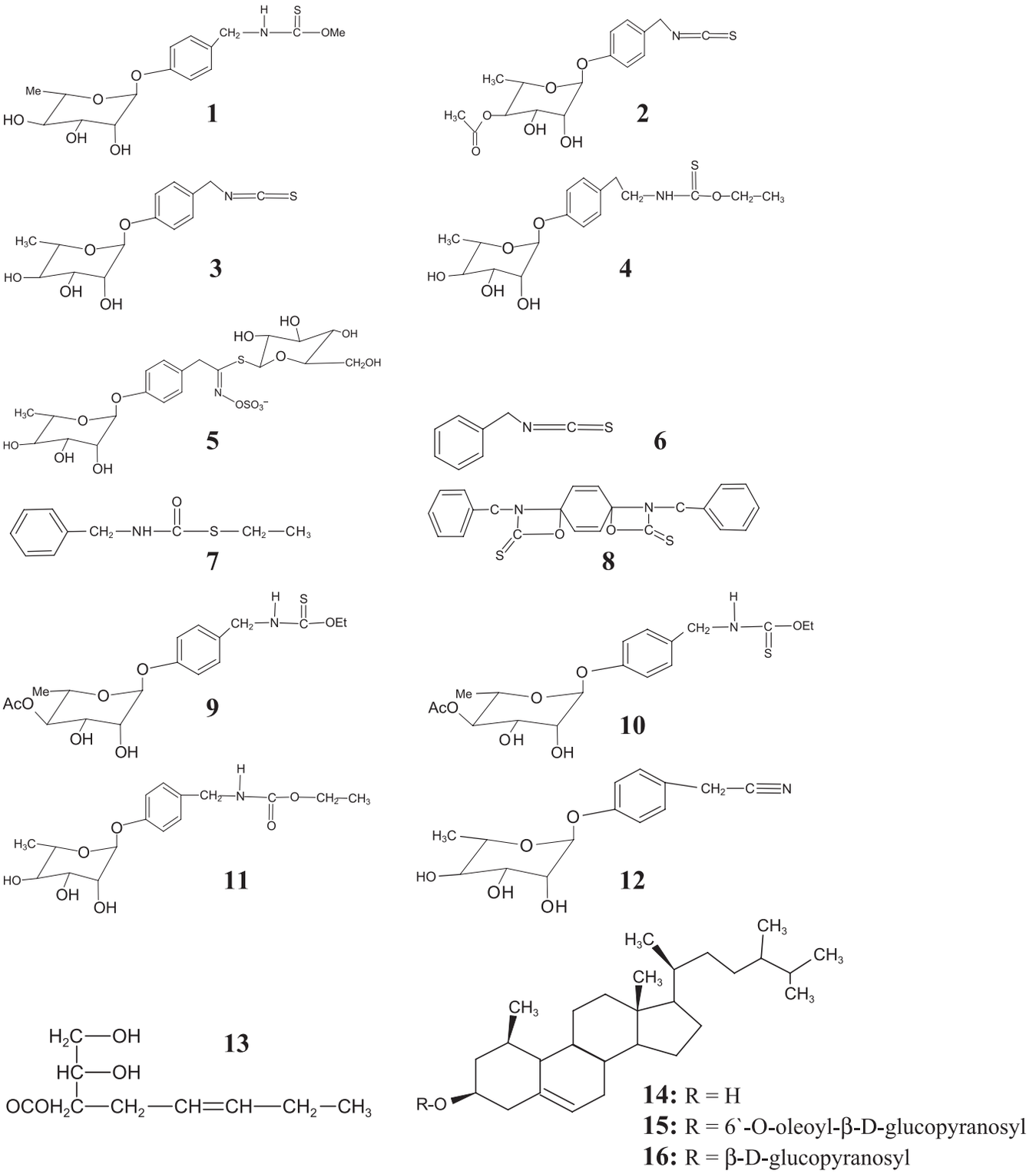

Fiqure 1. Structures of selected phytochemicals from Moringa: niazinin A **[1]**, 4-(4′-*O*-acetyl-*α*-L-rhamnopyranosyloxy)benzyl isothiocyanate **[2]**, 4-(-L-rhamnopyranosyloxy)benzyl isothiocyanate **[3]**, niazimicin **[4]**, 4-(*α*-L-rhamnopyranosyloxy)benzyl glucosinolate **[5]**, benzyl isothiocyanate **[6]**, aglycon of deoxy-niazimicine (N-benzyl, S-ethylthioformate) **[7]**, pterygospermin **[8]**, niaziminin **[9** + **10]**, *O*-ethyl-4-(*α*-L-rhamnosyloxy)benzyl carbamate **[11]**, niazirin **[12]**, glycerol-1-(9-octadecanoate) **[13]**, *β*-sitosterol **[14]**, 3-*O*-(6′-*O*-oleoyl-*β*-D-glucopyranosyl)-*β*-sitosterol **[15]**, *β*-sitosterol-3-*O*-*β*-D-glucopyranoside **[16]**.

together with seven known bioactive compounds, 4(*α*-L-rhamnosyloxy)-benzyl isothiocyanate [**3**], niazimicin [**4**], 3-*O*-(6′-*O*-oleoyl-*β*-D-glucopyranosyl)-*β*-sitosterol [**15**], *β*-sitosterol-3-*O*-*β*-D-glucopyranoside [**16**], niazirin [**12**], *β*-sitosterol [**14**] and glycerol-1-(9-octadecanoate) [**13**] have been isolated from the ethanol extract of the *Moringa* seed (Guevara *et al.*, 1999). Figure 1 shows the structures of selected phytochemicals from *Moringa*.

Lately, interest has been generated in isolating hormones/growth promoters from the leaves of *M. oleifera*. Nodulation of black-gram (*Vigna munga* L.)

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Table 2. Sterol composition (grams per 100 g of fatty acids) of the *M. oleifera* oils

Sterol	Anwar and Bhanger, 2003	Lalas and Tsaknis, 2002	Tsaknis *et al.*, 1999
Cholesterol	Not reported	0.10	0.13
Brassicasterol	Not reported	0.05	0.06
24-methylenecholesterol	1.49	0.08	0.88
Campesterol	16.00	15.29	15.13
Campestanol	Not reported	0.33	0.35
Δ^7-campestanol	0.50	Not reported	Not reported
Stigmasterol	19.00	23.06	16.87
Ergostadienol	Not reported	0.35	0.39
Clerosterol	1.95	1.22	2.52
Stigmastanol	1.00	0.64	0.86
β-sitosterol	46.65	43.65	50.07
Δ^7-avenasterol	0.96	Not detected	1.11
Δ^5-avenasterol	10.70	11.61	8.84
28-isoavenasterol	0.50	0.25	1.40
$\Delta^{7,14}$ Stigmastadienol	Not reported	0.39	Not reported
$\Delta^{7,14}$ Stigmastanol	Not reported	0.85	0.44

has been shown to increase vigorously with the application of an aqueous-ethanol extract (Bose, 1980) of *M. oleifera* leaves, although the nature of the active ingredient is still unknown. *Moringa* leaves act as a good source of natural antioxidant due to the presence of various types of antioxidant compounds such as ascorbic acid, flavonoids, phenolics and carotenoids (Anwar *et al.*, 2005; Makkar and Becker, 1996). The high concentrations of ascorbic acid, oestrogenic substances and β-sitosterol [**16**], iron, calcium, phosphorus, copper, vitamins A, B and C, α-tocopherol, riboflavin, nicotinic acid, folic acid, pyridoxine, β-carotene, protein, and in particular essential amino acids such as methionine, cystine, tryptophan and lysine present in *Moringa* leaves and pods make it a virtually ideal dietary supplement (Makkar and Becker, 1996).

The composition of the sterols of *Moringa* seed oil mainly consists of campesterol, stigmasterol, β-sitosterol, Δ^5-avenasterol and clerosterol accompanied by minute amounts of 24-methylenecholesterol, Δ^7-campestanol, stigmastanol and 28-isoavenasterol (Tsaknis *et al.*, 1999; Anwar and Bhanger, 2003; Anwar *et al.*, 2005; Table 2). The sterol composition of the major fractions of *Moringa* seed oil differs greatly from those of most of the conventional edible oils (Rossell, 1991). The fatty acid composition of *M. oleifera* seed oil reveals that it falls in the category of high-oleic oils (C18:1, 67.90%–76.00%). Among the other component fatty acids C16:0 (6.04%–7.80%), C18:0 (4.14%–7.60%), C20:0 (2.76%–4.00%), and C22:0 (5.00%–6.73%) are important (Tsaknis *et al.*, 1999; Anwar and Bhanger, 2003; Anwar *et al.*, 2005). *Moringa oleifera* is also a good source of different tocopherols (α-, γ- and δ-); the concentration of those is reported to be 98.82–134.42, 27.90–93.70, and 48.00–71.16 mg/kg, respectively (Anwar and Bhanger, 2003; Tsaknis *et al.*, 1999).

MEDICINAL USES AND PHARMACOLOGICAL PROPERTIES

Moringa oleifera also has numerous medicinal uses, which have long been recognized in the Ayurvedic and Unani systems of medicine (Mughal *et al.*, 1999). The medicinal attributes (Table 1) and pharmacological activities ascribed to various parts of *Moringa* are detailed below.

Antihypertensive, diuretic and cholesterol lowering activities

The widespread combination of diuretic along with lipid and blood pressure lowering constituents make this plant highly useful in cardiovascular disorders. *Moringa* leaf juice is known to have a stabilizing effect on blood pressure (The Wealth of India, 1962; Dahot, 1988). Nitrile, mustard oil glycosides and thiocarbamate glycosides have been isolated from *Moringa* leaves, which were found to be responsible for the blood pressure lowering effect (Faizi *et al.*, 1994a; 1994b; 1995). Most of these compounds, bearing thiocarbamate, carbamate or nitrile groups, are fully acetylated glycosides, which are very rare in nature (Faizi *et al.*, 1995). Bioassay guided fractionation of the active ethanol extract of *Moringa* leaves led to the isolation of four pure compounds, niazinin A [**1**], niazinin [**1**] B, niazimicin [**4**] and niazinin A + B which showed a blood pressure lowering effect in rats mediated possibly through a calcium antagonist effect (Gilani *et al.*, 1994a).

Another study on the ethanol and aqueous extracts of whole pods and its parts, i.e. coat, pulp and seed revealed that the blood pressure lowering effect of seed was more pronounced with comparable results in both ethanol and water extracts indicating that the activity is widely distributed (Faizi *et al.*, 1998). Activity-directed fractionation of the ethanol extract of pods of *M. oleifera* has led to the isolation of thiocarbamate and isothiocyanate glycosides which are known to be the hypotensive principles (Faizi *et al.*, 1995). Methyl *p*-hydroxybenzoate and β-sitosterol (**14**), investigated in the pods of *M. oleifera* have also shown promising hypotensive activity (Faizi *et al.*, 1998).

Moringa roots, leaves, flowers, gum and the aqueous infusion of seeds have been found to possess diuretic activity (Morton, 1991; Caceres *et al.*, 1992) and such diuretic components are likely to play a complementary

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role in the overall blood pressure lowering effect of this plant.

The crude extract of *Moringa* leaves has a significant cholesterol lowering action in the serum of high fat diet fed rats which might be attributed to the presence of a bioactive phytoconstituent, i.e. β-sitosterol (Ghasi *et al.*, 2000). *Moringa* fruit has been found to lower the serum cholesterol, phospholipids, triglycerides, low density lipoprotein (LDL), very low density lipoprotein (VLDL) cholesterol to phospholipid ratio, atherogenic index lipid and reduced the lipid profile of liver, heart and aorta in hypercholesteremic rabbits and increased the excretion of fecal cholesterol (Mehta *et al.*, 2003).

Antispasmodic, antiulcer and hepatoprotective activities

M. oleifera roots have been reported to possess antispasmodic activity (Caceres *et al.*, 1992). *Moringa* leaves have been extensively studied pharmacologically and it has been found that the ethanol extract and its constituents exhibit antispasmodic effects possibly through calcium channel blockade (Gilani *et al.*, 1992; 1994a; Dangi *et al.*, 2002). The antispasmodic activity of the ethanol extract of *M. oleifera* leaves has been attributed to the presence of 4-[α-(L-rhamnosyloxy) benzyl]-o-methyl thiocarbamate [**3**] (*trans*), which forms the basis for its traditional use in diarrhea (Gilani *et al.*, 1992). Moreover, spasmolytic activity exhibited by different constituents provides pharmacological basis for the traditional uses of this plant in gastrointestinal motility disorder (Gilani *et al.*, 1994a).

The methanol fraction of *M. oleifera* leaf extract showed antiulcerogenic and hepatoprotective effects in rats (Pal *et al.*, 1995a). Aqueous leaf extracts also showed antiulcer effect (Pal *et al.*, 1995a) indicating that the antiulcer component is widely distributed in this plant. *Moringa* roots have also been reported to possess hepatoprotective activity (Ruckmani *et al.*, 1998). The aqueous and alcohol extracts from *Moringa* flowers were also found to have a significant hepatoprotective effect (Ruckmani *et al.*, 1998), which may be due to the presence of quercetin, a well known flavonoid with hepatoprotective activity (Gilani *et al.*, 1997).

Antibacterial and antifungal activities

Moringa roots have antibacterial activity (Rao *et al.*, 1996) and are reported to be rich in antimicrobial agents. These are reported to contain an active antibiotic principle, pterygospermin [**8**], which has powerful antibacterial and fungicidal effects (Ruckmani *et al.*, 1998). A similar compound is found to be responsible for the antibacterial and fungicidal effects of its flowers (Das *et al.*, 1957). The root extract also possesses antimicrobial activity attributed to the presence of 4-α-L-rhamnosyloxy benzyl isothiocyanate [**3**] (Eilert *et al.*, 1981). The aglycone of deoxy-niazimicine (N-benzyl, S-ethyl thioformate) [**7**] isolated from the chloroform fraction of an ethanol extract of the root bark was found to be responsible for the antibacterial and antifungal activities (Nikkon *et al.*, 2003). The bark extract has been shown to possess antifungal activity (Bhatnagar *et al.*, 1961), while the juice from the stem bark showed antibacterial effect against *Staphylococcus aureus* (Mehta *et al.*, 2003). The fresh leaf juice was found to inhibit the growth of microorganisms (*Pseudomonas aeruginosa* and *Staphylococcus aureus*), pathogenic to man (Caceres *et al.*, 1991).

Antitumor and anticancer activities

Makonnen *et al.* (1997) found *Moringa* leaves to be a potential source for antitumor activity. *O*-Ethyl-4-(α-L-rhamnosyloxy)benzyl carbamate [**11**] together with 4(α-L-rhamnosyloxy)-benzyl isothiocyanate [**3**], niazimicin [**4**] and 3-*O*-(6′-*O*-oleoyl-β-D-glucopyranosyl)-β-sitosterol [**15**] have been tested for their potential antitumor promoting activity using an *in vitro* assay which showed significant inhibitory effects on Epstein–Barr virus-early antigen. Niazimicin has been proposed to be a potent chemopreventive agent in chemical carcinogenesis (Guevara *et al.*, 1999). The seed extracts have also been found to be effective on hepatic carcinogen metabolizing enzymes, antioxidant parameters and skin papillomagenesis in mice (Bharali *et al.*, 2003). A seed ointment had a similar effect to neomycin against *Staphylococcus aureus pyodermia* in mice (Caceres and Lopez, 1991).

It has been found that niaziminin [**9 + 10**], a thiocarbamate from the leaves of *M. oleifera*, exhibits inhibition of tumor-promoter-induced Epstein–Barr virus activation. On the other hand, among the isothiocyanates, naturally occurring 4-[(4′-*O*-acetyl-α-i-rhamnosyloxy) benzyl] [**2**], significantly inhibited tumor-promoter-induced Epstein–Barr virus activation, suggesting that the isothiocyano group is a critical structural factor for activity (Murakami *et al.*, 1998).

Other diverse activities

Moringa oleifera has also been reported to exhibit other diverse activities. Aqueous leaf extracts regulate thyroid hormone and can be used to treat hyperthyroidism and exhibit an antioxidant effect (Pal *et al.*, 1995a; 1995b; Tahiliani and Kar, 2000). A methanol extract of *M. oleifera* leaves conferred significant radiation protection to the bone marrow chromosomes in mice (Rao *et al.*, 2001). *Moringa* leaves are effective for the regulation of thyroid hormone status (Tahiliani and Kar, 2000).

A recent report showed that *M. oleifera* leaf may be applicable as a prophylactic or therapeutic anti-HSV (Herpes simplex virus type 1) medicine and may be effective against the acyclovir-resistant variant (Lipipun *et al.*, 2003). Table 1 depicts some common medicinal uses of different parts of this plant. The flowers and leaves also are considered to be of high medicinal value with anthelmintic activity (Bhattacharya *et al.*, 1982). An infusion of leaf juice was shown to reduce glucose levels in rabbits (Makonnen *et al.*, 1997).

Moringa oleifera is coming to the forefront as a result of scientific evidence that *Moringa* is an important source of naturally occurring phytochemicals and this provides a basis for future viable developments. Different parts of *M. oleifera* are also incorporated in various marketed health formulations, such as Rumalaya and

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Septilin (the Himalaya Drug Company, Bangalore, India), Orthoherb (Walter Bushnell Ltd, Mumbai, India), Kupid Fort (Pharma Products Pvt. Ltd, Thayavur, India) and Livospin (Herbals APS Pvt. Ltd, Patna, India), which are reputed as remedies available for a variety of human health disorders (Mehta *et al.*, 2003).

Moringa seeds have specific protein fractions for skin and hair care. Two new active components for the cosmetic industry have been extracted from oil cake. Purisoft® consists of peptides of the *Moringa* seed. It protects the human skin from environmental influences and combats premature skin aging. With dual activity, antipollution and conditioning/strengthening of hair, the *M. oleifera* seed extract is a globally acceptable innovative solution for hair care (Stussi *et al.*, 2002).

WATER PURIFYING ATTRIBUTES OF *M. OLEIFERA* SEED

Moringa seeds as coagulant

Moringa seeds are one of the best natural coagulants discovered so far (Ndabigengesere and Narasiah, 1998). Crushed seeds are a viable replacement of synthetic coagulants (Kalogo *et al.*, 2000). In Sudan, seed crude extract is used instead of alum by rural women to treat the highly turbid Nile water because of a traditional fear of alum causing gastrointestinal disturbances and Alzheimer's disease (Crapper *et al.*, 1973; Miller *et al.*, 1984; Martyn *et al.*, 1989; Muyibi, 1994).

Moringa seeds are very effective for high turbidity water and show similar coagulation effects to alum (Muyibi and Evison, 1995b). The coagulation effectiveness of *M. oleifera* varies depending on the initial turbidity and it has been reported that *M. oleifera* could reduce turbidity by between 92% and 99% (Muyibi and Evison, 1995b). *Moringa* seeds also have softening properties in addition to being a pH correctant (alkalinity reduction), as well as exhibiting a natural buffering capacity, which could handle moderately high to high alkaline surface and ground waters. The *Moringa* seeds can also be used as an antiseptic in the treatment of drinking water (Obioma and Adikwu, 1997).

Ongoing research is attempting to characterize and purify the coagulant components of *Moringa* seeds (Ndabigengesere *et al.*, 1995; Gassenschmidt *et al.*, 1995). It is believed that the seed is an organic natural polymer (Jahn, 1984). The active ingredients are dimeric proteins with a molecular weight of about 1300 Da and an iso-electric point between 10 and 11 (Ndabigengesere *et al.*, 1995). The protein powder is stable and totally soluble in water.

Moringa coagulant protein can be extracted by water or salt solution (commonly NaCl). The amount and effectiveness of the coagulant protein from salt and water extraction methods vary significantly. In crude form, the salt extract shows a better coagulation performance than the corresponding water extract (Okuda *et al.*, 1999). This may be explained by the presence of a higher amount of soluble protein due to the salting-in phenomenon. However, purification of the *M. oleifera* coagulant protein from the crude salt extract may not be technically and economically feasible.

The coagulation mechanism of the *M. oleifera* coagulant protein has been explained in different ways. It has been described as adsorption and charge neutralization (Ndabigengesere *et al.*, 1995; Gassenschmidt *et al.*, 1995) and interparticle bridging (Muyibi and Evison, 1995a). Flocculation by inter-particle bridging is mainly characteristic of high molecular weight polyelectrolytes. Due to the small size of the *M. oleifera* coagulant protein (6.5–13 kDa), a bridging effect may not be considered as the likely coagulation mechanism. The high positive charge (pI above 10) and small size may suggest that the main destabilization mechanism could be adsorption and charge neutralization.

Microbial elimination with *Moringa* seeds

Moringa seeds also possess antimicrobial properties (Olsen, 1987; Madsen *et al.*, 1987). Broin *et al.* (2002) reported that a recombinant protein in the seed is able to flocculate Gram-positive and Gram-negative bacterial cells. In this case, microorganisms can be removed by settling in the same manner as the removal of colloids in properly coagulated and flocculated water (Casey, 1997). On the other hand, the seeds may also act directly upon microorganisms and result in growth inhibition. Antimicrobial peptides are thought to act by disrupting the cell membrane or by inhibiting essential enzymes (Silvestro *et al.*, 2000; Suarez *et al.*, 2003). Sutherland *et al.* (1990) reported that *Moringa* seeds could inhibit the replication of bacteriophages. The antimicrobial effects of the seeds are attributed to the compound 4(α-L-rhamnosyloxy) benzyl isothiocynate (Eilert *et al.*, 1981).

Moringa seeds as biosorbent

Moringa seeds could be used as a less expensive biosorbent for the removal of cadmium (Cd) from aqueous media (Sharma *et al.*, 2006). The aqueous solution of *Moringa* seed is a heterogeneous complex mixture having various functional groups, mainly low molecular weight organic acids (amino acids). These amino acids have been found to constitute a physiologically active group of binding agents, working even at a low concentration, which because of the ability to interact with metal ions is likely to increase the sorption of metal ions (Brostlap and Schuurmans, 1988). The proteineous amino acids have a variety of structurally related pH dependent properties, generating a negatively charged atmosphere and play an important role in the binding of metals (Sharma *et al.*, 2006).

FUTURE PROSPECTS

So far numerous studies have been conducted on different parts of *M. oleifera*, but there is a dire need to isolate and identify new compounds from different parts of the tree, which have possible antitumor promoters as well as inhibitory properties. Although preliminary studies are under way in different laboratories to use the antispasmodic, antiinflammatory, antihypertensive and diuretic activities of *M. oleifera* seed, these studies

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should be extended to humans in view of the edible nature of the plant. *Moringa* roots and leaves have been used traditionally to treat constipation. Studies to verify these claims need to be carried out in the light of the reported antispasmodic activities, which are contrary to its medicinal use as a gut motility stimulant. Earlier studies on the presence of a combination of spasmogenic and spasmolytic constituents in different plants used for constipation (Gilani *et al.*, 2000; 2005a; Bashir *et al.*, 2006) might be of some guidance in designing experiments in which the presence of antispasmodic constituents at higher doses are explained as a possible mode to offset the side-effects usually associated with high dose of laxative therapy. Similarly, the known species differences in the pharmacological actions of medicinal plants (Ghayur *et al.*, 2005; Ghayur and Gilani, 2006) may also be taken into account when planning studies involving contradictory results.

Food plants are considered relatively safe as they are likely to contain synergistic and/or side effect neutralizing combinations of activities (Gilani and Atta-ur-Rahman, 2005). *Moringa oleifera*, known to be rich in multiple medicinally active chemicals, may be a good candidate to see if it contains effect enhancing and/or side-effects neutralizing combinations. Medicinal plants are relatively rich in their contents of calcium channel blockers (CCBs) which are known to possess a wide variety of pharmacological activities such as antihypertensive, hepatoprotective, antiulcer, antiasthmatic, antispasmodic and antidiarroeal (Stephens and Rahwan, 1992; Gilani *et al.*, 1994b; 1999; 2005b; Yaeesh *et al.*, 2006; Ghayur *et al.*, 2006) and it remains to be seen whether such activities reported to be present in *Moringa oleifera* have a direct link with the presence of CCBs.

Niazimicin, a potent antitumor promoter in chemical carcinogenesis is present in the seed; its inhibitory mechanism on tumor proliferation can be investigated by isolating more pure samples. The mechanism of action of *M. oleifera* as prophylactic or therapeutic anti-HSV medicines for the treatment of HSV-1 infection also needs to be examined.

The available information on the α-, β- and γ-tocopherol content in samples of various parts of this edible plant is very limited. β-Carotene and vitamins A and C present in *M. oleifera*, serve as an explanation for their mode of action in the induction of antioxidant profiles, however, the exact mechanism is yet to be elucidated. β-Carotene of *M. oleifera* leaves exerts a more significant protective activity than silymarin against antitubercular induced toxicity. It would be interesting to see if it also possesses hepatoprotective effect against other commonly used hepatotoxic agents such as CCl_4 and galactosamine, which are considered more suitable models and close to human viral hepatitis (Gilani and Janbaz, 1995; Yaeesh *et al.*, 2006).

Although *Moringa* leaves are considered a best protein source, it still has to be shown whether or not this protein source could compete with the more common protein sources in highly productive growing or milk-producing ruminants.

Many studies have also been conducted on the performance of *Moringa* seeds as an alternative coagulant, coagulant aid and in conjunction with alum for treating waste water. Therefore, it is important to identify the active constituents of *Moringa* seed for a better understanding of the coagulation mechanism. Reports on the antimicrobial effects of the protein purified from *M. oleifera* are very rare.

Since this plant naturally occurs in varying habitats, it is naïve to expect a great magnitude of variation in the concentration and composition of chemical ingredients in different parts of the tree. However, the extent to which the chemical composition varies in populations adapted to varying habitats is not known. Thus, detailed studies are required to examine this aspect.

In view of its multiple uses, the *M. oleifera* plant needs to be widely cultivated in most of the areas where climatic conditions favor its optimum growth. In this way, a maximum yield of its different useable parts could be achieved to derive the maximal amount of commodities of a multifarious nature for the welfare of mankind.

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