Available online on www.ijcpr.com
International Journal of Current Pharmaceutical Review and Research; 8(2); 163-183
doi: 10.25258/ijcprr.v8i02.9200
ISSN: 0976 822X

Review Article

Moringa oleifera: A Review on Morphological, Phytochemical and Pharmacological Aspects

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Available Online: 25th April, 2017

ABSRACT

Moringa oleifera is one of the best known, most widely distributed and naturalized species of a monogeneric family *Moringaceae.* Various parts of this plant such as the leaves, roots, seeds, barks, fruits etc. have been found to be immense important because of their pharmaceutical and medicinal applications such as antipyretic, antiepileptic, diuretic, cholesterol lowering, cardiac and circulatory stimulating activities. Various compounds isolated from this plant are being employed for the treatment of different ailments in the indigenous system of medicine. A thorough literature survey reveals that the aqueous, methanolic and ethanolic extracts of roots and barks were found to be effective in preventing various diseases as well as infections. These pharmaceutical and medicinal applications have made their study considerably important in the field of natural product and have prompted the research towards the isolation of such compounds with enhanced pharmacological activity.

Keywords: *Moringa oleifera*, Pharmacological effect, Secondary metabolites.

INTRODUCTION

Moringa oleifera is one of the best known and most widely distributed and naturalized species of a monogeneric family *Moringaceae*[1,2]. It is native of the western and sub-Himalayan tracts, India, Pakistan, Asia Minor, Africa and Arabia[3,4]. It is now distributed in the Philippines, Cambodia, Central America, North and South America and the Caribbean Islands[5]. The roots are acrid, digestive, anthelmentic, constipating, anodyne, bitter alexipharmic stimulant and vesicant. They are useful in paralysis, inflammation, fever, cough, cold, bronchitis, pectoral diseases, epilepsy and hysteria. Its leaves are useful in scurvy, vitiated conditions of kapha and vata. The seeds are acrid, bitter, anti-inflammatory, purgative, and are useful in neuralgia, inflammations and intermittent fevers[6]**.** Various parts of this plant such as the leaves, roots, seeds, barks, fruits, 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[7,8].

Habitat

It is an exceptionally nutritious vegetable tree with a variety of potential uses. The tree itself is rather slender, with drooping branches that grow to approximately 10 m in height. In cultivation, it is often cut back annually to 1 meter or less and allowed to regrow so that pods and leaves remain within arm's reach. 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[6]. The tree ranges in height from 5 to 10 m[5]. 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[9,10].

Taxonomical Classification

Kingdom : *Plantae*
Subkingdom: *Tracheobionta*
Division : *Magnoliophyta*
Class : *Magnoliopsida*
Subclass : *Dilleniidae*
Order : *Capparales*
Family : *Moringaceae*
Genus : *Moringa*
Species : *Moringa oleifera*

Ethnic uses

It is considered one of the world's most useful trees, as almost every part of the *Moringa* tree can be used for food or has some other beneficial property. In the tropics, it is used as forage for livestock, and in many countries, *Moringa* is used as a micronutrient powder to treat diseases including the treatment of inflammation and infectious diseases along with cardiovascular, gastrointestinal, hematological and hepatorenal disorders. The whole plant is used in the treatment of psychosis, eye diseases, fever and as an aphrodisiac[11,12]. A thorough literature survey reveals that the aqueous extracts of roots and barks were found to be effective in preventing

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implantation[13], aqueous extracts of fruits have shown significant anti-inflammatory and hepatoprotective activity[14], methanolic extracts of leaves have shown anti-ulcer activity[15], and ethanolic extracts of seeds exhibited anti-tumour activity[16].

Study of pharmacological effects

Antihypertensive Activity

Moringa oleifera leaves have traditionally been used in Ayurvedic medicine for their antihypertensive activity. Water extract of leaves is efficacious in reducing the chronotropic and inotropic effects on the isolated frog heart. The alkaloids obtained by the fractionation of the water extract of the leaves of *M. oleifera*, converted into their salt form, were tested for their activity on the isolated frog heart. The total alkaloidal salts were found to have a negative inotropic effect on the frog heart[17].

Cholesterol lowering Activity

Potential mechanism of hypocholesterolaemic action of selected plants, namely *Hibiscus sabdariffa*, *Moringa oleifera*, *Cucurbita moschata Duchesne* etc was studied. The potency of extracts from *H. sabdariffa*, *M. oleifera* and *C. moschata* at 100 µg mL(-1) was found to be similar to 0.4 µg mL pravastatin in inhibiting HMG-CoA reductase and possibly reduced cholesterol biosynthesis. This study also demonstrated that several of the tested plants possessed multiple sites of action that were possibly responsible for their cholesterol-lowering effect in the *in vivo* model[18].

Antitumor Activity

Four of the isolated compounds from the seeds of *Moringa oleifera* namely 4(alpha-L-rhamnopyranosyloxy)-benzyl isothiocyanate (2), niazimicin (3), 3-O-(6'-O-oleoyl-beta-D-glucopyranosyl)-beta-sitosterol (7), and beta-sitosterol-3-O-beta-D-glucopyranoside (8), which were obtained in relatively good yields, were tested for their potential antitumor promoting activity using an *in vitro* assay which tested their inhibitory effects on Epstein-Barr virus-early antigen (EBV-EA) activation in Raji cells induced by the tumor promoter, 12-O-tetradecanoyl-phorbol-13-acetate (TPA). All the tested compounds showed inhibitory activity against EBV-EA activation, with compounds 2, 3 and 8 have shown very significant activities. Based on the in vitro results, niazimicin was further subjected to *in vivo* test and found to have potent antitumor promoting activity in the two stage carcinogenesis in mouse skin using 7,12-dimethylbenz(a)anthracene (DMBA) as initiator and TPA as tumor promoter. From these results, niazimicin is proposed to be a potent chemo-preventive agent in chemical carcinogenesis[19].

Three known thiocarbamate (TC) and isothiocyanate (ITC)-related compounds have been isolated from the leaves of *Moringa oleifera*, as inhibitors of tumor promoter teleocidin B-4-induced Epstein-Barr virus (EBV) activation in Raji cells. Interestingly, only niaziminin among 10 TCs including 8 synthetic ones showed considerable inhibition against EBV activation. The structure-activity relationships indicated that the presence of an acetoxy group at the 4'-position of niaziminin is important and indispensable for inhibition. On the other hand, among the ITC-related compounds, naturally occurring 4-[(4'-O-acetyl-alpha-L-rhamnosyloxy)benzyl]ITC and commercially available allyl- and benzyl-ITC significantly inhibited activation, suggesting that the isothiocyano group is a critical structural factor for activity[20].

Antiulcer Activity

To showed protection of gastric ulceration by aqueous leaf extract of *Moringa oleifera*, study was conducted on Adult Holtzman strain albino rats (weight 150-200g) of either sex. Ulceration was induced using aspirin (500 mg/kg body weight) and using *Moringa oleifera* (MO), a herbal formulation, the modulatory mechanism has been studied and compared with a commonly used antagonist of 5-HT(3) receptors, ondansetron by assessing parameters like mean ulcer index, 5-HT content, EC cell count and mucosal thickness. The results of this study suggest that MO showed maximum protective activity at a dose of 300 mg/kg body weight against above mentioned experimental rat ulcer model by modulating 5-HT secretion through EC cell via 5-HT (3) receptors in gastrointestinal tract which has given a glimpse of a therapeutic approach for gastric ulcer management, which may be beneficially used in contrast to the classical antacid, antihistamine or surgical treatment[21].

Hepatoprotective Activity

The hepatoprotective effect of an ethanolic extract of *Moringa oleifera* leaves was studied on liver damage induced by antitubercular drugs such as isoniazid (INH), rifampicin (RMP) and pyrazinamide (PZA) in rats. Oral administration of the extract showed a significant protective action made evident by its effect on the levels of glutamic oxaloacetic transaminase (aspartate aminotransferase), glutamic pyruvic transaminase (alanine aminotransferase), alkaline phosphatase, and bilirubin in the serum; lipids, and lipid peroxidation levels in liver. This observation was supplemented by histopathological examination of liver sections. The results of this study showed that treatment with *M. oleifera* extracts appears to enhance the recovery from hepatic damage induced by antitubercular drugs[22].

Antibacterial Activity

Antibacterial effects of aqueous and ethanolic extracts of seeds of *Moringa oleifera* in the concentration of 1:5 and 1:10 in volumes 50, 100, 150 and 200 µL were examined against *Staphylococcus aureus*, *Vibrio cholerae*, *Escherichia coli* and *Salmonella Enteritidis*. Antibacterial activity (inhibition halo > 13 mm) against *S. aureus*, *V. cholerae* and *E. coli* was detected in aqueous and ethanolic extracts of *Moringa oleifera*. *E. coli* isolated from tilapiafish, *Oreochromis niloticus*, was sensitive to the ethanolic extract of moringa[23].

Antifungal activity

Ethanol extracts of seeds and leaves of *Moringa oleifera* showed antifungal activities *in vitro* against dermatophytes such as *Trichophyton rubrum*, *Trichophyton mentagrophytes*, *Epidermophyton floccosum*, and *Microsporum canis*. Isolated extracts

could be used for the future development of anti-skin disease agents[24].

Antimicrobial property

The chloroform and ethanol extracts of seeds and leaves of *Moringa oleifera* were investigated for antimicrobial activity against some selected food – borne microorganisms as a first step in the screening of the extracts for preliminary sanitizing/preservative properties on food. The results of the phytochemical analysis revealed differences in the presence of the phytochemicals among the extracts. Tannins were detected in *Moringa oleifera* chloroform extract of leaves. The antibacterial assay results show that extract exhibited broad spectrum activity against the test organisms with *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Enterobacter aerogenes* susceptible. The MIC values ranged between 2.0 and >4.0 mg/ml for all the organisms. chloroform extract of *M. oleifera* seed was only active against *E. coli* and *Salmonella typhimurium*. The MIC values ranged between 1.0 and >4.0mg/ml for the tested organisms respectively. Antifungal activity result revealed 100% inhibition in growth of Mucor and *Rhizopus* species by *M. oleifera* seed chloroform extract at concentration of 1mg/ml. Standard Ketoconazole (control) inhibited the test organisms by 100% at 0.5 mg/ml concentration. Results of this study have shown the potentials of *M. oleifera* extracts as sanitizers/preservatives by inhibiting the growth of the test organisms[25].

The antimicrobial activities of *Moringa oleifera* leaves, roots, barks and seeds were investigated *in vitro* against bacteria, yeast, dermatophytes and helminths pathogenic to man. It was demonstrated by a disk-diffusion method that the fresh leaves juice and aqueous extracts from the seeds inhibit the growth of *Pseudomonas aeruginosa* and *Staphylococcus aureus* and that extraction temperatures above 56 ^{0}C inhibited this activity[26].

Bioavailability-enhancing Property

The influence of active fraction isolated from pods of an indigenous plant, *Moringa oleifera* (*MO*) was studied on the pharmacokinetic profile of the orally administered frontline anti-tuberculosis drug rifampicin (20 mg/kg b.w.) in Swiss albino mice. The antibiotic rifampicin alone and in combination with *MO* (0.1 mg/kg b.w.) was administered orally and heparanized blood samples were collected from the orbital plexus of mice for plasma separation at 0, 1, 2, 3, 4 and 5 h, post treatment. Plasma rifampicin concentration, pharmacokinetic parameters and drug metabolizing enzyme (cytochrome P-450) activity were determined. The pharmacokinetic data revealed that *MO*-treated animals had significantly increased rifampicin plasma concentration, C_{max}, K_{el}, $t_{½(a)}$, $t_{½(el)}$, K_a and AUC as well as inhibited rifampicin-induced cytochrome P-450 activity. In conclusion, the result of this study suggested that the bioavailability-enhancing property of *MO* may help to lower the dosage level and shorten the treatment course of rifampicin[27].

Antioxidant Effect

Different parts of *Moringa oleifera* were analyzed for polyphenol content as well as *in vitro* antioxidant potential. The methanol extract of the leaves of *M. oleifera* contained chlorogenic acid, rutin, quercetin glucoside and kaempferol rhamnoglucoside, whereas in the root and stem barks, several procyanidin peaks were detected. With the xanthine oxidase model system, all the extracts exhibited strong *in vitro* antioxidant activity, with 50% inhibitory concentration [IC (50)] values of 16, 30, and 38 µL for the roots, leaves, and stem barks respectively. Similarly, potent radical scavenging capacity was observed when extracts were evaluated with the 2-deoxyguanosine assay model system, with IC(50) values of 40, 58, and 72 µL for methanol extracts of the leaves, stems, and root barks, respectively[28]. All aqueous methanol and aqueous ethanol extracts of leaves were capable of scavenging peroxyl and superoxyl radicals. Similar scavenging activities for different solvent extracts of each collection were found for the stable (DPPH$^{(*)}$) radical. Among the three different *moringa* samples, both methanol and ethanol extracts of Indian origins showed the highest antioxidant activities, 65.1 and 66.8%, respectively, in the beta-carotene-linoleic acid system. Nonetheless, increasing concentration of all the extracts had significantly ($P < 0.05$) increased reducing power, which may in part be responsible for their antioxidant activity. The major bioactive compounds of phenolics were found to be flavonoid groups such as quercetin and kaempferol. Overall, both methanol (80%) and ethanol (70%) were found to be the best solvents for the extraction of antioxidant compounds from moringa leaves[29]. Scavenging activity of *Moringa oleifera* leaves extract on DPPH and the inhibitory effect on Cu $^{(2+)}$-induced low-density lipoprotein (LDL) oxidation were determined in *in vitro* experiment. The effects of the extract on cholesterol levels, conjugated diene (CD) and thiobarbituric acid reactive substances (TBARS) and plaque formations in cholesterol-fed rabbits were investigated. Results suggest that in scavenging DPPH radicals the extract and Trolox had IC(50) of 78.15+/-0.92 and 2.14+/-0.12 µg/ml, respectively. The extract significantly ($P<0.05$) prolonged the lag-time of CD formation and inhibited TBARS formation in both *in vitro* and *ex vivo* experiments in a dose-dependent manner. In hypercholesterol-fed rabbits, at 12 weeks of treatment, it significantly ($P<0.05$) lowered the cholesterol levels and reduced the atherosclerotic plaque formation to about 50 and 86%, respectively[30].

The effects of four extracting solvents [absolute ethanol, absolute methanol, aqueous ethanol (ethanol: water, 80:20 v/v) and aqueous methanol (methanol: water, 80:20 v/v)] and two extraction techniques (shaking and reflux) on the antioxidant activity of root extracts of *Moringa oleifera* was investigated. The tested plant materials contained appreciable amounts of total phenolic contents (0.31-16.5 g GAE /100g DW), total flavonoid (2.63-8.66 g CE/100g DW); reducing power at 10 mg/mL extract concentration (1.36-2.91), DPPH $^{(*)}$ scavenging capacity (37.2-86.6%), and percent inhibition of linoleic acid (66.0-90.6%)[31]. The aqueous extract of leaf (LE), fruit (FE) and seed (SE) of *Moringa oleifera* was assessed to examine the ability to inhibit the oxidative DNA damage,

antioxidant and anti-quorum sensing (QS) potentials. It was found that these extracts could significantly inhibit the $OH^{(*)}$-dependent damage of pUC18 plasmid DNA and also inhibit synergistically with trolox, with an activity sequence of LE > FE > SE. The LE was with comparatively higher total phenolics content (105.04 mg gallic acid equivalents (GAE)/g), total flavonoids content (31.28 mg quercetin equivalents (QE)/g), and ascorbic acid content (106.95 mg/100 g) and showed better antioxidant activity (85.77%), anti-radical power (74.3), reducing power (1.1 ascorbic acid equivalents (ASE)/ml), inhibition of lipid peroxidation, protein oxidation, $OH^{(*)}$-induced deoxyribose degradation, and scavenging power of superoxide anion and nitric oxide radicals than did the FE, SE and standard α-tocopherol. Eventually, LE and FE were found to inhibit violacein production, a QS-regulated behavior in *Chromobacterium violaceum* 12472[32].

Study was carried out to evaluate the effect of *Moringa oleifera* seed extract on liver fibrosis. Liver fibrosis was induced by the oral administration of 20% CCl_4, twice weekly and for 8 weeks. Simultaneously, *M.oleifera* seed extract (1g/kg) was orally administered daily. The biochemical and histological results showed that *Moringa* reduced liver damage as well as symptoms of liver fibrosis. The administration of *Moringa* seed extract decreased the CCl_4-induced elevation of serum aminotransferase activities and globulin level. The elevations of hepatic hydroxyproline content and myeloperoxidase activity were also reduced by *Moringa* treatment. Furthermore, the immunohistochemical study showed that *Moringa* markedly reduced the numbers of smooth muscle alpha-actin-positive cells and the accumulation of collagens

I and III in liver. *Moringa* seed extract showed significant inhibitory effect on DPPH free radical, as well as strong reducing antioxidant power. The activity of superoxide dismutase as well as the content of both malondialdehyde and protein carbonyl, which are oxidative stress markers, were reversed after treatment with *Moringa*. Finally, these results suggested that *Moringa* seed extract can act against CCl_4-induced liver injury and fibrosis in rats by a mechanism related to its antioxidant properties[33]. The antioxidant properties of *Moringa oleifera* leaves against CCl_4-induced oxidative damage in liver slices reveals that CCl_4 treatment significantly decreased the activities of antioxidant enzymes such as superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase, and glutathione- S-transferase and caused decreased glutathione content and increased the thiobarbituric acid-reacting substances (TBARS). Treatment with *Moringa oleifera* extract increased the activities of antioxidant enzymes and glutathione content and reduced the levels of TBARS significantly. Observed reduction in the level of lipid peroxides showed a decreased tendency of peroxidative damage[34].

Cyanobactericidal Activity

Moringa oleifera seeds extract were tested for their effects on growth and Photosystem II efficiency of the common bloom-forming cyanobacterium *Microcystis aeruginosa*. *M. aeruginosa* populations exhibited good growth in controls and treatments with 4- and 8-mg crushed *Moringa* seeds per liter, having similar growth rates of 0.50 (+/-0.01) per day. In exposures of 20- to 160-mg crushed *Moringa* seeds L (-1), growth rates were negative and on average -0.23 (+/-0.05). day (-1). High-density populations of *M. aeruginosa* [chlorophyll-a concentrations of approximately 270 microg L(-1)] were reduced to very low levels within 2 weeks of exposure to >/=80-mg crushed seeds per liter. At the highest dosage of 160 mg L(-1), the Phi(PSII) dropped to zero rapidly and remained nil during the course of the experiment (14 days). This study suggested that *Moringa* seed extracts might have a potential as an effect-oriented measure lessening cyanobacterial nuisance[35].

Immunosuppressive Activity

Study was performed to assess the efficacy of ethanolic extract of *Moringa oleifera* seeds in experimental immune inflammation. Circulatory and splenic leukocyte counts, delayed-type hypersensitivity reactions and humoral antibody responses were measured in mice using SRBC as the antigen. In addition, macrophage phagocytosis was measured by the carbon clearance test.

The extract dose-dependently (50, 100 and 200 mg/kg) inhibited spleen weight as well as circulatory leukocyte and splenocyte counts. The delayed-type hypersensitivity reaction was significantly inhibited ($P<0.01$) by decreasing the mean foot pad thickness at 48 h. The production of the humoral antibody titer was significantly ameliorated at a dose of 100 and 200mg/kg ($P<0.05$ and $P<0.01$, respectively). Furthermore, the extract caused a down-regulation of macrophage phagocytosis due to carbon particles. Taken together, the above findings suggest that the seeds of *Moringa oleifera* have immunosuppressive activity[36].

Hemagglutinating and Larvicidal Activity

Moringa oleifera seeds contain a water-soluble lectin (WSMoL). The effect of *M. oleifera* seed extracts (MoE(1-15)) and WSMoL on development of *A. aegypti* larvae. WSMoL peptide from in-gel trypsin digestion is also described. MoE(1-15) showed hemagglutinating activity and WSMoL had similarity with flocculating proteins from *M. oleifera* seeds. MoE(1) and MoE(3) delayed larval development which stopped in the third instar (L3) in MoE(6) and MoE (15). Significant ($p<0.0001$) larval mortality was only detected in MoE(15). Native WSMoL showed larvicidal activity [LC(50) 0.197 mg mL(-1)] and heated lectin, without hemagglutinating activity, did not kill fourth instar (L4) larvae. Optical microscopy showed that live L4 from MoE(1) presented underlying epithelium, increased gut lumen and hypertrophic segments; dead L4 from WSMoL were absent of underlying epithelium, had increased gut lumen and hypertrophic segments. The presence of hemagglutinating activity in the extracts suggest that soluble lectin promotes the delay of larval development[37].

Biological effects of the water extract of *Moringa oleifera* seeds (WEMOS) were assessed on eggs and 3rd instar larvae of *Aedes aegypti* and on its toxicity upon

laboratory animals (Daphnia magna, mice and rats). Crude WEMOS showed a LC50 value of 1260 µg/mL, causing 99.2 +/- 2.9% larvae mortality within 24 h at 5200 µg/mL, though this larvicidal activity has been lost completely at 80 masculine C/10 min. WEMOS did not demonstrate capacity to prevent egg hatching. After extensive dialyses of the crude WEMOS into water soluble dialyzable (DF) and non dyalizable (NDF) fractions, only DF maintained its efficacy to kill larvae. Acute toxicity evaluations on daphnids (EC50 of 188.7 µg/mL) and mice (LD50 of 446.5 mg/kg body weight) pointed out to low toxicity. In conclusion, WEMOS has thermostable bioactive compounds against *Aedes aegypti* larvae with apparent molecular mass lower than 12 kDa and moderately toxic potential[38].

Anti-inflammatory Activity

The effect of ethanolic extract of seeds of *Moringa oleifera* (MOEE) on the potential prevention of immune-mediated inflammatory responses in toluene diisocyanate (TDI as antigen)-induced asthma in Wistar rats. Rats were divided into five different group (n = 8/group): Group-I = unsensitized control; Group-II = TDI control/vehicle; Group-III = dexamethasone (DXM) 2.5 mg/kg and Groups IV and V = 100 mg/kg and 200 mg/kg body weight [BW] of MOEE, respectively. All rats (except unsensitized controls) were sensitized by intranasal application of 10% TDI to induce airway hypersensitivity. Animals in Groups II-V were given their respective drug treatment per os from 1 wk prior to initiation of sensitization until the day of final provocation with 5% TDI. After this last challenge, all rats were examined for hyper reactivity symptoms and then sacrificed to determine their total and differential leucocytes in blood and bronchoalveolar (BAL) fluid and levels of TNF proportional, variant, IL-4, IL-6 in their BAL and serum. The results suggest that asthmatic symptoms were found in TDI control rats only, while both MOEE- and DXM-treated rats did not manifest any airway abnormality. In MOEE- and DXM-treated rats, neutrophil and eosinophil levels in the blood were decreased significantly; levels of total cells and each different cell in their BAL fluid were markedly decreased as compared to those in TDI controls. TNF α, IL-4 and IL-6 were predominant in serum as well as in BAL fluids in TDI controls, but these levels were reduced significantly by MOEE treatment[39].

Moringa oleifera is used in folk medicine for the treatment of rheumatic and articulary pain. An anti-inflammatory action of an aqueous extract of root in rats with weight between 120 and 160 g. We administered per os either distilled water (control group), the aqueous root extract (750 mg/kg or 1000 mg/kg) or in domethacin (10 mg/kg) 30 min before an oedema was induced in the rat-paw by subcutaneous injection of carrageenin. The rat-paw volume was measured 1, 3 and 5 hours after injection of carrageenin. At a dose of 750 mg/kg the *Moringa oleifera* treatment significantly inhibited the development of oedema at 1, 3 and 5 hours (reduction by 53.5, 44.6 and 51.1% respectively). Increasing the dose of *Moringa oleifera* to 1000 mg/kg did not increase the inhibitory effect on oedema development at 1 and 3 hours, whereas this dose potentiated the oedema at 5 hours. Treatment with in domethacin significantly inhibited the development of oedema 1, 3 and 5 hours (49.1, 82.1 and 46.9% respectively). These findings indicate that an aqueous root extract of Moringa oleifera at 750 mg/kg reduces the carrageenin induced oedema to similar extent as the potent anti-inflammatory drug in domethacin[40].

Antiarthritic Property

Anti-arthritic activity of ethanolic extract of seeds of *Moringa oleifera* (MOEE) in adjuvant-induced arthritis in adult female Wistar rats was studied. During the experimental period, body weight, pawedema volume (primary lesion) and arthritic index (secondary lesion) was observed. On the 21st day, serum from each animal was used for estimation of Rheumatoid Factor (RF) value and levels of selected cytokines (TNF α, IL-1, and IL-6). Whole blood was used for measurement of erythrocyte sedimentation rate (ESR). Liver homogenate was utilized for assessment of oxidative stress and histopathology was performed to measure degree of inflammation in synovial joint. Results suggest that, percentage reduction in body weight was less, paw edema volume and arthritic index score was decreased significantly as compared to diseased control animals. Serum levels of RF, TNF-α, IL-1, and IL-6 also showed decreased levels as compared to those in the diseased control group. Histopathological observations showed mild or less infiltration of lymphocytes, angiogenesis and synovial lining thickening. From all above results and observations, it can be concluded that *Moringa oleifera* possesses promising antiarthritic property[41].

Coagulation Activity

Use of extracts from *Moringa oleifera* (MO) is of great interest for low-cost water treatment. The coagulant from both extracts is a cationic protein with pI greater than 9.6 and molecular mass less than 6.5 kDa. Mass spectrometric analysis of the purified water extract indicated that it contained at least four homologous proteins, based on MS/MS peptide sequence data. The protein is thermoresistant and remained active after 5h heat treatment at 95^0C. The coagulant protein showed both flocculating and antibacterial effects of 1.1-1.4 log reduction. With samples of high turbidity, the MO extract showed similar coagulation activity as alum. Cecropin A and MO extract were found to have similar flocculation effects for clay and microorganisms[42].

Wound healing Property

Aqueous extract of leaves of *M. oleifera* was rationalised for its wound healing activity. The aqueous extract was studied at dose level of 300 mg/kg body weight using resutured incision; excision and dead space wound models in rats. Significant increase in wound closure rate, skin-breaking strength, granuloma breaking strength, hydroxyproline content, granuloma dry weight and decrease in scar area was observed. The prohealing actions seem to be due to increased collagen deposition as well as better alignment and maturation. From the results,

it may be concluded that the aqueous extract of *M. oleifera* has significant wound healing property[43].

Antiurolithiatic Activity

The effect of oral administration of aqueous and alcoholic extract of *Moringa oleifera* root-wood on calcium oxalate urolithiasis has been studied in male Wistar albino rats. Ethylene glycol feeding resulted in hyperoxaluria as well as increased renal excretion of calcium and phosphate. Supplementation with aqueous and alcoholic extract of *Moringa oleifera* root-wood significantly reduced the elevated urinary oxalate, showing a regulatory action on endogenous oxalate synthesis. The increased deposition of stone forming constituents in the kidneys of calculogenic rats was also significantly lowered by curative and preventive treatment using aqueous and alcoholic extracts. The results indicate that the root-wood of *Moringa oleifera* is endowed with antiurolithiatic activity[44].

Reduced Locomotor Activity

Effect of chronic treatment of standardized aqueous extract of *Moringa oleifera* (MO) root (100, 200, 300, 350, 400, 450 mg/kg; po) on penicillin (PCN) induced convulsion, locomotor behaviour, brain serotonin (5-HTT), dopamine (DA) and norepinephrine (NE) level was studied in Holtzman strain adult albino rats. The results revealed that pretreatment with MO inhibited PCN-induced seizure and markedly reduced locomotor activity. Chronic treatment with MO significantly increased the 5-HT and decreased the DA level in cerebral cortex (CC), midbrain (MB), caudate nucleus (CN) and cerebellum (CB). NE level was significantly decreased in CC but no appreciable change was observed in MB, CB and CN. Thus, the central inhibitory effect of MO is discussed in the light of the disturbed balance between 5-HT, DA and NE[45].

Hypoglycaemic Activity

In all the experiments with dried 95% ethanolic extracts of *Moringa oleifera*, definite blood glucose lowering effect within 2 weeks have been confirmed in alloxan diabetic albino rats. Blood glucose values are brought down close to normal fasting level using herbal samples *M. oleifera* at a dose of 250 mg/kg once, twice or thrice daily, as needed. While evaluating comparative hypoglycaemic activity of the experimental herbal samples, significant blood glucose lowering activities are observed[46].

Flocculent Activity

Seeds of the tropical tree *Moringa oleifera* contain small storage proteins able to flocculate particles in suspension in water. The cDNA encoding one of these flocculent proteins MO was cloned and the recombinant protein was expressed in *Escherichia coli*. The flocculent activity of the purified recombinant MO was assayed on clays and bacteria using light and confocal microscopy and GFP-overexpressing bacteria. MO is able to aggregate montmorillonite clay particles as well as gram-positive and gram-negative bacteria[47].

A flocculating protein from the seeds of *Moringa oleifera* was isolated by extraction with phosphate buffer followed by cation exchange chromatography. The molecular mass of the protein determined by SDS-PAGE was about 6.5 kDa, the isoelectric point was above pH 10. Amino acid analysis and sequencing showed high contents of glutamine, arginine and proline and a total of 60 residues. The flocculant capacity, determined in glass powder suspension, is comparable to that of a cationic polymer on polyacrylamide basis. Flocculation activity may be explained by the patch charge mechanism due to low molecular weight and high charge density[48].

Radioprotective Property

Radioprotective property of *Moringa oleifera* leaves was investigated in healthy adult Swiss albino mice. Animals were injected (ip) with 150 mg/kg body weight of 50% methanolic extract (ME) of *M. oleifera* leaves, as a single dose, or in 5 daily fractions of 30 mg/kg each, and exposed to whole body gamma irradiation (RT, 4 Gy) 1 hr later. Five animals from each group were sacrificed at 1, 2 and 7 days after treatment. Bone marrow protection was studied by scoring aberrations in metaphase chromosomes and micronucleus induction in polychromatic erythrocytes and normochromatic erythrocytes. Pretreatment with a single dose of 150 mg/kg ME significantly reduced the percent aberrant cells to 2/3rd that of RT alone group on day 1 and brought the values to normal range by day 7 post-irradiation. A similar effect was also seen for the micronucleated cells. Fractionated administration of ME (30 mg/kg x 5) gave a higher protection than that given by the same dose administered as a single treatment. These results demonstrate that pretreatment with the methanolic leaf extract of *M. oleifera* confers significant radiation protection to the bone marrow chromosomes in mice and this may lead to the higher 30 day survival after lethal whole body irradiation[49].

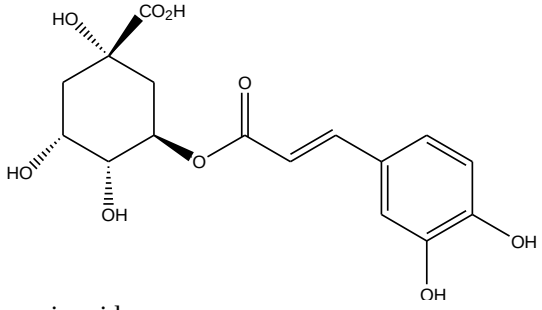
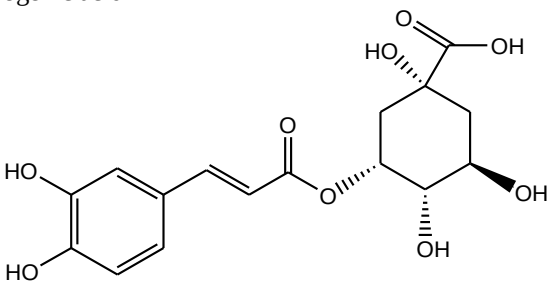
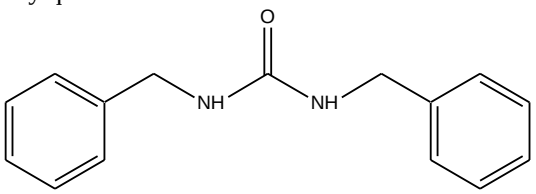
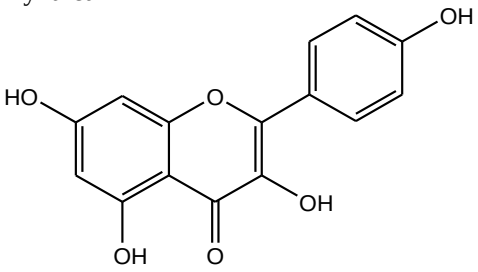
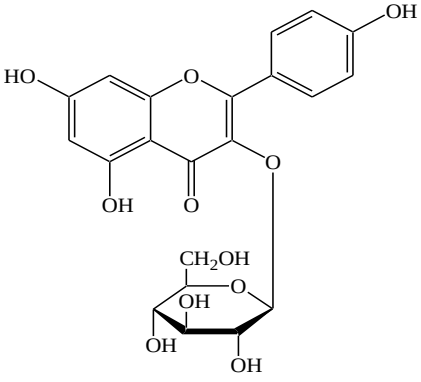
Hypocholesterolemic Activity

It was found that administration of the crude leaf extract of *Moringa oleifera* along with high-fat diet decreased the high-fat diet-induced increases in serum, liver, and kidney cholesterol levels by 14.35% (115-103.2 mg/100 ml of serum), 6.40% (9.4-8.8 mg/g wet weight) and 11.09% (1.09-0.97 mg/g wet weight) respectively. The effect on the serum cholesterol was statistically significant. No significant effect on serum total protein was observed. However, the crude extract increased serum albumin by 15.22% (46-53 g/l). This value was also found to be statistically significant. It was concluded that the leaves of *Moringa oleifera* have definite hypocholesterolemic activity[50].

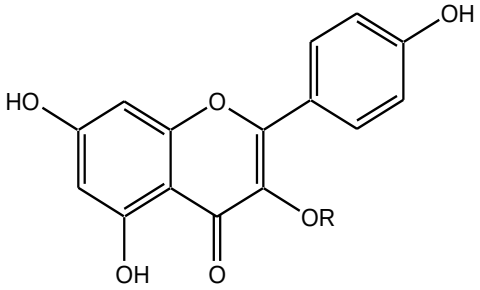
Hypotensive Activity

Hypotensive activity of the ethanolic and aqueous extracts of *Moringa oleifera* whole pods and their parts namely, coat, pulp and seed was investigated. The activity of the ethanolic extract of both the pods and the seeds was equivalent at the dose of 30 mg/kg. The ethyl acetate phase of the ethanolic extract of pods was found to be the most potent fraction at the same dose. Its bioassay-directed fractionation led to the isolation of thiocarbamate and isothiocyanate glycosides which were also the hypotensive principles of the pods as observed in case of Moringa leaves. The methyl p-hydroxybenzoate,

Table 1: Secondry metabolites obtained from the different parts of *Moringa oleifera*

Structure	Parts of plant	Biological Activity	Ref.
 Chlorogenic acid	Leaves, Fruits, Seeds	Antioxidant	[27]
 5-Caffeoylquinic acid	Leaves		[56]
 1,3-Dibenzyl urea	Roots	Analgesic activity	[57]
 Kaempferol	Leaves, Fruits, Seeds		[58]
	Leaves		[56]

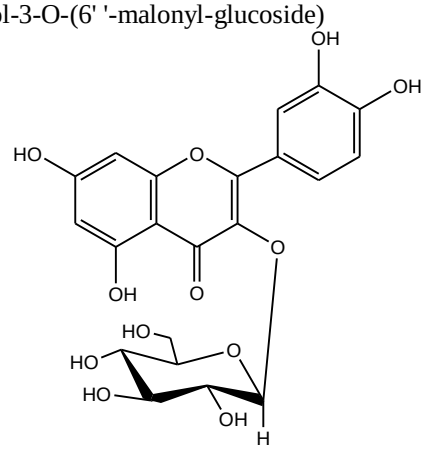
Kaempferol-3-O-glucoside



Leaves [56]

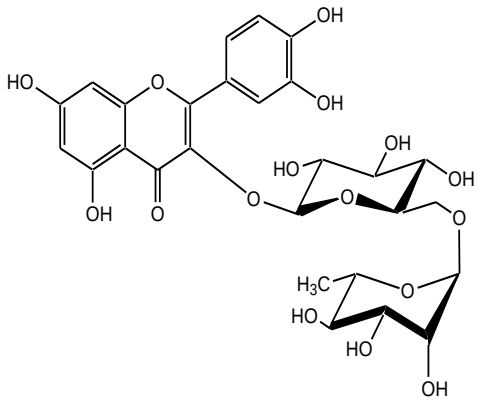
R = Glc-6’’-O-CO-CH_2-COOH

Kaempferol-3-O-(6' '-malonyl-glucoside)



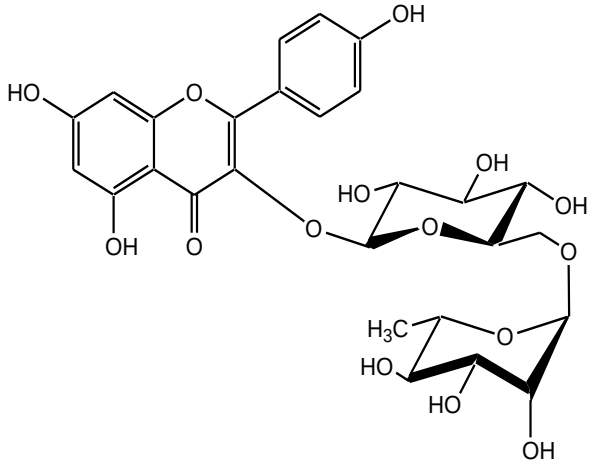
Leaves [58]

Kaempferol 3-O-α-rhamnoside



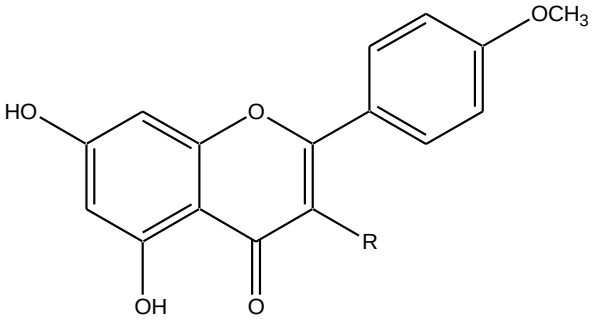
Leaves Antioxidant [27] [58]

Quercetin-3-O-rhamnosylglucoside (Rutin)



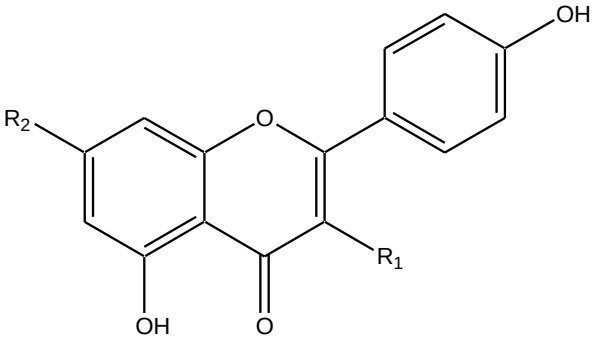
Leaves Antioxidant [27]

Kaempferol rhamnoglucoside



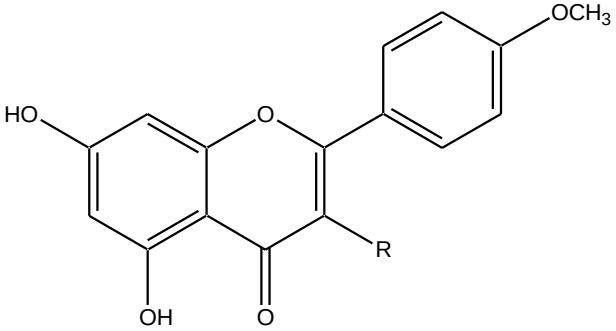
Leaves [58]

R= O-2”,3”-diacetylglucoside
Kaempferide 3-O-(2",3"-diacetylglucoside)



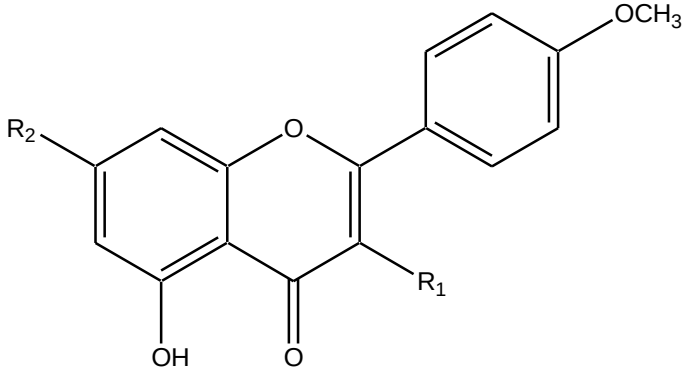
Leaves [58]

R_1= O-[Glucosyl-(1’’’-2’’)-rhamnosyl(1’’’-6’’)]-glucoside
R_2 = O-rhamnose
Kaempferide 3-O-(2"-O-galloylrhamnoside)



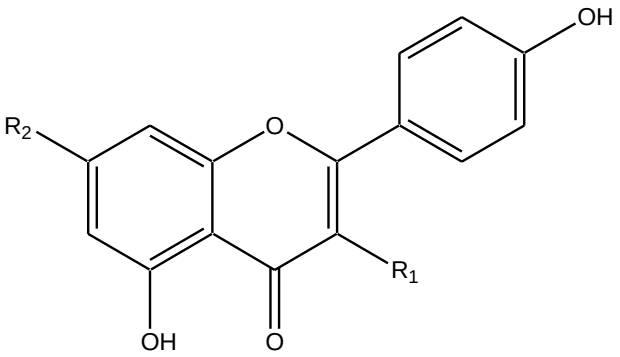
Leaves [58]

R= O-(2’’-galloylrhamnoside)
Kaempferide3-O-(2"-O-galloylrutinoside)-7-O-alpha-rhamnoside



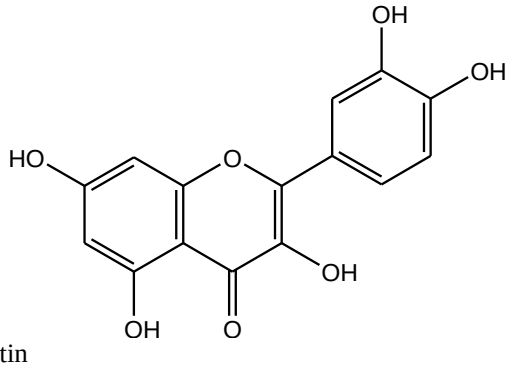
Leaves [58]

R_1= O-(2’’-galloylrutinoside)
R_2 = O-rhamnose
Kaempferol 3-O-[β-glucosyl-(1 --> 2)]-[α-rhamnosyl-(1 --> 6)]-β-glucoside-7-O-α-rhamnoside



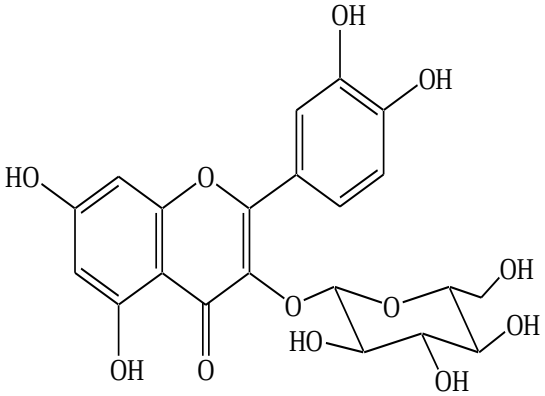
Leaves [58]

R_1=O-[Rhamnosyl-(1’’’-2’’)]-rhamnosyl(1’’’-4’’) glucoside
R_2 = O-rhamnose
Kaempferol 3-O-[α-rhamnosyl-(1 --> 2)]-[α-rhamnosyl-(1 --> 4)]-β-glucoside-7-O-α-rhamnoside



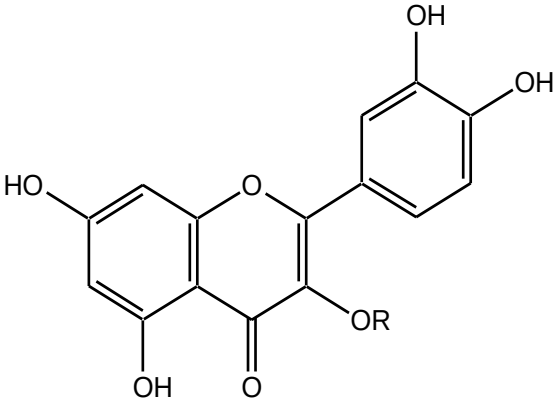
Leaves, Fruits, Seeds — Antioxidant — [31]

Quercetin



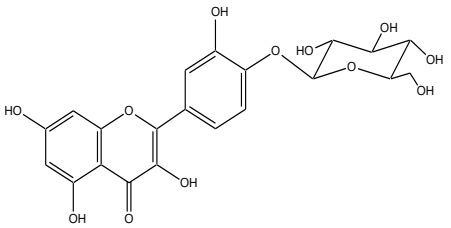
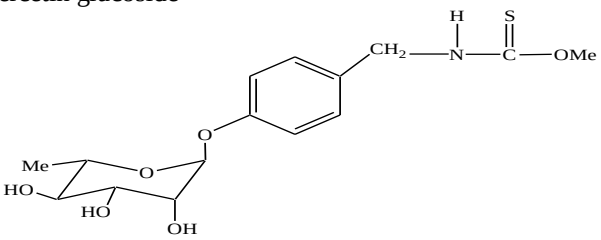
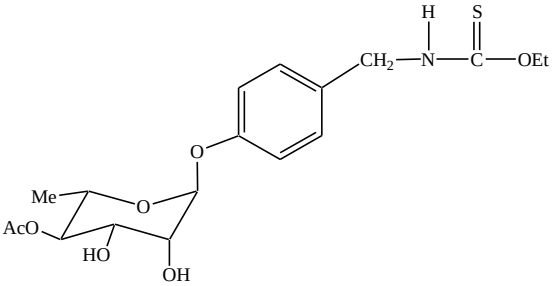
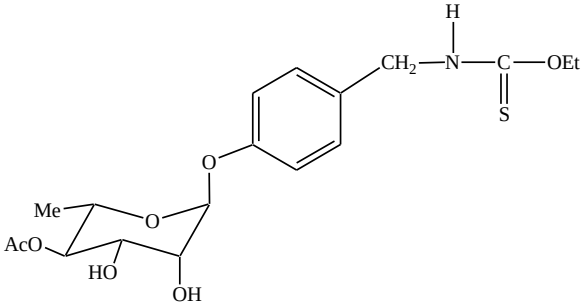
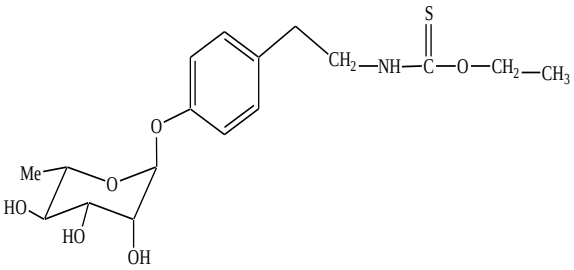
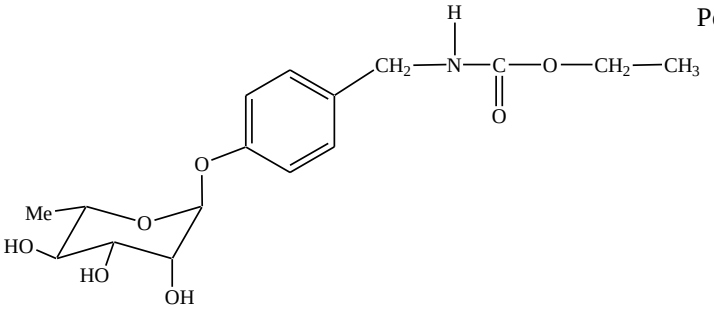
Leaves [56] [58]

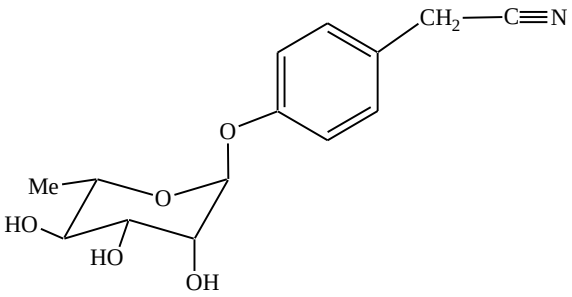
Quercetin 3-O-β-glucoside



Leaves [56]

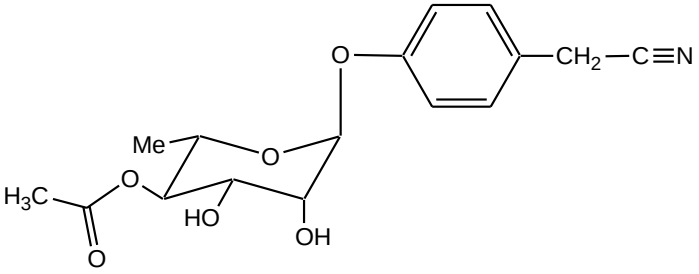
R= Gly-6’’-O-CO-CH_2-COOH
Quercetin-3-O-(6' '-malonyl-glucoside)

 Quercetin glucoside	Leaves	Antioxidant	[27]
 Niazinin A	Stem barks		[59]
 Niaziminin A	Leaves	Hypotensive activity	[51] [59] [60]
 Niaziminin B	Leaves	Hypotensive activity	[51] [59] [60]
 Niazimicin	Seeds	Antitumor	[19]
 O-ethyl-4-[(alpha-L-rhamnosyloxy)-benzyl] carbamate	Pods	Hypotensive activity	[59] [60]



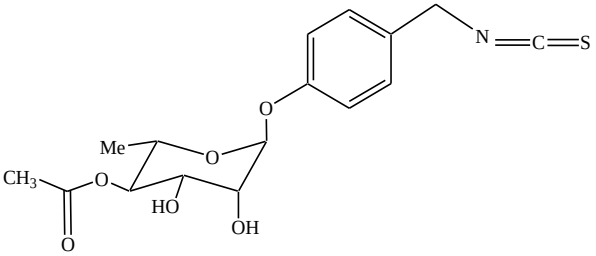
Leaves, Roasted seeds	Mutagenic activity Hypotensive activity	[54] [60]

Niazirin
4(alpha-L-rhamnosyloxy)phenylacetonitrile



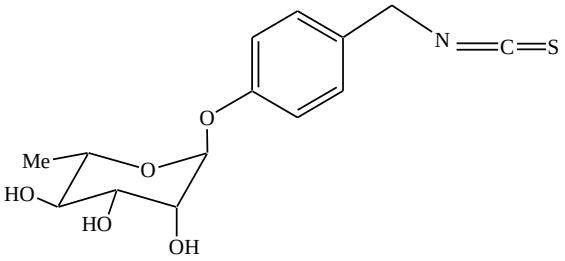
Leaves		[60]

Niazirinin



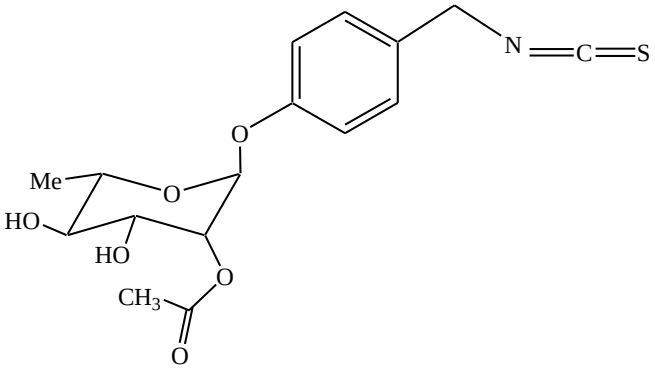
Leaves	Antitumor, Hypotensive activity	[20] [60]

4-(4′-O-acetyl-α-L-rhamnopyranosyloxy)benzyl isothiocyanate



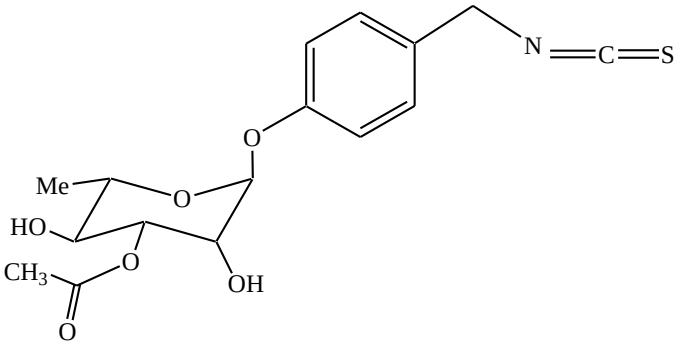
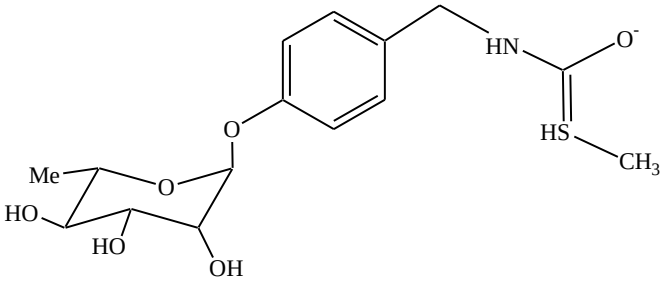
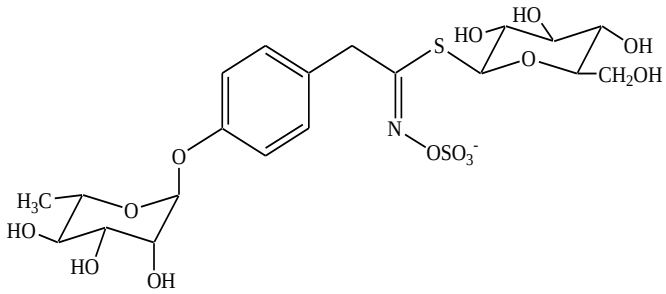
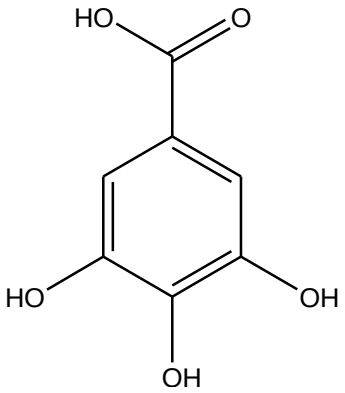
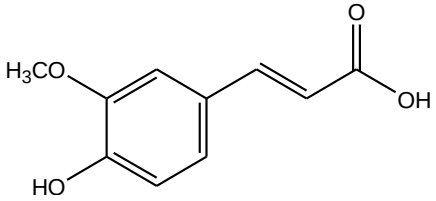
Seeds, Leaves	Antitumor	[19] [20]

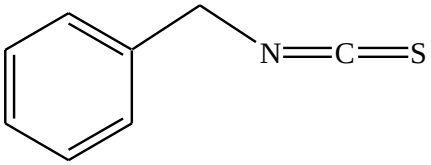
4-(α-L-rhamnopyranosyloxy)benzyl isothiocyanate



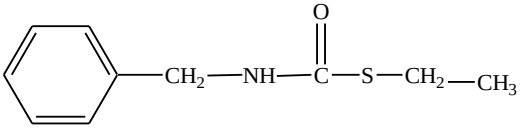
Leaves, Fruits	Antitumor, Anti-inflammatory	[20] [61]

4-[(2'-O-acetyl-alpha-L-rhamnosyloxy) benzyl]isothiocyanate

 4-[(3'-O-acetyl-alpha-l-rhamnosyloxy)benzyl]isothiocyanate	Fruits	Anti-inflammatory	[61]
 S-methyl-N-{4-[(α-L-rhamnosyloxy)benzyl]}thiocarbamate	Fruits	Anti-inflammatory	[61]
 4-(α-L-rhamnopyranosyloxy)benzyl glucosinolate	Leaves		[53]
 Gallic acid	Leaves, Fruits, Seeds	Antioxidant	[31] [58]
Ferulic  acid	Leaves, Fruits, Seeds		[31]
	Seeds		[59]

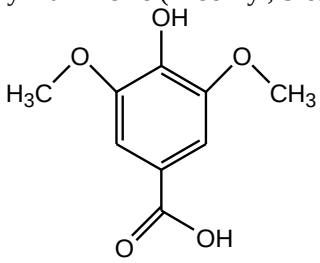


Benzyl isothiocyanate



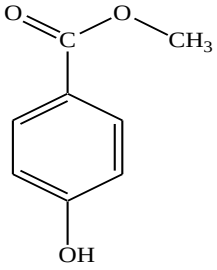
Seeds [59]

Aglycon of deoxy-niazimicine (N-benzyl, S-ethylthioformate)



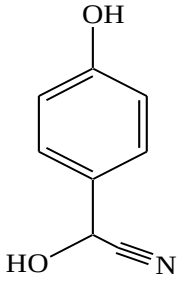
Leaves [58]

Syringic acid



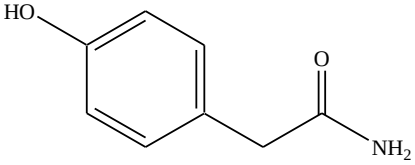
Pods Hypotensive activity [60]

Methyl p-hydroxybenzoate



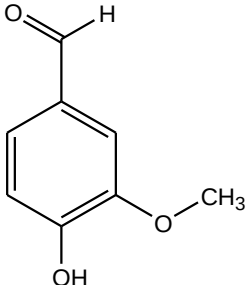
Roasted seeds [54]

Hydroxyphenylacetontrile



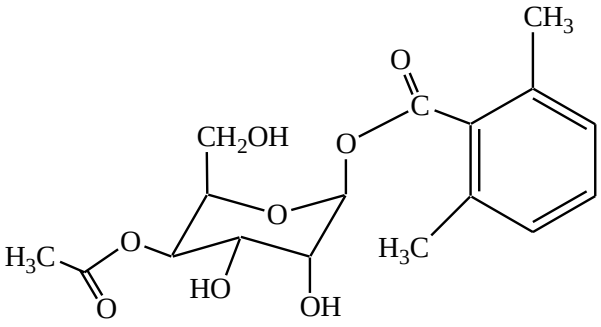
Roasted seeds [54]

Hydroxyphenyl-acetamide



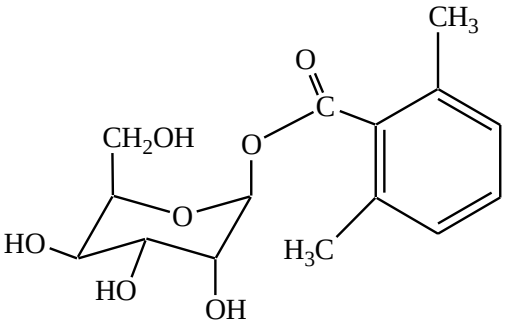
Leaves, Fruits, Seeds [31]

Vanillin



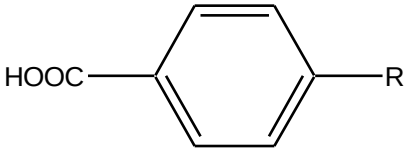
[59]

Moringinine



Seeds [59] [62]

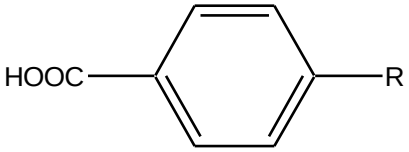
Moringyne



Leaves [58]

R = *O*- Glucose

Benzoic acid 4-O-beta-glucoside

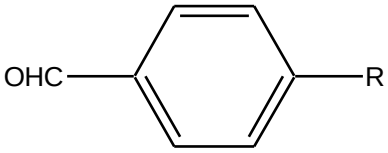


Leaves [58]

R=O-

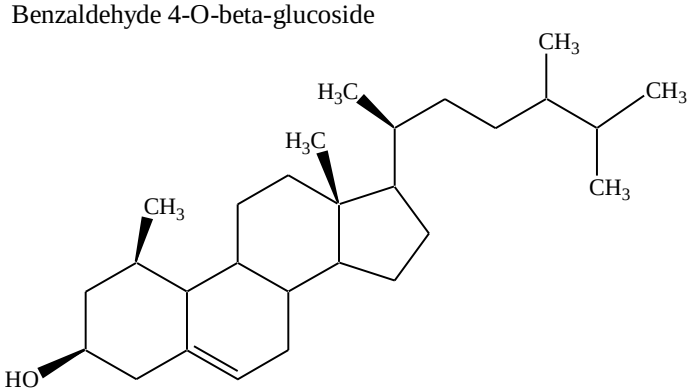
Rhamnosyl-(1″→2′)-glucose

Benzoic acid4-O-alpha-rhamnosyl-(1 --> 2)-beta-glucoside



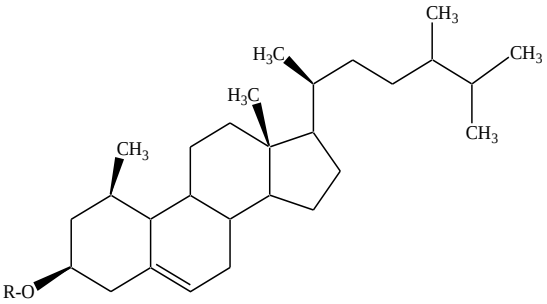
R_2 = *O*- Glucose Leaves [58]

Benzaldehyde 4-O-beta-glucoside



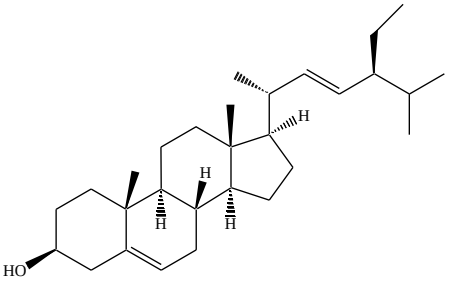
Stems Hypotensive activity [51] [59]

β-Sitosterol



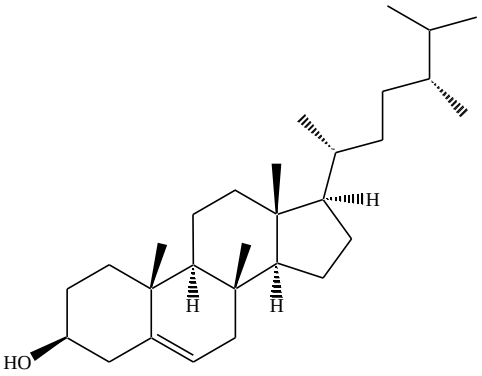
Seeds | Antitumor | [19] [59]

R = 6’-O-oleoyl-β-D-glucopyranosyl
3-O-(6'-O-oleoyl-β-D-glucopyranosyl)-β-sitosterol



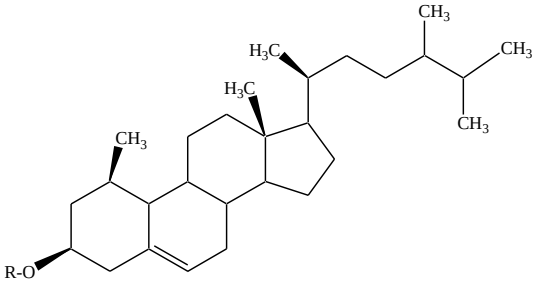
Seeds | [63]

Stigmasterol



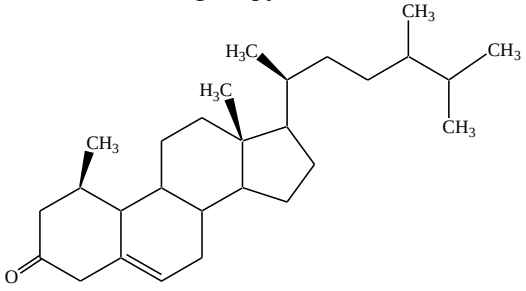
Seeds | [63]

Campesterol



Seeds | Antitumor | [19] [59]

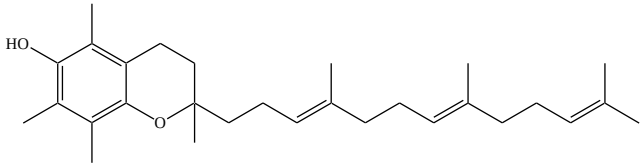
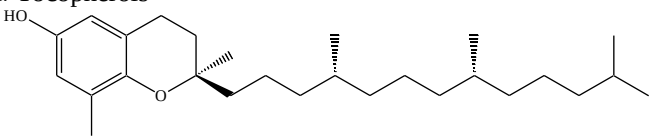
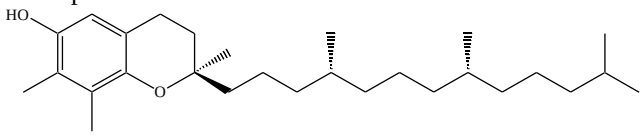
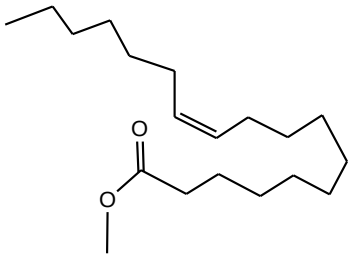
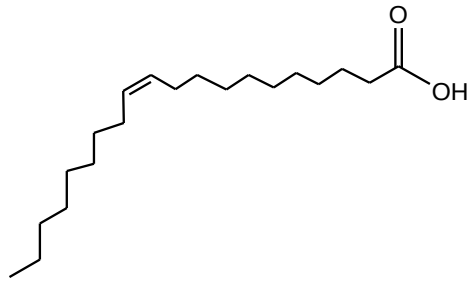
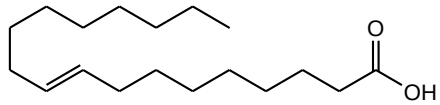
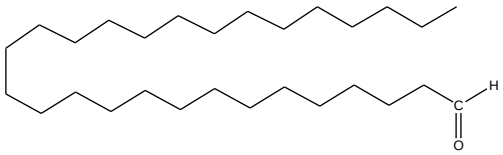
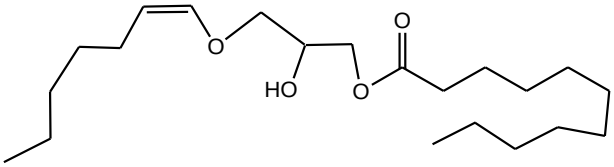
R = β-D- glucopyranosyl
β-Sitosterol-3-O-beta-D-glucopyranoside

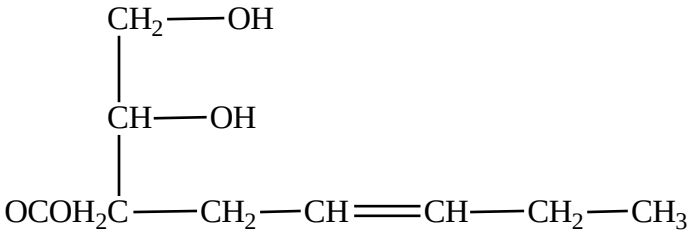
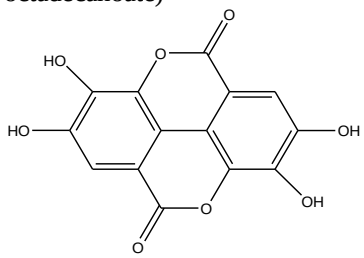
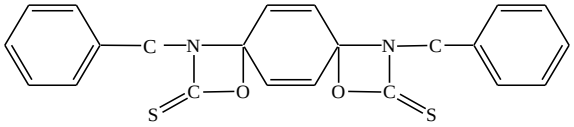
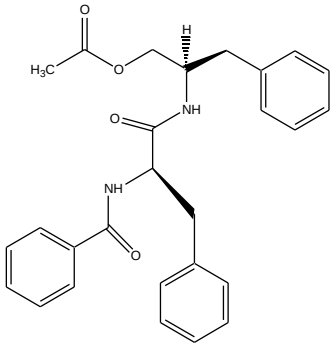
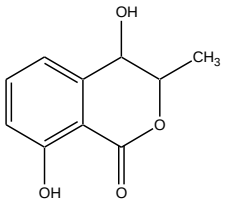


Stem | [60]

β-

Sitostenone,

 α-Tocopherols	Seeds		[63]
 δ- Tocopherols	Seeds		[63]
 γ- Tocopherols	Seeds		[63]
 Cis-11-octadecenoic acid (Vaccenic acid)	Seeds		[56]
 Cis-11-eicosenoic acids	Seeds		[56]
 Cis-9-octadecenoic acid	Seeds		[56]
 Octacosanoic acid	Stem		[60]
 O-[2'-hydroxy-3'-(2"-heptenyloxy)]-propyl undecanoate	Pods	Hypotensive activity	[60]

 Glycerol-1-(9-octadecanoate)		Seeds	[59]
Ellagic acid		Leaves, Fruits, Seeds	[31]
Pterygospermin			[59]
Aurantiamide acetate		Roots	[57]
4-Hydroxymellein		Stem	[60]

beta-sitosterol and p-hydroxybenzaldehyde showed promising hypotensive activity[51]. Isothiocyanate 4 and the thiocarbamate glycosides niaziminin A and B from EtOH extract of *Moringa oleifera* leaves showed hypotensive activity while nitrile glycosides 1 and 2 were found to be inactive in this regard[52].

Glycosides, isolated from the leaves of *Moringa oleifera*, employing a bioassay-directed isolation method on the ethanolic extract. Most of these compounds, bearing thiocarbamate, carbamate or nitrile groups, are fully acetylated glycosides, which are very rare in nature. Thiocarbamates showed hypotensive activity[53].

Antispasmodic and Diuretic Activity

Hot water infusions of flowers, leaves, roots, seeds and stalks or bark of *Moringa oleifera* were screened to detect three pharmacologic activities in experimental models in rats. The antispasmodic activity was demonstrated using isolated duodenum, oral anti-inflammatory activity by carrageenan-induced hindpaw edema and oral diuretic activity by urine output in metabolic cages. The seed infusion showed a significant inhibition of acetylcholine-induced contraction with an ED50 of 65.6 mg/ml bath concentration, inhibition of carrageenan-induced edema at 1000 mg/kg and diuretic activity at 1000 mg/kg. Some activity was also demonstrated in the roots[54].

Mutagenic Activity

The micronucleus test, an *in vivo* method, using albino mice as the test system, was used for monitoring the mutagenicity of the isolated compounds from the roasted seeds of *Moringa oleifera*. Structure-activity correlation studies showed that 4(alpha-L-rhamnosyloxy)phenylacetonitrile, 4-hydroxyphenylacetontrile, and 4-hydroxyphenyl-acetamide exhibited mutagenic activity[55].

Figure 1: Flowers and pods of *M. oleifera*

Figure 2: Stems and pods of *M. oleifera*

Antifertility Effect

An aqueous extract of *Moringa oleifera* roots was investigated for its estrogenic, anti-estrogenic, progestational and antiprogestational activities. Oral administration of extract progressively increased the uterine wet weight of bilaterally ovariectomized rats. This estrogenic activity was supported by stimulation of uterine histo-architecture. When the extract was given conjointly with estradiol dipropionate (EDP), there was a successive reduction in the uterine wet weight when compared to the gain with EDP alone and uterine histological structures were also inhibited. In the deciduoma test, the highest dose of 600 mg/kg interfered with the formation of deciduoma in 50% of the rats, showing some antiprogestational activity. Doses up to 600 mg/kg of the extract orally failed to induce a decidual response in the traumatized uterus of ovariectomized rats. The antifertility effect of the extract appears to be due to multiple attributes[56].

CONCLUSION

Over the past two decades, many reports have appeared in scientific journals describing *Moringa oleifera* nutritional and medicinal properties. It is reported to contain alkaloids, flavonoids, anthocyanins, proanthocyanidins and cinnamates and is highly reputed in folklore and traditional system of medicine as a remedy for variety of ailments. In addition to its compelling water purifying powers and high nutritional value, the notable medicinal uses of various parts of this plant reported are as antitumor, antipyretic, antiepileptic, antiinflammatory, antiulcer, antispasmodic, diuretic, and many more. This review presents a detailed survey of the literature on pharmacognosy, phytochemistry, traditional and biologically evaluated medicinal uses of *Moringa oleifera*.

ACKNOWLEDGEMENT

Authors are thankful to Head, Department of Chemistry, University of Rajasthan, Jaipur for providing laboratory facilities.

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