REVEIW ARTICLE

Scientific Basis of Ethno-pharmacological Claims of *Moringa Oleifera* Lam.

Md. Niyaz Alam[1]*, Rahul Kaushik[2], Md. Sarfaraj Hussain[3], Lubhan Singh[4], Najam A. Khan[1]

[1]*Faculty of Pharmacy, IFTM University, Moradabad, Uttar Pradesh, India*
[2]*Faculty of Pharmacy, Ram-Eesh Institute of Vocational and Technical Education, Greater Noida, Gautam Budh Nagar, Uttar Pradesh, India*
[3]*Lord Buddha Koshi Pharmacy College, Saharsa, Bihar, India*
[4]*Kharvel Subharti College of Pharmacy, Subharti University, Meerut, Uttar Pradesh, India.*

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ABSTRACT

Moringa oleifera Lam. or munga is one of the most important plants widely cultivated in India. It belongs to family Moringaceae. It is a popular Indian medicinal plant, has long been used commonly in *Ayurvedic* system of medicine. *M. oleifera* is rich in various active phyto-constituents (tannins, sterols, terpenoids, flavonoids, saponins, anthraquinones, alkaloids, and vitamins) in addition to different minerals in its leaves and seeds. The plant has been found to exhibit diverse number of pharmacological activities such as analgesic, anti-inflammatory, antipyretic, anticancer, antioxidant, nootropic, hepatoprotective, gastroprotective, anti-ulcer, cardiovascular, anti-obesity, antiepileptic, anti-asthmatic, antidiabetic, anti-urolithiatic, diuretic, local anaesthetic, anti-allergic, anthelmintic, wound healing, antimicrobial, immunomodulatory, and antidiarrheal properties. The present paper gives an account of updated information on its phytochemical and pharmacological activities. So, the aim of the present review is to provide comprehensive information from recognized sources on the ethnobotany, traditional uses, phytochemistry and pharmacological efficacy and of the medicinal plant, *M. oleifera*. These reports are very encouraging and indicate that herb should be studied more extensively for its therapeutic benefits. Clinical trials using *Moringa* for a variety of combinations in different formulations should also be conducted.

Keywords: Ethnobotany, *Moringa oleifera*, Moringaceae, Phytochemistry, Phytopharmacology.

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Conflict of interest: None

INTRODUCTION

The earliest evidence we have of human beings, using plants for medicines could not be traced out. It is possible that man has been experimenting with nature accidentally and deliberately. Much of the accumulated knowledge of useful plants was to a great degree the knowledge of common people. But when one knows something of the medicinal uses, people have made of thousands of wild plants around us; the plant takes on a new meaning, a new value greater than their beauty, their cooling shade or their pleasant scent.[1,2] Nature has always been a first-rate drug store, with its enormous range of plants that are known to have effective therapeutic qualities. The profound knowledge of herbal remedies in traditional cultures developed through trial and error over centuries. And most important cures were passed verbally from one generation to the next.[3,4] Medicinal plants and plant derived medicines have been widely used in cultures all over the world and are becoming increasingly popular in modern society, as natural alternatives to synthetic chemicals. Well known examples of plant derived medicines include quinine, morphine, codeine, atropine, reserpine and digoxin.[5] It is an undisputed fact that the plants are the biggest laboratories of naturally constituents. Plant drugs began to enjoy an important revival. One reason was that the constituents and active principles of the medicinal plants began to be isolated and identified.[6-8] Traditional medicines has a very long history, it is the sum total of the practices based on the theories, beliefs and experiences of different cultures and time, often inexplicable, used in maintenance of health as like in the prevention, diagnosis, improvement and treatment of illness.[9] People who used traditional remedies may not understand the scientific rationale behind the remedies, but they seem to know from personal experience that some medicinal plants could be highly effective, if used at the therapeutic doses. Since over the ages, now we have eventually a better

*Author for Correspondence: niyazpharma79@gmail.com

understanding today of how the body functions, we are in a better position to understand the healing powers of plants and their potential as multi-functional chemical entities for treating complicated health problems.[10-13]

Moringa oleifera Lam, a plant in the Moringaceae family, is also known as the drumstick tree or ben oil tree.[14] It is a fast-growing, soft-wooded tropical perennial tree that has been used for a long time for both medicine and food. This was written about 5000 years ago in the Charaka Samhita, which is a book about Indian medicine. People in Africa use this kind of medicine all the time. Rich in nutrients, the plant's flowers and fruits have a lot of good things in them. In the *M. oleifera* leaves, you can find a lot of vitamins and other nutrients. They also have a lot of other things, like phenolic acids and flavonoids.[15] People say that all parts of the plant can be used for different things, like making food or making medicines. Generally, *M. oleifera* has a wide range of medicinal and biomedical uses.[16-18] The Moringa family has been used for a long time to improve health. Moringa was used by kings and queens to stay alert and keep their skin healthy. Indian warriors used the leaves of *M. oleifera* to boost their energy and help them deal with pain and stress during the wars they were in the studies Mahmood CT, *et al*.[19] Also, the genus has been used to treat skin infections, anxiety, asthma, wounds, fever, diarrhoea, and sore throats in the past. The genus is well-known for its many different uses. The seeds are used to clean water, the leaves are used as nutrition supplements, the oil is used as a biofuel, the trunks are used as gum, the flowers are used to make honey, and all of the plant parts can be used for medicine.[20] People call *M. oleifera* the "Miracle Tree" and "Mother's Best Friend," but it's also called a lot of other things. Other than having a lot of vitamin A, vitamin C, potassium, and calcium, the plant also has all the amino acids that your body needs. *M. oleifera*, which has been under study since the 1970s, has been the subject of a lot of different research.[19] It is now known that the plant has anti-inflammatory, antioxidant, anticancer, anti-tubercular, and anti-diabetic properties. This review will first look at the traditional uses, phytochemical contents, and biological activities of the *M. oleifera*. Its goal is to encourage new research on other plants.

MATERIALS AND METHODS

Ethnobotanical descriptions, plant compounds, and biological effects were all covered in this review article. It also included all of the information from the peer-reviewed journal on *M. oleifera* that could be found. To find the right literature, we did a very thorough search on the internet databases like ACS Publications and Elsevier. We also looked through the books in the library. "Moringa," "*M. oleifera*," "traditional uses of *M. oleifera*," "ethnobotany," "phytochemistry," "biological activities," Indian herbal classic texts, and a Ph.D. dissertation were some of the words used to find information about the plant. Before January 2021, only English-language publications until then were chosen. Non-English language papers, unpublished data, and non-original papers were not chosen. The plant scientific name was established on The Plant List website: www.theplantlist.org.

BOTANICAL DESCRIPTION

Distribution

The plant is indigenous to India and grows quickly to a height of 10 metres. It is commonly grown throughout the Indian plains and has become naturalized in tropical areas to elevations of 1400 metres above sea level. Besides north-eastern Pakistan and north-eastern Bangladesh, it is also grown in Sri Lanka, West Asia, the Arabian Peninsula, East and West Africa, the West Indies and southern Florida, as well as Central and South America, from Mexico to Peru, as well as Brazil and Paraguay. It is grown in hedges and in the home's garden. It grows in all sorts of soil, but it thrives the most in the climates of North India and South India, where it is native.[21-23] The family Moringaceae contains approximately 33 species, according to available information. There are thirteen different species of Moringa among them.[24-26]

Morphological Characters *M. oleifera*

The tree belongs to the Moringaceae family and is a deciduous plant with a height of 5–10 metres and a greyish green bark adapted to high aridity; it is the fastest growing Moringa species.[27]

Leaves: The leaves are bipinnate or usually tripinnate and can grow up to 45 cm in length. The leaflets are hairy, green, and virtually hairless on the top surface of the leaflet on the lower surface. The twigs are hairy and green, and the leaves are compound, with leaflets ranging in length from 1 to 2 cm. When the leaves mature, one of the distinguishing characteristics of *M. oleifera* is the falling of their leaflets, which leaves the leaf rachises bare.

Flowers: Axillary panicles 10 to 25 cm long with fragrant, bisexual, yellowish white flowers on hairy stalks are produced in axillary panicles that are either spreading or drooping. Individual flowers are approximately 0.7 to 1 cm long and 2 cm wide, with five unequal yellowish-white, thinly veined, spathulate petals, five stamens with five smaller sterile stamens, and a pistil composed of a 1-celled ovary and a slender style. The flower is borne on a stem that is approximately 0.7 to 1-cm long and 2 cm wide.

Fruits: Fruits are tri-lobed capsules that are referred to as pods; they are pendulous, brown triangular, and split into three parts lengthwise when dry; they are 30 to 120 cm long and 1.8 cm wide; they are produced primarily in March and April; they are produced in large quantities throughout the year. During the development stage of a fruit, it has approximately 26 seeds. The hue of immature pods is green, but when they reach maturity, they turn brown.

Seeds: Acorn seeds are round and one centimetre in diameter, with a brownish semi-permeable seed hull and three papery wings. The hulls of the seeds are brown to black in colour but can be white if the kernels are of low viability. Viable seeds

germinate in two weeks or less and each tree can yield between 15,000 and 25,000 seeds per year. The average weight per seed is 0.3 grammes. Another distinguishing characteristic of *M. oleifera* is the production of root tubers during the seedling stage. Figure 1 depicts the many components of the plant (A-E).[28,29]

Traditional Applications

The medicinal properties of *M. oleifera* were originally mentioned some 5000 years ago in India's Vedic literature, where it has remained ever since.[30] In traditional Chinese medicine, *M. oleifera* leaf extract is applied topically to the skin to treat paralysis and skin rashes.[31] During wartime, *M. oleifera* leaves are used to boost soldiers' vitality while also relieving their pain and tension.[19] Other traditional applications of the genus include the treatment of skin infections, anxiety, asthma, wounds, fever, diarrhoea, and sore throats, among other ailments (Table 1). The genus is well-known for the variety of applications it has. Plant components utilised for therapeutic purposes include the seeds for water purification, the leaves for nutrition supplements, the oil for use as a biofuel, the trunks for gum, the flowers for honey, and all of the plant parts for medicinal uses.[20] *M. oleifera*, popularly known as the "Miracle Tree" and "Mother's Best Friend," has been recognised as the plant with the highest concentration of nutrients. The plant also contains all of the essential amino acids, in addition to a high concentration of vitamin A, vitamin C, potassium, and calcium, among other nutrients.[19] In the Sultanate of Oman, the seeds of this plant are the most widely used to treat diabetes.[32,33] Convulsions or infantile paralysis are treated using pod oil in the northern region of Oman, where it is utilised to cure the condition.[34] Additionally, it is widely used in the Indian subcontinent to treat diabetes-related symptoms such as hyperlipidemia and hyperglycemia, among other things. In Arab countries, the young leaves of *M. oleifera* are traditionally used in folk medicine as an antioxidant and wound healer, and this practise continues today. According to Marwah *et al.* (2007),[35] the bark juice is also used as a disinfectant and to treat a variety of ailments such as fever, headache, constipation, back and muscle discomfort, slimness, burns, and labour pain.[36-38] Medicinal uses include the use of the leaves for wound healing[39] and the seeds for stomach pain.[40] Infusions of the roots and leaves of *M. oleifera* are made with water and used to treat conditions such as high blood pressure (hypertension), malaria, asthma, stomach ailments, diabetes, and a retained placenta.[41] Traditionally, the oil extracted from this plant has been used to cure skin conditions such as freckles, itches, and scabies, among others.[42] Aside from their medical value, the plant also offers great nutritional value to humans. It is possible to eat the young leaves of the plant as a vegetable.[43] In India, the immature seeds are consumed raw, whereas in Malawi, the adult seeds are either roasted or deep-fried.[44,45] In traditional herbal medicine, the seeds of the plant are combined with other herbs and used as a meal to treat malnutrition in the form of a dietary supplement.[46] Furthermore, *M. oleifera* is considered to be one of the most important natural trees in the United Arab Emirates because of its cultural, spiritual, and religious significance. The leaves of the plant are used to flavour the meat during the preparation of smoked meat (tanour) in some parts of the world. The native inhabitants of the United Arab Emirates continue to practise this ancient ritual.[46]

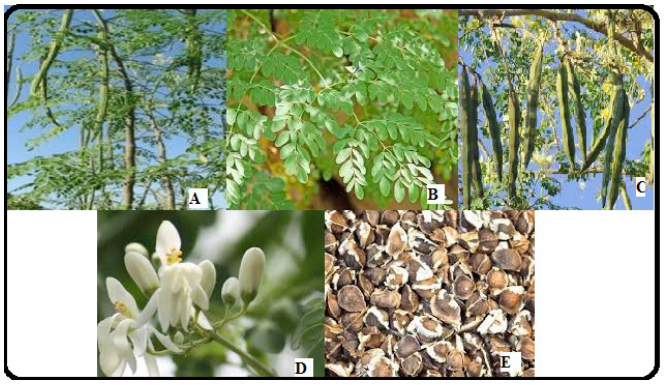


Figure 1:(A – E). Exomorphic features of *M. oleifera*

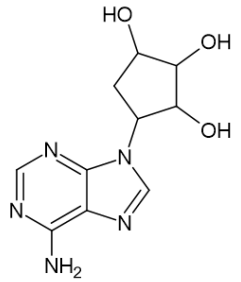
Phytochemistry

M. oleifera species contain a wide range of phytoconstituents, including alkaloids, saponins, tannins, steroids, phenolic acids, glucosinolates, flavonoids, and terpenes. The variety of phytochemicals found in this genus leads to the genus's wide range of pharmacological applications. When evaluated for a variety of biological functions, several of these substances yielded favourable findings in some tests. In the leaf of the plant, a total of 35 chemicals were identified using gas chromatography–mass spectrometry; among them were n-hexadecanoic acid, tetradecanoic acid, cis-vaccenic acid, octadecanoic acid, palmitoyl chloride, beta-l-rhamnofuranoside, 5-O-acetyl-thio-octyl, gamma.[47] E-lutein was discovered to be the carotenoid with the greatest concentration in leafage. The radicle of the plant contains 4-(l-rhamnopyranosyloxy)-benzylglucosinolate as well as benzylglucosinolate (as well as other compounds).[48] The antibacterial compounds spirochin and anthonine, which are present in roots, are effective against bacteria.[49] The peduncle of the plant contains a variety of compounds such as β-sitosterone, vanillin, 4-hydroxymellein, β-sitosterol, and octacosanoic acid are found in the peduncle of the plant, and its crust is composed of 4-(α-l-rhamnopyranosyloxy)-benzylglucosinolate [48] (Figure 2 and Table 2).

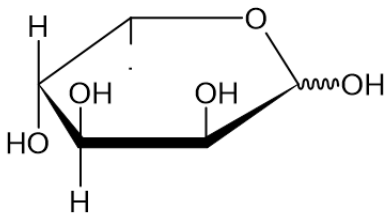
Flavonoids

According to Wang *et al*., 2017,[50] the plant possesses significant antioxidant activity, which is mostly owing to its high level of flavonoids. The flavanol and glycoside forms of flavonoids are the most abundant in this genus, accounting for about 90% of total flavonoids. Rutin, quercetin, rhamnetin, kaempferol, apigenin, and myricetin are the flavonoids that are most commonly found in the genus. Optimization studies have been carried out in order to determine the most efficient method of extracting flavonoids from *M. oleifera* Lam with the maximum yield (Figure 2).

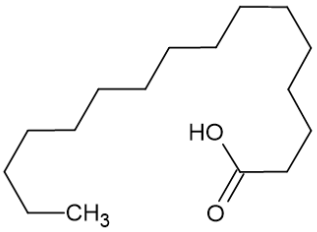
+Previously isolated phytoconstituents from *M. oleifera*



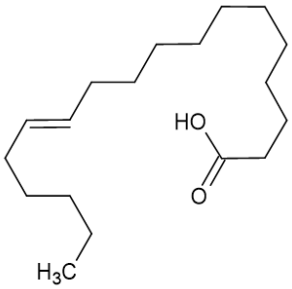
1,2,3-Cyclopentaanetriol



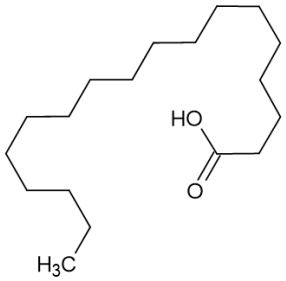
L-galaaactose,6-deoxy



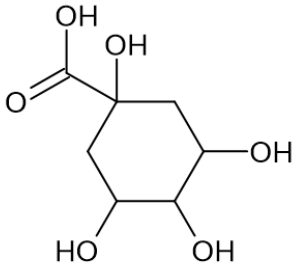
***n*-hexadecanoic acid**



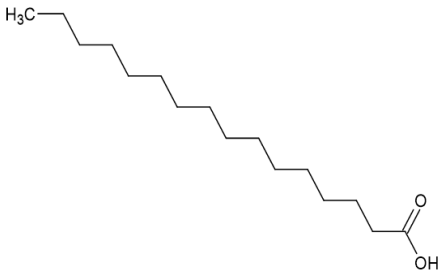
***Cis*-Vacenic acid**



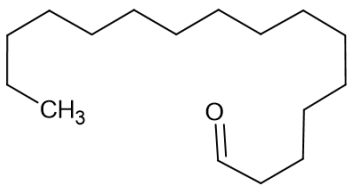
Tetradecanoic acid



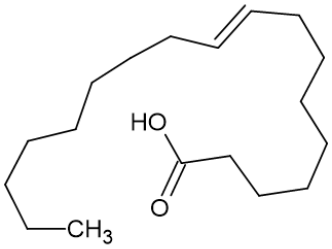
Quinic acid



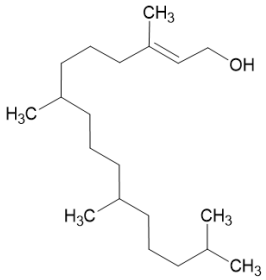
Oleic acid



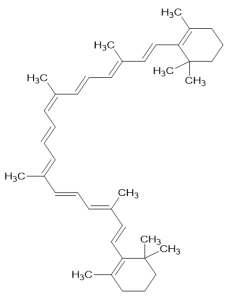
L-(+) Ascorbic acid



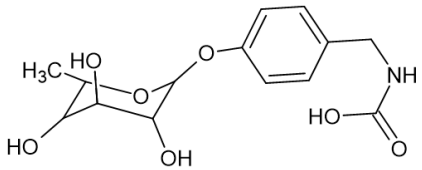
Ethyl oleate



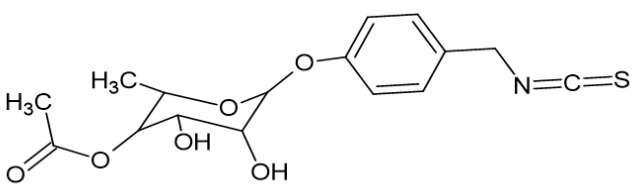
Phytol



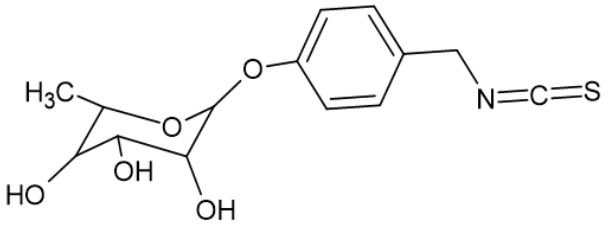
β-carotene



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



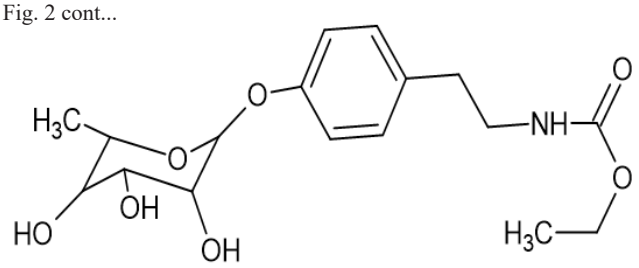
4-(-L-rhamnopyranosyloxy)benzyl isothiocyanate



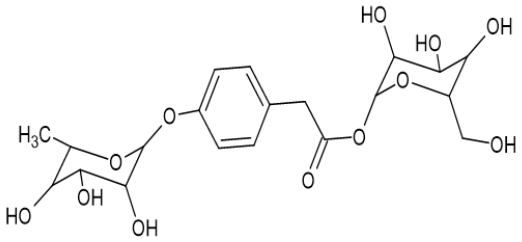
niazimicin

Figure 2: Structures of some important phytoconstituents from *M. oleifera.*

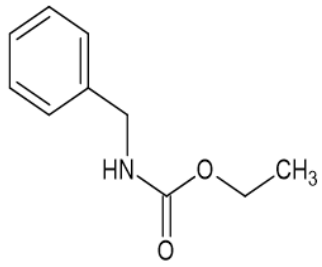
Fig. 2 cont...



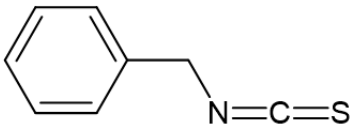
4-(α-L-rhamnopyranosyloxy)benzyl glucosinolate



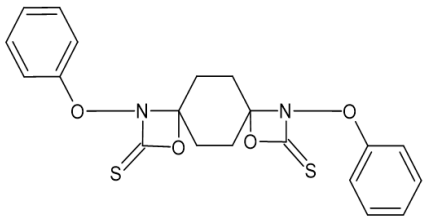
benzyl isothiocyanate



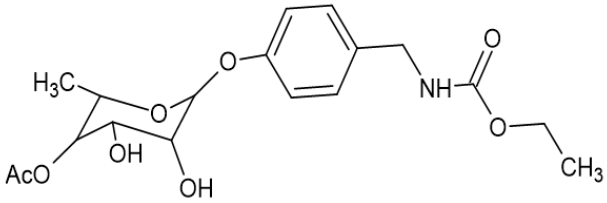
pterygospermin



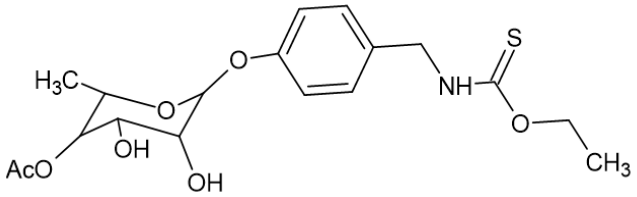
deoxy-niazimicine (N-benzyl, S-ethylthioformate)



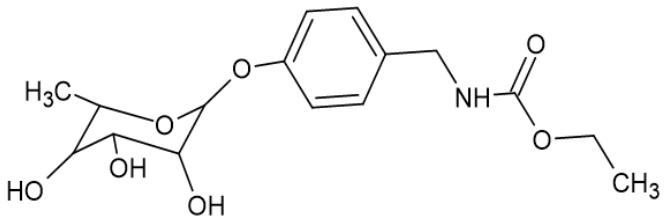
niaziminin



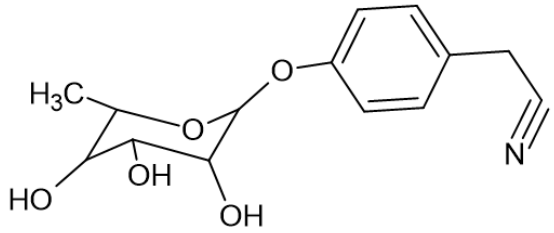
O-ethyl-4-(α-L-rhamnosyloxy)



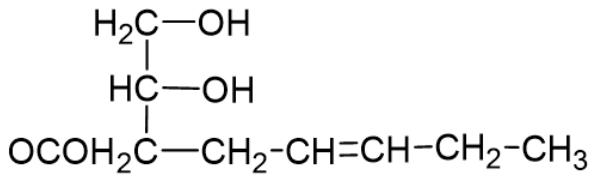
benzyl carbamate



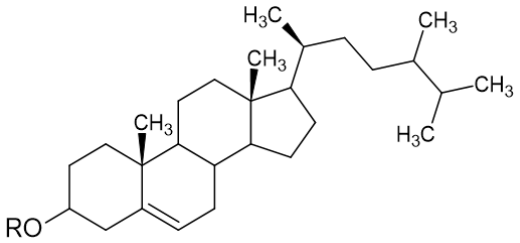
Niazirin



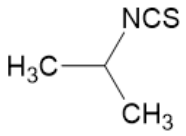
glycerol-1-(9-octadecanoate



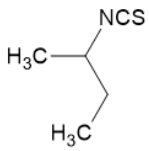
β-sitosterol



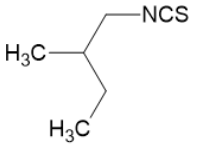
3-O-(6′-O-oleoyl-β-D-glucopyranosyl)-β-sitosterol



2-propyl isothiocyanate



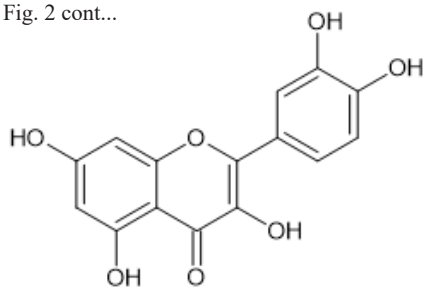
2-butyl isothiocyanate



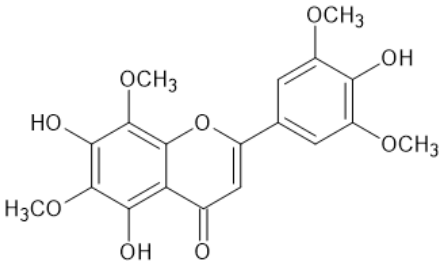
2-methylpropyl isothiocyanate

Figure 2: Structures of some important phytoconstituents from *M. oleifera.*

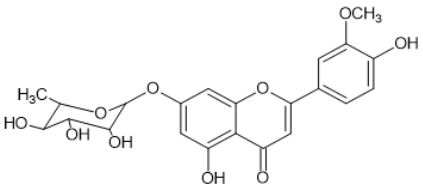
Fig. 2 cont...



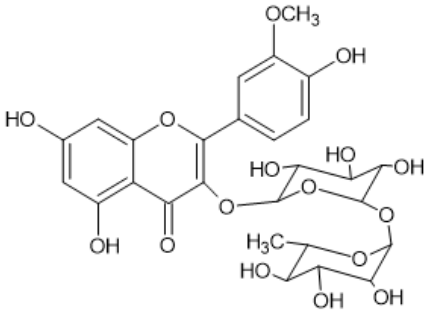
Quercetin



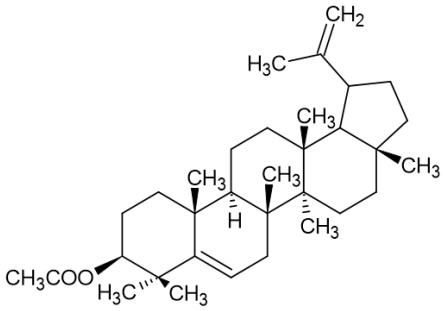
6, 8, 3, 5-tetramethoxy apigenin



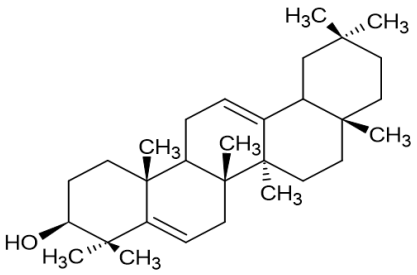
Chrysoeriol-7-O-rhamnoside



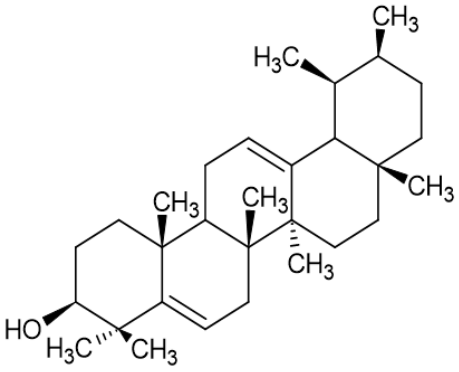
Rutin



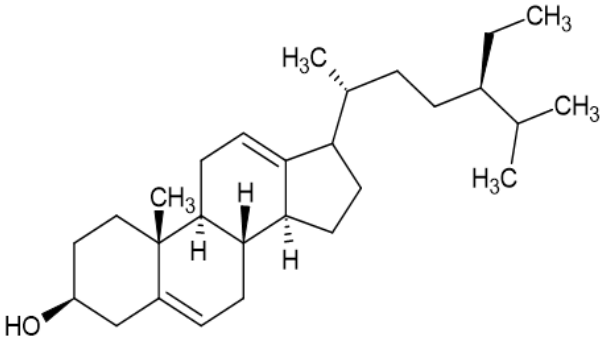
Lupeol acetate



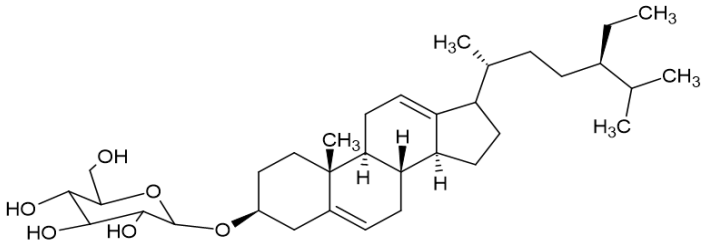
β-amyrin



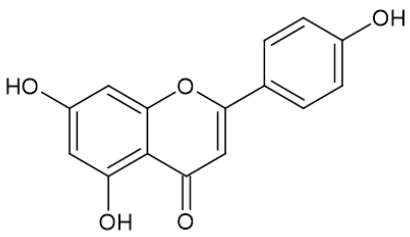
α-amyrin



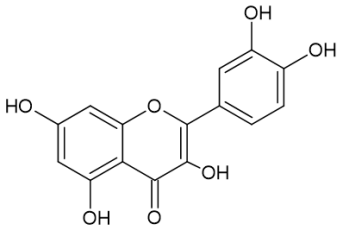
Thytosterols [β-sitosterol



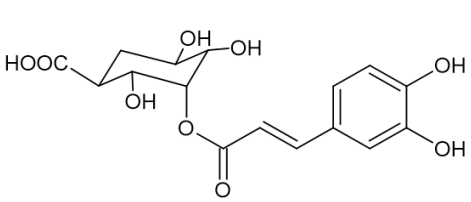
β-sitosterol-3-O-glucoside



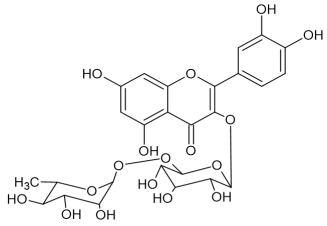
Apigenin



Rhamnetin



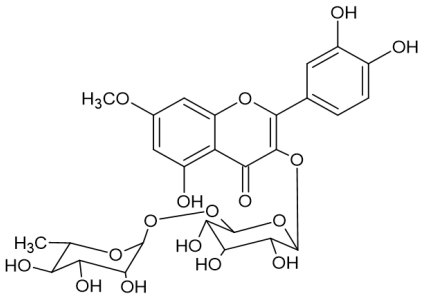
Polyphenol [neochlorogenic acid



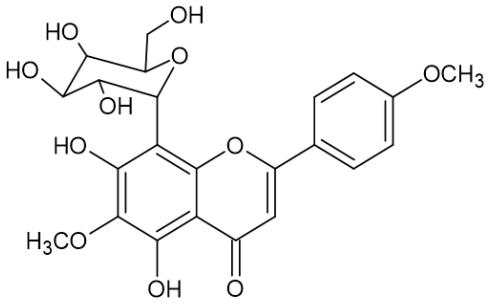
Quercetin-3-O-rutinoside

Figure 2: Structures of some important phytoconstituents from *M. oleifera.*

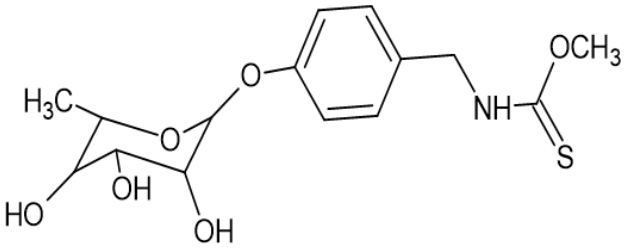
Fig. 2 cont...



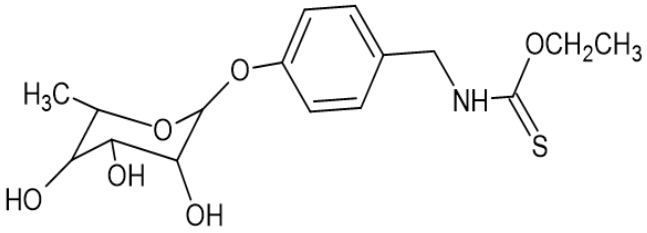
Rhamnetin-3-O-utinoside



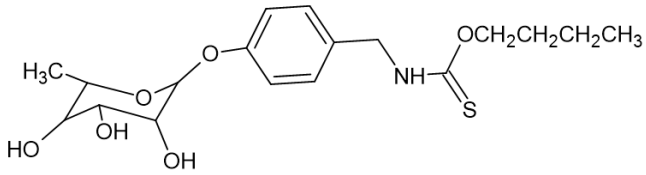
6-methoxy-acacetin-8-C- β-glucoside



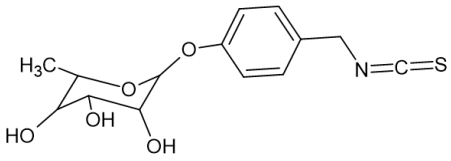
O-methyl-4-[(a-L-rhamnosyloxy)benzyl], thiocarbamate



O-ethyl-4-[(a-L-rhamnosyloxy)benzyl] thiocarbamate



O-butyl-4-[(α-L-rhamnosyloxy) benzyl thiocarbamate



One isothiocyanate [4-(α-L-rhamnosyloxy) benzyl isothiocyanate

Figure 2: Structures of some important phytoconstituents from *M. oleifera.*

Alkaloids

- Kerharo (1969) isolated two alkaloids, namely moringine and moringinine from the stem bark of *M. oleifera*.[51]
- Sahakitpichan *et al.,* 2011 reported on the existence of two novel pyrrole alkaloid glycosides that were obtained from the leaves of *M. oleifera*, which were identified as marumoside A and marumoside B, together with pyrrolemarumine-4″-O-α-L-rhamnopyranoside[52] (Figure 2)**.**

Sterols

- In a chloroform extract of *M. oleifera* stem bark, Bargah and Das (2014) reported the existence of a sterol glycoside, namely β-sitosterol-3-O-β-Dgalactopyranoside, which was previously unknown.[53]
- A phytochemical investigation conducted by Abd El Baky and El-Baroty (2013) found that the main steroidal components in *M. oleifera* oil were contain β-sitosterol, campesterol and stigmasterol being the most abundant.[54]
- Maiyo *et al.* (2016) extracted β-sitosterol from the leaves and seeds of Moringa oleifera, and they published their findings in 2016.[55]

Terpenes

- Teixera *et al.*, 2014 and Saini *et al.*, 2014 reported the lutein is the most abundant carotenoid found in the leaves of *M. oleifera*.[56,57]
- Saini *et al.*, 2014 reported that *M. oleifera* did not contain the antioxidant α-carotene, which is often found in green leafy plants. The author made the assumption that all of the α-carotene had been transformed completely into lutein. Carotenoids discovered in the plant include all-E luteoxanthin, 13-Z-β- lutein, 15-Z-carotene, and all-E zeaxanthin, among others.[57]
- *M. oleifera* aerial part ethanol extract was used to isolate lupeol acetate, -amyrin, and -amyrin from the n-hexane fraction of the ethanol extract, according to El-Alfy and colleagues (2011) (Figure 2).[58]

Phenolic Acid

Gallic acid is the primary phenolic acid found in the leaves of *M. oleifera*. There are also trace levels of elagic acid, ferulic acid, caffeic acid, o-coumaric acid, and chlorogenic acid in the leaves, as well as gentisic acid, syringic acid, r-coumaric acid, and sinapic acid, all of which were discovered in the leaves.[59-60]

Glucosinolate

Glucosinolates are prevalent in the leaves of *M. oleifera*. In the species, the most abundant glucosinolate present is 4-O-(α-L-rhamnopyranosyloxy)-benzyl glucosinolate, also known as glucomoringin, which is the most abundant glucosinolate present (GMG). Additionally, three isomers of

4-O-(α-L-acetylrhamnopyrosyloxy)-benzyl glucosinolate were discovered in *M. oleifera* leaves, with the number of isomers observed varying according to the age and physiological features of the leaves.[60]

Others Phytoconstituents

Shanker *et al*., 2007 reported that two nitrile glycosides, niazirin and niaziridin, were detected using reverse phase high performance liquid chromatography (HPLC).[61] Only the leaves and pods of *M. oleifera* were found to contain peaks for these nitrile glycosides, while no equivalent peaks were found in the bark or other portions of the plant. The leaves contained a higher concentration of niazirin than the pods, which contained a lower percentage of niaziridin than the leaves. The compound 6-methoxy-acacetin-8-C—glucoside was discovered in an ethanolic extract of the aerial portion of the plant *M. oleifera*.[58] The fatty acids oleic acid and linoleic acid are the most abundant in *M. oleifera*. Additionally, the oil has a high concentration of tocopherols and phenols.[62] *M. oleifera* contains a variety of fatty acids, including oleic acid, linoleic acid, myristic acid, palmitic acid, palmitoleic acid, stearic acid, arachidic acid, linolenic acid, behenic acid, and paullinic acid (Figure 2).

Phytopharmacological Activities

The following are some of the folk and traditional applications of the plant; it has also been studied scientifically in animal models to see whether or not the plant has the ability to treat a number of maladies.

Anti-inflammatory Activity

- The anti-inflammatory activity of ethanolic and aqueous extracts of *Moringa oleifera* was investigated in rats with fresh egg albumin induced inflammation (oedema).[63] After testing, it was discovered that the aqueous and ethanol extracts effectively decreased the acute inflammation caused by fresh egg albumin. Using a dose level of 300 mg/kg, aqueous and ethanol extracts were found to significantly reduce inflammation by 72.96 and 81.01%, respectively, three hours after the oedema was inflicted on the animals. In contrast, the anti-inflammatory medicine diclofenac, administered at a dose level of 100 mg/kg, completely eliminated the inflammation by the third hour.
- *M. oleifera* root and bark extracts, as well as methanolic extracts of leaves and flowers, and ethanolic extracts of seeds, have been shown to have anti-inflammatory effect. It was determined that the hot water infusions of flowers, leaves, roots, seeds and stalks or bark of *M. oleifera* had anti-inflammatory action *in vitro* utilising carrageenan-induced and the extract had pharmacologically significant anti-inflammatory activity *in vitro*.[64]
- Arulselvan *et al*., 2016 investigated the major anti-inflammatory mechanism of four fractions of *M. oleifera* leaf (hexane, chloroform, ethyl acetate, and butanol) and discovered that they reduced IL-1b, IL-6, PGE2, TNF-α, and nitric oxide production in LPS macrophages.[65] Arulselvan *et al*., 2016 investigated. The fraction ethyl acetate had the largest inhibitory effects of the fractions tested, and as a result, it was further investigated. The findings revealed that *M. oleifera* was capable of inhibiting the nuclear factor-kB pathway. The fruit extract of *M. oleifera* inhibited nuclear translocation of NF-kB and elevated inhibitor kB expression, which was also observed at higher concentrations (500 and 1,000 g/mL), particularly in the chloroform fraction, and was proven to be cytotoxic in animals.
- When administered to LPS-induced RAW264.7 macrophages, an ethanolic floral extract of *M. oleifera* dramatically reduced the activity of inflammatory mediators and proinflammatory cytokines including PGE2, IL-6, IL-1, TNF--α, NF-kB, NO, and COX2 in the presence of ethanolic flower extract. Furthermore, the extract boosted the activity of the anti-inflammatory cytokines IL-10 and 1kB-, which were previously found to be inactive. The fruit extract of *M. oleifera* shown the greatest effectiveness in decreasing NO release generated by LPS in RAW264.7 cells when compared to the other parts of the plant.[66,67]
- According to Adedapo *et al*., 2015, the methanol extract of *M. oleifera* Carrageenan-induced paw edoema and histamine-induced paw edoema were both less edoematogenic when leaves were used. The extract reduced the amount of writhes in mice that were caused by acetic acid when given to the mice. At doses of 100 and 200 mg/kg, the analgesic activity of the extract was found to be higher than that of the reference medication, indomethacin, in a study involving rats.[68]
- An investigation on the anti-inflammatory response of ethanolic leaf extract (*M. oleifera*) on atopic dermatitis mice and human keratinocytes was carried out by Choi and colleagues (2016). Mannose receptor mRNA, retinoic acid-related orphan receptor gT, and thymicstromal lymphopoietin expression were all reduced in ear tissue after treatment with the extract (Figure 1). In an *in vitro* study, it was discovered that the extract decreased the expression of mitogen-activated protein kinases, CCL17, IL-6 pro-inflammatory cytokine-related mRNA, TNF-α, and IL-1β. These findings were confirmed in a clinical trial. Additionally, the pod extract of *M. oleifera* prevented the rise of protein levels as well as mRNA levels of cyclooxygenase-2, TNF-, IL-6, and iNOS by inhibiting the phosphorylation of mitogen-activated protein kinases and kB proteins *in vitro*.[69]
- A dose-dependent improvement in cellular and humoral immunity was seen in normal and immunosuppressed mice after ingestion of hydroethanolic and methanolic extracts of the leaf of *M. oleifera*. The extract enhanced the phagocytic index, the weight of the thymus and spleen, the antibody titer, and the quantity of white blood cells and neutrophils in the bloodstream.[70,71]
- The immunosuppressive and anti-inflammatory efficacy of the ethanolic seeds extract of *M. oleifera* was investigated

by Mahajan and Mehta 2010 in their study.[72] The extract's immunosuppressive effect was demonstrated by its ability to inhibit macrophage phagocytosis and to prevent the development of delayed type hypersensitivity in mice by reducing the mean foot pad thickness of the animals' feet. The ethanolic extract of the seeds also had a negative effect on white blood cell and leukocyte concentrations, which are normally associated with an immune response. It exacerbated paw edoema, which frequently culminated in the development of type IV, hypersensitivity.

- The methanolic leaf extracts of *M. oleifera* displayed analgesic effects in Freund's adjuvant arthritis-induced rats, with mechanical allodynia and thermal hyperalgesia being reduced in both groups. *M. oleifera* methanolic root extracts, on the other hand, only had a mild anti-inflammatory effect on the rats' thermal hyperalgesia. The activity of the root and leaf extracts was found to be comparable to that of indomethacin in some studies. The researchers also discovered that a combination of root and leaf extracts produced a greater reduction in thermal hyperalgesia when administered at lower doses.[73]
- An ethanol extract of *M. oleifera* leaves, as well as its major constituent's quercetin-3-O-glucoside, kaempferol-3-O-glucoside and crypto chlorogenic acid demonstrated anti-inflammatory activity by inhibiting the migration and chemotactic oxidation of polymorphonuclear leukocytes in a mouse model of inflammation.[74]

Antileishmanial

- A 70% ethanolic extract of *M. oleifera* roots and a methanolic extract of the same plant's leaves showed antileishmanial action against *Leishmania donovani* promastigotes, according to Kaur *et al.*, 2014.[75] The ethyl acetate portion of a methanolic extract prevented leishmaniasis with an inhibitory concentration of 27.5 g/mL, indicating a 50% inhibition. Niazinin, which was isolated from the ethyl acetate fraction, had the greatest antileishmanial activity, with an IC50 of 27.5 g/mL. Niazinin was recovered from the ethyl acetate fraction.
- A study conducted by Singh et al., 2015 discovered anti-leishmanial activity in many areas of the *M. oleifera* plant, including the bark, leaf, stem, flower, and root of the plant. *L. donovani* promastigotes infected macrophages were shown to be particularly susceptible to the flower, particularly the ethyl acetate fraction, which demonstrated the most powerful activity against parasite viability in a dose- and time-dependent manner. The extract also had a parasite-reduction effect in the spleen and liver of Balb/c mice, who were both exposed to the extract.[76]

Antioxidant Activity

- The high phenolic content of Moringa species is one of the factors that contribute to their excellent antioxidant properties. Phenolic chemicals operate as antioxidants by stabilising free radicals created in cells by donating or absorbing electrons, thereby preventing cell damage. The DPPH (1,1-di-phenyl-2-picrylhydrazyl) inhibition of a water extract of *Moringa stenopetala* leaves (IC50: 40 g/mL) was found to be higher than that of a comparable extract of *M. oleifera* leaves (IC50: 215g/mL) in this study. In addition, rutin exhibited significant antioxidant activity (IC50: 5g/mL) in a DPPH experiment. An HPLC investigation revealed that *M. stenopetala* contains a higher concentration of rutin than *M. oleifera*, indicating that it is a more potent antioxidant.[77]
- The aqueous and alcoholic extracts (methanolic and ethanolic) of the leaves and roots of *M. oleifera* have shown to have significant anti-oxidant and radical scavenging action *in vitro*, according to the findings. Its leaves are a rich source of antioxidant chemicals, and they may be able to protect animals from diseases caused by oxidative stress if they are consumed. Treatment with a *M. oleifera* leaf extract appears to be effective in preventing oxidative damage caused by a high-fat diet.[78]
- According to Verma et al., 2009, the ethyl acetate fraction of an *M. oleifera* leaf hydromethanolic extract was the fraction with the greatest amount of activity. The fraction had an IC_{50} of 0.04 mg/mL, which was equivalent to quercetin activity, which had an IC_{50} of 0.02 mg/mL and had inhibited DPPH with an IC_{50} of 0.02 mg/mL, respectively. In addition to *in-vitro* studies, the ethyl acetate fraction of *M. oleifera* leaves has been tried on rats who have been intoxicated with CCl_4.[79]
- A study stated that myricetin from *M. oleifera* seeds had stronger antioxidant activity than α-tocopherol and BHT.[80]
- A leaf extract of *M. oleifera* contained isoquercetin, astragalin and crypto-chlorogenic acid. The leaf extract of the plant, together with the compounds, reduced reactive oxygen species in HEK-293 cells that were induced by H_2O_2. The compound that had the highest antioxidant activity was determined to be isoquercetin as it increased the mRNA expression levels of CAT, heme oxygenase 1, and SOD.[81]
- Maiyo *et al.*, 2016 isolated two compounds from *M. oleifera* seeds and leaves that showed antioxidant activity: quercetin-3-O-glucoside displayed significant antioxidant activity while 4-(-D-glucopyranosyl-1->4--L-rhamnopyranosyloxy) benzylisothiocyanate activity was moderate.[82]

Antiepileptic Activity

- The methanolic extract of *M. oleifera* leaves exhibited strong anti-convulsant efficacy against pentylenetetrazole and maximum electroshock produced convulsions when delivered intraperitonially at doses of 200 and 400 mg/kg in rats. Reference standards such as diazepam and phenytoin were used in this study. Both doses of methanolic extract considerably reduced the duration of hind limb extension in the MES test and greatly delayed the onset of seizures in the PTZ produced convulsions, indicating that it has anticonvulsant properties. This could be due to the presence of alkaloids, flavonoids, and tannins in the extract, all of which have antioxidant properties.[83]
- MES and PTZ-induced seizures in Swiss albino mice were subjected to in-vivo testing to investigate the anticonvulsant

effect of an ethanolic extract of *M. oleifera* leaves (200 mg/kg, i.p.) on the animals' seizure activity. MES seizures, as well as reduction of tonic hind limb extension, were discovered during the observation. It was discovered that the convulsions were no longer present in PTZ seizures. The ethanolic extract of *M. oleifera* leaves may exert its anti-convulsant actions through a variety of routes, as demonstrated by the fact that it prevented hind limb extension triggered by MES as well as seizures induced by PTZ.[84]

Anti-diabetic Activity

- The aqueous extract of *M. oleifera* leaves exhibits anti-diabetic action and regulates diabetes, and as a result, it has glycaemic control properties.[85]
- The antioxidant and anti-diabetic properties of methanol extracts of *M. oleifera* pods *in vitro* and *in vivo* were investigated in diabetic albino rats that had been treated with streptozotocin (STZ) to become diabetic. Diabetic rats were given either 150 or 300 mg/kg of the extract for 21 days, and the anti-diabetic effects were assessed by assessing changes in biochemical markers in serum and pancreatic tissue after the treatment. When the extract was used to treat diabetes, the progression of the disease was greatly slowed. In rats treated with the extract, both doses resulted in a considerable drop in serum glucose and nitric oxide levels, with corresponding increases in serum insulin and protein concentrations.[86]
- *M. oleifera* seed powder 50 mg/kg and 100 mg/kg were used to test the anti-diabetic effects of two different dosages of Moringa seed powder on STZ-induced diabetes male rats. When compared to the diabetic negative control group, the diabetic positive control group had higher levels of interleukin-6 (IL-6), higher levels of lipid peroxide, and lower levels of antioxidant enzyme in the blood and kidney tissue homogenate.[87]

Anti-fertility Activity

The aqueous extract of *M. oleifera* roots as an anti-fertility agent in the presence or absence of estradiol dipropionate and progesterone was found to be effective. Using an aqueous extract, an in-vivo antifertility and histopathology investigation was carried out to determine whether it had any effect on the histoarchitecture of the uterus during the pre- and post-implantation stages.[88]

Antiurolithiatic Activity

The *in-vitro* anti-urolithiatic activity was performed in aqueous and alcoholic extract of bark of *M. oleifera*. It showed reduction in weight of stone produced using ethylene glycol induced urothiasis. It also possesses both preventive and curative property.[89]

Anti-asthmatic Activity

- A study was conducted in order to determine the efficacy of *M. oleifera* seed kernel in the treatment of bronchial asthma in patients. Patients with mild-to-moderate asthma of either sexes were treated for three weeks with finely powdered dried seed kernels at a dose of 3 gm/kg of body weight. The clinical efficacy of the treatment was determined by utilising a spirometer both before and after the treatment. The majority of patients experienced a rise in haemoglobin (Hb) levels as well as a decrease in the erythrocyte sedimentation rate (ESR). Improvements were also reported in the intensity of asthmatic attacks and the severity of their symptoms. After three weeks of treatment, the drug produced significant improvements in forced vital capacity, forced expiratory volume in one second, and peak expiratory flow rate values in asthmatic subjects, with 32.97 ± 6.03%, 30.05 ± 8.12%, and 32.09 ± 11.75% improvements, respectively, after three weeks of treatment.[90,91]
- Alcoholic extracts of *M. oleifera* seed kernels were found spasmolytic in acetylcholine, histamine, $Bacl_2$ and 5HT, induced bronchospasm.[92]

Anti-cancer Activity

- Ethanolic extracts of leaves and seeds of *M. oleifera* show potent anti-tumor activity. Thiocarbamate and isothiocyanate related compounds were isolated and which act as inhibitor of tumor promoter. The *in-vivo* antitumor potential was due the presence of three known thiocarbamate and isothiocynate related compounds which act as inhibitors of tumor promoter teleocidin B-4-induced Epstein–barr virus, interestingly.[64]
- *In vitro* anti-cancer properties of seed oil of *M. oleifera* was studied on various cell lines such as MCF-7 (breast cancer cell line), HepG2 (liver cancer cell line), CACO-2 (colon cancer cell line), HeLa (cervical cancer cell line), and L929 (mouse fibroblasts). A significant cytotoxic potential was observed against all the cell lines tested and activity was dose dependent manner. One milligram of the seed oil showed the highest cytotoxic potential against the tested cell lines. Cell viability decreased to 24.65, 24.18, 42.51, 46.57, and 32.11% and the IC50 values of the oil were 366.3, 604.3, 850.9, 721.7, and 935.8µg/mL for HeLa, HepG2, MCF-7, CACO-2, and L929 cell lines, respectively.[93] Based on these results, extensive investigation on the isolation of anticancer molecule is recommended.
- A water extract of *M. oleifera* pods was found to have anti-carcinogenic properties on dextran sodium sulfate- and azoxymethane-induced murine colon carcinogenesis in mice. The extract decreased the expression of COX-2 proteins and iNOS in the mice, in addition to lowering the animals's PCNA index. The extract also had a positive effect on the tumours' multiplicity and incidence. In the study, researchers discovered that the high concentration of omega-9 oleic fatty acid in the extract, which has anti-inflammatory properties, may be responsible for modulating cell growth. Glucomoringin, on the other hand, may also be responsible for its anticancer effect.[94]
- It was also shown that a hydro-alcoholic extract of *M. oleifera* has anti-tumorigenic activity, which was due to its ability to balance xenobiotic metabolism between Phase I and Phase II. The extract boosted the activity of Cyt P450 and Cyt b5 in Phase I, while also boosting the activity of glutathione S-transferase, glutathione reductase, and glutathione peroxidase, and decreasing the levels of glutathione (GSH), which is responsible for Phase II. The researchers also discovered that the extract may have the ability to operate as a "blocking agent" in the reduction of xenobiotic substrates in Phase II. The extract also enhanced the concentration of CAT in the blood while

decreasing the occurrence of mouse skin papillomas and lipid peroxidation.[95]

Anti-microbial Activity

- Leaves, roots, bark and seeds of *M. oleifera* show anti-microbial activity against bacteria and fungi. The plant shows *in vitro* activity against bacteria, yeast, dermatophytes and helminths by disc- diffusion method. The fresh leaves and aqueous extract from the seeds inhibit the growth of *Pseudomonas aeruginosa* and *Staphylococcus aureus*.[64]
- Ethyl acetate, acetone, and ethanol extracts of *M. oleifera* seeds, roots, leaves, and a mixture, were assessed for their dental antibacterial and antifungal activity. All of the extracts showed inhibition of Streptococcus aureus and Streptococcus mutans with the ethanol extract and leaf extract showing the highest inhibition.[96]
- Another study found that larger amounts of *M. oleifera* seeds were required to prevent the growth of *Candida albicans*, according to the findings.[97] Mouthwash and toothpaste with ethanolic leaf extract of *M. oleifera* have been developed.[96] Therefore, the toothpaste demonstrated suppression of the bacteria *S. aureus, S. mutans*, and *C. albicans*, but the mouthwash had solely antimicrobial action. Additionally, ethanol extracts of the seeds and leaves of *M. oleifera* inhibited the growth of the dermatophytes *Trichophyton mentagrophytes, Microsporum canis, Trichophyton rubrum,* and *Epidermophyton floccosum*, among other dermatophytes.[98]
- *M. oleifera* leaf extracts were also evaluated on a variety of diarrhea-associated bacteria, including *Serratia marcescens, Shigella dysenteriae, Enterobacter* sp., *E. coli, Klebsiella pneumoniae*, and Salmonella sp. Hexane, ethyl acetate, methanol, and chloroform extracts of *M. oleifera* leaves.[99] With minimum inhibitory concentrations ranging from 62.5 to 1000 µg/mL and zones of inhibition of 8–23.2 mm, all of the extracts demonstrated antibacterial activity against the bacterium. The researchers at Peixoto et al., 2011 discovered that aqueous and ethanolic extracts of *M. oleifera* leaves inhibited the growth of bacteria such as *S. aureus*, *Vibrio parahaemolyticus*, *Enterobacter faecalis*, and *Aeromonas caviae*. The extracts, on the other hand, had no effect on *E. coli*, *Salmonella enteritidis*, or *P. aeruginosa*, according to the results. During the research, it was discovered that the extract had greater inhibitory activity against gram-positive bacteria than against gram-negative bacteria.[100]
- *M. oleifera* root bark extract was used to isolate aglycon of deoxy-niazimicine (N-benzyl, S-ethyl thioformate) from a chloroform extract, and this compound was found to be more effective at inhibiting the growth of *S. aureus, S. dysenteriae, Shigella boydii, Shigella typhii, P. aeruginosa* and *C. alicans.* The bark of *M. oleifera* was tested against bacteria including *Pseudomonas fluorescens*, *S. aureus, Bacillus megaterium*, and *Citrobacter freundii*, and the results revealed that the ethyl acetate extract was more effective against these bacteria than the methanol, chloroform, and aqueous extracts from the same part of the plant.[100]
- Torondel *et al.*, 2014 investigated the efficacy of dried and wet *M. oleifera* leaf powder as a hand-washing product in healthy volunteers and found it to be effective. The results revealed that only the highest dose of *M. oleifera*, 4g, demonstrated levels of inhibition of *E. coli* that were comparable to those of a non-medicated liquid soap in the study. According to the findings of the study, this activity was not related to the mechanical friction created by washing hands. Considering that aqueous preparations of *M. oleifera* leaf powder demonstrated more microbial suppression than dried preparations, the researchers hypothesised that this activity could be attributed to the presence of saponin in the extract, which has surfactant characteristics.[101]

Antiviral Activity

- A 100µg/mL dose of *M. oleifera* extract demonstrated antiviral activity against the herpes simplex virus type 1 (HSV-1) by decreasing plaque formation by more than 50% at a 100 g/mL dose.[102] HSV-1 strains resistant to phosphonoacetate and kinase deficient HSV-1 strains were both suppressed by the extract in mice. The extract, given at a dose of 750 mg/kg, reduced the mortality of infected mice by increasing the mean survival time and delayed the development of skin lesions in the infected animals. Using an aqueous extract of *M. oleifera* leaves, researchers were able to activate cellular immunity in mice that had been infected with HSV-1 by lowering the virus concentration and restricting the formation of herpetic skin lesions.[103]
- Activation of the Epstein-Barr virus was found to be blocked by 4-[(4′-Oacetyl-alpha-L-rhamnosyloxy) benzyl] isothiocyanate and niaziminin according to Murakami and colleagues (1998). When tested against the foot and mouth disease virus at doses ranging from 1–50 µg/mL, *M. oleifera* demonstrated significant suppression.[104]
- A buffer extract of *M. oleifera* fruits displayed anti-HBV action, while a hydroalcoholic extract of the plant's leaves lowered the ccDNA level of HBV in HepG2 cells, suggesting that the plant may have anti-HBV activity.[105]
- Although *M. oleifera* was found to be effective as a complement to antiretroviral therapy for HIV infection, no additional research has been done on the plant's efficacy as an antiviral agent.[106]

Anthelmintic Activity

- *In-vitro* study assessed the efficacy of macerated and infused aqueous extract as well ethanolic extract of *M. oleifera* against fresh eggs, embryonated eggs, L_1 and L_2 larvae of *Haemonchus contortus*. Five different concentrations of extracts were prepared (0.625, 1.25, 2.5, 3.75 and 5 mg/mL). Fresh eggs were exposed to these different concentrations for 48 hours, while embryonated eggs and larvae were exposed for 6 and 24 hours respectively. Distilled water and 1.5% DMSO were used as negative control. Results revealed that ethanolic leaf extract of *M. oleifera* was most efficient on eggs by inhibiting

Table 1: Ethnomedicine of *M. oleifera*

Plant	*Part*	*Ethno botanical uses*	*References*
M. oleifera	Barks	Aiding digestion, stomach pain, poor vision, ulcer, hypertension, joint pain, anemia, diabetes	[112, 113]
	Flowers	Tumor, inflammation, hysteria, enlargement of spleen, muscle diseases, aphrodisiac substances	[114, 113]
	Gums	Fevers, dysentery, asthma, dental decay	[115]
	Leaves	Antibacterial, antimalarial, Cardiac stimulants, malaria, arthritis, diseases of the skin, hypertension, typhoid fevers, swellings, parasitic diseases, diabetes, cuts, contraceptive remedy, genio-urinary ailments, boost immune system, elicit lactation	[112-117]
	Leaf	Diarrheal, dysentery, colitis, sores, skin infection, anemia, cuts, scrapes, rashes, sign of aging	[115]
	Oils	Gout, acute rheumatism	[118]
	Seeds	Warts	[115]

60.3% ± 8.2% and 92.8% ± 6.2% eggs embryonation at 3.75 and 5 mg/mL respectively.[107]

- The anti-helmentic effect of ethanolic extracts of *M. oleifera* and *Vitex negundo* against the helminth *Pheritima posthuma* was investigated using different doses of the extracts. Distilled water served as the control group, with piperazine citrate (10 mg/mL) serving as the reference standard. The results were stated in terms of the amount of time it took for the worms to become paralysed and die. In a dose-dependent manner, *M. oleifera* outperforms *V. negundo* in terms of activity and antioxidant capacity.[107]

Cardiovascular Activity

The ethanolic extract of *M. oleifera* leaves exhibited significant anti-hypertensive and hypotensive action, respectively. The in-vivo action was tested in an animal's heart, and it was discovered that the glycosides thiocarbamate and isothiocyanate were responsible for the intense hypotensive activity observed in the animal.[108]

CNS Activity

M. oleifera leaf extract has been shown to increase monoamine levels in the brain, which may be beneficial in the treatment of Alzheimer's disease. Based on in-vitro anticonvulsant activity from the aqueous extract of *M. oleifera* roots and ethanolic extract of leaves, the researchers examined penicillin-induced convulsions as well as locomotor behaviour as well as the levels of serotonin (5-HT), dopamine, and norepinephrine in the brain.[109]

Hepatoprotective Activity

- The in-vivo hepatoprotective activity of ethanolic extracts of leaves and alcoholic extracts of seed of *M. oleifera* was assessed in rats that had been exposed to isoniazid, rifampicin, and pyrizinamide-induced liver damage. The effects of methanolic extract of *M. oleifera* roots on the haematological and hepatorenal functions of the plant, as well as the effects of different doses of the crude extract (CE) on the liver and kidney functions, have all been documented.[110]
- The hepatoprotective effect of ethanol leaf extract of *M. oleifera* was investigated through oral administration, and the results revealed that the extract considerably lowered the activity of serum hepatic marker enzymes after administration. *M. oleifera* leaf extract was studied for its influence on oxidative stress indicators in acetaminophen-induced hepatotoxicity. The results revealed that administration

Table 2: Phytoconstituents of *M. oleifera*

Phytoconstituents of M. oleifera leaves		
Class of phytoconstituents	*Compound name*	*References*
Flavanol glycosides and flavanoids	Isoquercetin	[119]
	Astragalin,	[119]
	Rhamnetin,	[119]
	Isorhamnetin,	[60]
	Apigenin,	[121]
	Luteolin,	[59]
	Genistein,	[59]
	Daidzein,	[59]
	Myricetin,	[59, 80]
	Epicatechin	[59]
	Procyanidins	[122]
	Vicenin-2	[123]
	Quercetin-3-O-glucoside	[120; 60]
	Quercetin-3-O-(6″-malonyl) glucoside	[59]
	Kaempferol-3-O-glucoside	[59]
	Kaempferol-3-O-(6″-malonyl) glucoside	[59]
	Kaempferol-3-rutinoside	[59]
	Kaempherol-3-O-α-rhamnoside	[120]
	Kaempferide 3-O-(2″,3″-diacetylglucoside	[120]
	Kaempferol-3-O-[β-glucosyl-(1→ 2)]-[α-rhamnosyl-(1→ 6)]-β-glucoside-7-O-α-rhamnoside Kaempferide-3-O-(2″Ogalloylrhamnoside	[120]
	Kaempferol-3-O-[-rhamnosyl-(1→2)]-[-rhamnosyl-(1→4)] -glucoside-7-O-α -rhamnoside	[120]
	4-[(4′-O-Acetyl-_-L-rhamnosyloxy)benzyl] Glucosinolate	[124, 60]

Glucosinolate and isothiocyanate	4-[(α-L-rhamnosyloxy)benzyl] Isothiocyanate	[124, 60]
	4-[(2′-O-acetyl-_-L-rhamnosyloxy) benzyl] Isothiocyanate	[125, 60]
	4-[(3′-O-acetyl-_-L-rhamnosyloxy) benzyl] Isothiocyanate	[125, 60]
	4-[(4′-O-acetyl-_-L-rhamnosyloxy) benzyl] Isothiocyanate	[125, 60]
	Sinalbin	[60]
	Benzyl glucosinolate (glucotropaeolin)	[60
	4-[(β-D-glucopyranosyl-1-α-4-β-Lrhamnopyranosyloxy) benzyl] Isothiocyanate	[79]
Phenolic compound	Gallic acid	[79]
	Salicylic acid	[59]
	Gentisic acid	[59]
	Syringic acid	[59]
	Ellagic acid	[79]
	Ferulic acid	[79]
	Caffeic acid	[59]
	o-Coumaric acid	[59]
	p-Coumaric acid	[59]
	Sinapic acid	[59]
	Chlorogenic acid	[59, 60]
	Cryptochlorogenic acid	[119]
Terpene	All-E-lutein	[58]
	All-E-luteoxanthin	[56, 57]
	13-z-Lutein	[57]
	15-z-_-Carotene	[57]
	All-E-Zeaxanthin	[57]
Alkaloid and Sterol	4′-hydroxyphenylethanamide-α-L-rhamnopyranoside (marumoside A)	[52]
	3″-O-β-D-glucopyranosyl derivatives (marumoside B)	[52]
	N,α-L-Rhamnopyranosyl vincosamide	[126]
	Pyrrolemarumine-4″-O-α-L-rhamnopyranoside	[52]
	Aurantiamide acetate	[127]
	O-Ethyl-4-[(α-L-rhamnosyloxy)-benzyl] carbamate	[128]
	Niazimicin	[128]
	N-benzyl,S-ethylthioformate	[129]
	1, 3-Dibenzyl urea	[127]
	Pterygospermin	[130]
	Niaziminin	[131]
	β-sitosterol	[121, 130]
	β-Sitosterol-3-O-β-D-galactopyranoside	[121, 130]
Others constituents	Oleic acid	[132]
	Linoleic acid	[132]
	Myristic acid	[132]
	Palmitic acid	[132]
	Palmitoleic acid	[54]
	Stearic acid	[132, 54]
	Arachidic acid	[132]
	Linolenic acid	[132]
	Behenic acid	[132]
	Paullinic acid	[132]
	Benzoic acid 4-O-β-rhamnosyl-(1→ 2)-β-glucoside	[120]
	Benzaldehyde 4-O-β-glucoside	[120]
	Niaziridin	[61]

of the extract was effective in replenishing the reduced glutathione levels in the liver, blood, and brain of the animals. In the meantime, the activities of the antioxidant enzymes superoxide dismutase, catalase, and glutathione peroxidase were significantly reduced in the rats that were intoxicated with acetaminophen. When the *M. oleifera* leaf extract was administered, the activity of the antioxidant enzymes superoxide dismutase, catalase, and glutathione peroxidase were successfully increased.[111]

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