A Review on Significance of Moringa oleifera in the Treatment of Heme-Related Disorders and Malnutrition

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Abstract

The Moringa plant is widely grown worldwide because of its ability to withstand both drought and frost. It has ethnopharmacological significance, as Moringa oleifera thrives in tropical and subtropical areas. This plant has two common names: “drumstick tree” and “horseradish tree.” It is possible to eat or sell every part of the tree because of its high nutritional value. This review's objective is to examine the phytochemical composition, therapeutic uses, and pharmacological features of this tree species that serve to treat hematological disorders. There was a thorough search of all of the scholarly databases, including PubMed, Scopus, Google Scholar and ACS, and published books. Vitamins, minerals, and phytochemicals abound in the leaves. Lactating moms may benefit from leaf extracts, which are routinely used to treat malnutrition. It is being researched as an anticancer, antioxidant, anti-diabetic, anti-inflammatory, and antibacterial agent. Natural coagulant M. oleifera seed is utilized in water purification. Even in commercial products, Moringa could be employed to boost the nutritional value or treat ailments like diabetes and cancer, for example. Several elements of commercial, nutritional, and cultivation of Moringa are explored in this article. M. oleifera plant can be used as a nutritional supplement in the treatment of heme-related disorder and malnutrition.

Keywords: Magic tree; nutrition; bio-pesticide; agriculture; food processing

INTRODUCTION

In the developing world, malnutrition has a devastating effect on human health and social and economic development (Dukhi, 2020; Wells et al., 2021). Iron deficiency accounts for half of all cases of anaemia, which affects 162 billion people (24.8 percent of the world’s population) (UNICEF, 2020; Palanog et al., 2019). Iron deficiency can impair a child's ability to grow physically and mentally and hinder their ability to learn and exercise (Roganović, 2018). Histidine, a small organic compound called protoporphyrin, serves as an essential component in haemoglobin and many other essential hemoproteins (Sawicki et al., 2015; Vlasova et al., 2018; Morris and Mohiuddin, 2022; Pasini et al., 2021).

Heme-synthesis-impaired red blood cells may lead to death (Dailey and Meissner, 2013; Yang et al., 2016; Chiabrando et al., 2014; Zivot et al., 2018). Heme production is initiated prior to the synthesis of the globin protein. When valine is substituted for glutamic acid at the sixth position of haemoglobin's chain, a hydrophobic molecule is swapped out for a hydrophilic one, resulting in sickle cell disease (SCD) (Renaudier, 2014; Inusa et al., 2019; Cordovil, 2018). In hypoxic settings, erythrocytes sickle due to a loss of electrical charge (Liu et al., 2019; Grygorczyk and Orlov, 2017; Xu et al., 2020). The most effective means of preventing and treating anaemia are iron supplements and fortified foods (Ramsay, 2015). Both of these methods are out of reach for the poor.

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Moringa oleifera: A Miracle Tree

Moringaceae is a family of just 13 Moringa species (Fahey et al., 2018). Because it is derived from a natural source and has fewer side effects than other nutritional supplements, it is widely used in industrialized countries. As well as Moringa oleifera, many other Moringa species are essential and beneficial to humans, such as M. longituba, M. arborea, M. rivae, M. drouhardii, M. borziana, and M. hildebrandtii.

Born in the sub-Himalayan regions of North-West India and spreading throughout the world, the Moringa oleifera tree is now found in many parts of the Caribbean and South America, a native species and thrives (Mpanga et al., 2020; Devkota et al., 2020). Because of its therapeutic benefits, Moringa, which is a staple meal in these regions, is also well-known and widely used. Because of the therapeutic value of Moringa seed oil, which has a high oleic acid concentration of 72 percent, it is widely utilized in African and Asian countries for medicinal purposes (Dhakad et al., 2019).

The plant parts possess antipyretic, anti-inflammatory, anti-epileptic, and anti-spasmodic properties. It also has diuretic, cholesterol-lowering, anti-hypertensive, antibacterial, antifungal, and antifungal properties in its various parts. Their usage in indigenous systems of medicine, notably in South Asia, to cure a wide range of diseases is well established (Anwar et al., 2007). This plant has been used for centuries to treat a variety of maladies, including asthma, blackheads, impurities in the blood, bronchitis, coughing up mucus, chest congestion, and even the deadly sickness known as cholera, among others. Its potential to lower high blood pressure and cholesterol levels, as well as its ability to protect the liver and kidneys from damage caused by diabetes and other metabolic illnesses, are just a few of the benefits of Moringa oleifera (Nova et al., 2020; Mbikay et al., 2012; Akter et al., 2021).

In addition to its excellent cosmetic properties, Moringa has recently gained popularity as an ingredient in several healthcare products, including body and hair moisturizers and conditioners. Moringa oil has been discovered to be used in various skin ointment compositions dating back to ancient Egypt (Ahmad, 2014; Nadeem and Imran, 2016; González-Miner and Bravo-Díaz, 2018). Because its antioxidant and phytochemical qualities will help animal feed and food processing, human nutrition will benefit from its inclusion, and the human diet will profit from its inclusion as a novel food element. Figure 2 illustrates how the plant M. oleifera can be employed in different businesses.
Botanical description of M. oleifera

Morphology and physical characteristics

Trees like the Moringa have a unique morphology and physical traits that set them apart from the rest of the natural world. Even though it may grow up to 10 metres (33 feet) in height, this tree is usually considered small to medium-sized due to its lower size (Figure 3).

Stem

The stem is usually straight, although it can occasionally be curved due to the plant's growth process. Before branching, the tree has a short, straight stem that can reach a height of 1.5-2 metres before branching.

Branch

The umbrella-shaped canopy formed by the branches' disorganized growth protects the ground underneath it.

Leaves

Tripinnate compound leaves have elliptical, 1-2 cm long, light green to dark green, green to dark green leaflets. Because the leaves of this tree resemble those of a legume, it is often mistaken for one. The tips of the branches are typically where the alternate, twice, or three times pinnate leaves are found. Long petiole, 8-10 pairs of pinnae, and two pairs of opposing, elliptical or oblone leaflets, each with an apex, allow them to grow from 20-70 cm in length (Raja et al., 2016).

Flowers

Creamy-white to ivory-white It is found on inflorescences between 10-25cm (4-10in) long and stems between 10-25cm (4-10in) long and features white to cream-coloured 2.5cm-diameter flowers, with five at the top of the flower; axillary panicles that are drooping Plants that are 10-25 cm long yield flowers that are 2.5 cm wide and 10-25 cm long. A white or cream colouration is seen at the plant's base, dotted with yellow spots. Five reflexes adorn the linear-lanceolate sepals. The five petals of this flower have slender-patulate forms. Except for the lowest stamen, they entirely encircle the five stamens and five staminodes (Raja et al., 2016).

Fruits

There are several more names for these trilobed fruit capsules besides fruits, including Pods. Immature pods of some cultivars are green or reddish, which is frequent. These pendulous, dark-brown, triangular pods dry to a width of 1.8 cm and contain about 20 sec buried in the pith. They are divided lengthwise into three halves and measure 30 to 120 cm in length. The pods are pendulous, dark brown, triangular, and split lengthwise into three sections when dry.

Seeds

They contain three papyry wings and a brownish semi-permeable seed shell, borne in clusters. Three white wings cover the top and bottom of the hull at 120° intervals, spanning the top and bottom of the hull. Seed hulls with low viability can look white due to the presence of low-viability kernels. Healthy seeds begin to germinate within two weeks of being planted. Depending on the species, a tree can generate anywhere between 15,000 and 25,000 seeds each year. When it comes to seed weight, the kernel to hull ratio is 75:25, with an average seed weight of 0.3 g.

Traditional and commercial uses

Regular consumption of M. oleifera may help prevent degenerative disorders such as Alzheimer's (Sutalangka et al., 2013). Aside from rheumatism, venomous attacks, enhanced cardiac function, inflammation and liver illness, M. oleifera is also thought to improve haematological, renal, and liver function. A wide range of ailments, including inflammation and infectious diseases, digestive, cardiovascular, haematological, and hepatic problems, can be treated with this plant's practically limitless number of parts, including the root. More than two thousand years have passed since Moringa was used in traditional medicine for treating anything from acne to anaemia to asthma to blemishes and blood disorders. The treatment of cholera, conjunctivitis, bronchitis, cataracts, psoriasis, hysteria, scurvy, psoriasis of the eyes and ears, swelling, hysteria, psoriasis, irregular blood pressure, psoriasis, respiratory illnesses, and semen insufficiency has all been accomplished with it as well.

Traditional medicine practitioners have long recognized Moringa oil therapeutically potential. Moisturizing and skin conditioning properties of Moringa oil can be applied to the body and hair. Moringa oil has been used in skin preparations and ointments since the time of the Egyptians. It has anti-Vata and anti-Kapha properties. An added benefit is lowered infection risk. It is incredibly effective in terms of igniting the neurological system. Constipation, worm infestation, and digestive issues benefit from its harsh flavour and astringent texture. Because of its potency, it elevates blood pressure and stimulates the heartbeat. Bitterness has antitussive and mucus-resolving effects. The intense potency of the plant makes it easier to maintain a regular menstrual cycle. Because it stimulates the body to perspire, it is also effective for treating skin conditions. It can be used in everything from cosmetics to dietary supplements to pharmaceuticals. Kiranawati et al. came up with the concept of Moringa noodles using three distinct cooking methods, i.e. sautéing, steaming, and boiling. To see if this strategy enhanced milk production in rats, researchers fed them sautéed noodles to test it out. There are now M. oleifera-based chocolates on the market, as well. A recent study found that integrating 20% Moringa powder into the cocoa powder was the best amount of Moringa to incorporate in the chocolate fortification. The nutritious value of halawa was improved by the addition of Moringa. Chocolate and halawa rich in protein and minerals
can be made, as a study has revealed (Abou-zaid et al.,
2014).

The nutritional value of Moringa-based foods for children
can be improved in several manners. Perfumes and
lubricants can benefit from olive oil’s versatility as a cooking
replacement. The pods can absorb insecticides and other
organic contaminants. For example, aluminium sulphate
(alum) and ferric sulphate (Fe) or polymers remove
suspended particles in wastewater by neutralizing the
electrical charges of suspended particles in the water to
produce flocs, which make particles filterable. Using a
cationic protein found in M. oleifera seed, murky water can
be made clear once again. There are many antimicrobial
qualities in seed extracts, including the ability to inhibit the
growth of bacteria. Because M. oleifera seeds are readily
available in rural areas, they can be utilized to prevent
disease and improve quality of life. In addition to being a
source of biodiesel and cosmetics, the seeds of the Moringa
plant can be utilized as green manure or fertilizer. Moringa
blossoms can be used to make a cholesterol-lowering tea
( Abd El-Hack et al., 2018).

According to legend, Fry Moringa flowers will look like
mushrooms (Arise et al., 2014). For their honey, beekeepers
collect nectar from Moringa blossoms. The root bark is used
to cure dyspepsia, eye disorders, and heart problems
(Adejumo et al., 2012). Moringa’s taproot is used as a spice
in many Asian dishes. Printing on calico can be achieved
using the tree’s gum as ink. In addition, the gums and roots
contain antibacterial, antifungal, and anti-inflammatory
compounds (Shank et al., 2013). Zeatin, a plant growth
hormone, is a tremendous foliar that can increase crop yields
by 25% to 30%. According to Fuglie, 2015 Moringa
inclusion and fortification may be helpful in the fight against
malnutrition and nutrient insufficiency. Various dishes have
included Moringa as an ingredient. Cookies created using a
combination of maize flour and Moringa seed flour was
found to taste better than cookies made with just one of these
two ingredients. 92.5% maize flour and 7.5 percent Moringa
seed flour were the most popular. The flours were blended
in varying quantities. Crispness, scent, flavour, and aesthetic
appeal made this a tremendous hit with the crowds.
Additionally, Owusu and Oduro (2011) used Moringa and
Ipomoea batatas to fortify their cream and butter crackers to
raise the nutritional content of the snacks. After a taste test,
it was discovered that cream crackers were rather popular.
M. oleifera leaves can be substituted for more expensive
items like soybean meal and groundnut cake in hens and
layer birds (Raphal, 2015; Olugbemi et al., 2010). Several
studies have shown that Moringa can be added to maize flour
to boost the snack's protein, energy, and minerals content.
Before Moringa as an Indian snack gets commercialized,
further research into its benefits has to be done.

**Nutritional composition of Moringa oleifera**

Because of their high nutrient content and low anti-
nutritional components, M. oleifera products have been
widely recognized and employed in human and livestock
diets. According to recent studies, the plant’s leaves, seeds,
and stems are packed with protein, amino acids, minerals,
vitamins, and other bioactive components. In the leaves of M.
oleifera, crude protein concentrations range from 10.74 -
30.29 g/100 g of dry matter. There are 13.41–63.11 g/100 g
of carbohydrates, 6.50–20.00 g/100 g of lipids, and 7.64–
10.71 g/100 g of ash for crude fibres. M. oleifera leaf contains
the highest concentration of α-Linolenic acid among its
unsaturated fatty acids (57%) (Moyo et al., 2011; Milla et al.,
2021). Most of the fatty acids are saturated (43%). The M.
oleifera leaf contains 16 to 19 amino acids depending on the
source. A significant concentration of vitamins A, B, C, and
E in the M.oleifera leaf can help combat malnutrition in
infants and nursing mothers (Falowo et al., 2018). This
flower's protein content is 25%, its fiber content is 7.55%.,
its ash content is 6.1%, its fat content is 1.57%, its water content
is 5.78%, and its carbohydrate content is 53.67%. (Arise et al.,
2014). M. oleifera seeds, on the other hand, had a crude
protein and fat content of 39.12% and 40%, respectively
(Liang et al., 2019).

**Phytoconstituents of M. oleifera**

Niaziarin A and Niazinimin B are two of the three mustard oil
glycosides found in the leaves. There are four benzyl
isothiocyanates, three mustard oil glycosides, and a
thiocarbamate called niaziminin. Quercetin-3-O-glucoside
and quercetin-3-O-(6′′-Malonyl-glucoside),Niazimicin are
two related compounds. Potent antioxidants include the 40-
hydroxyphenylethanalamide (marumoside A and B) and
the pyrrole alkaloid (pyrrolemarumine 400-O-A-
rhamnopyranoside) in particular Niazimicin and niazinimicin
niazirin are discovered in the seeds of the plant that is high in
both methionine and cysteine. A wide range of compounds
present in the pods, including methyl-p-hydroxybenzoate,
beta-sitosterol, isothiocyanate, and thiocarbamates. Besides
Moringine and Moringinine, the roots include Spirachin, 1, 3-
dibenzy lurea, alpha-phenllandrene, p-cymene, Deoxy-
niazimicine, and 4-(alpha L-rhamnopyranosyloxy)benzyl
glucosinolate (Paikra et al., 2017) (Table 1 and Figure 4).

**Health benefits of Moringa oleifera**

Phytomedicines as an alternative to conventional
pharmaceuticals are receiving increased attention. For
centuries, Moringa oleifera has been used as food and
medicine in various parts of the world. Researchers have
linked this plant with many health benefits, including
nutritional and medicinal. Essential amino acids and
carotenoids are available in Moringa oleifera leaves and can
be used in food preparation (Oyeinika and Oyeinika, 2018).
The nutrient content of leaf and stem samples has been
determined through laboratory testing. Essential antibiotics,
antioxidants, and vitamins and minerals contribute to
Moringa oleifera's vast spectrum of medical benefits. There
are numerous uses for the Moringa tree’s various parts,
including providing food or other benefits (Abdull Razis et
al., 2014). The white blossoms include anti-inflammatory,
antioxidant, and neuroprotective effects. The white blossoms
also contain vitamin E and calcium. The stem's anti-obesity,
Research evidence of the efficacy of M. oleifera in blood-related disorders

According to researchers, supplementation with M. oleifera leaf powder reduced anaemia in children under two years of age (Shija et al., 2019). Mean Hb concentrations were 7.9 g/dl in control and 8.3 g/dl in the intervention groups at baseline. In the intervention group, anaemia prevalence decreased by 53.6 percent compared to 13.6 percent in the control community after six months. As the amount and length of time of M. oleifera supplementation increased, anaemia cases decreased significantly, making it a viable alternative to infant formulas and fortified food products in treating anaemia in children, mainly if they use these products low (Shija et al., 2019). Thirty-four participants (excluding pregnant and lactating women) were randomly assigned to receive a three-month supply of the value-added supplement "Moringa oleifera" in a research study. Three meals a day were incorporated into the diet by making these recipes a regular part. Dried Moringa powder was used in each recipe in about 15 g. Three females out of 34 had normal Hb levels of 12 g/dl after the intervention. Overall, 94% of the study's participants saw an average increase of 1.8 g/dl in Hb levels after the intervention. The Hb level and the increase in Hb level were significantly correlated, with a p-value of 0.001 for each (0.928). When it came to improving haemoglobin levels after the intervention, age and educational attainment were weakly but significantly (p=0.001) linked (Anwar and Bhaner, 2003).

Anaemic women were the subjects of a 2017 study by Suzana et al., randomized, double-blind, and placebo-controlled. Moringa leaf water extract (200 mg/tablet) was tested as an additional therapy for a patient taking ferrous sulphate (200 mg/tablet). MCHC (Mean Corpuscular Haemoglobin Concentration) (2.4592 g/dL) and RDW (Red Distribution Wide) (1.42 percent) were all significantly higher, while platelets (36529.4±59024.48/uL) were significantly lower. They found that women with iron deficiency anaemia could benefit from taking Moringa leaves extract. Moringa oleifera leaves were tested for antisickling effects on sickle cell haemoglobin by Nwaoguikpe et al., 2015. There were 88.88% for the WAS (water-soluble) fraction up to 98.35% for the FAS (fat-soluble) fraction antisickling effects found by the researchers. The Fe2+/Fe3+ ratio improved between 5.48 percent and 18.89 percent. Antisickling efficacy of the haemoglobin polymerization inhibition experiment fractions, antisickling amino acids, and other nutritional syndromes may all point to the possibility that Moringa oleifera leaf extracts hold therapeutic promise for treating sickle cell disease and other related nutritional syndromes. Moringa leaves are rich in phytoneutrins. When pregnant women are given Moringa oleifera leaf flour biscuits, does their haemoglobin level, iron intake, and zinc intake improve? It was addressed by Manggil et al., 2021. Researchers in Karnataka tested the efficacy of Moringa powder on anaemic children to increase their haemoglobin levels (Nandimath et al., 2021). Only iron tablets were consumed by the control group, which was given Moringa leaf flour (40%) and a combination of 2 times 250 mg of iron tablets per biscuit. Haemoglobin levels rose significantly, iron intake increased, and zinc intake increased. After the intervention, the children in the interventional group had an average haemoglobin level of 10.967 g/dL higher than before. According to the study's author, an improvement in haemoglobin levels was noted after three months in the intervention group.

M. Oleifera in treatment therapies

For thousands of years, the roots, seeds, flowers, and leaves of the Moringa tree have been used as a natural remedy. Moringa has long been used in Ayurvedic medicine, from inflammation to joint pain to cardiovascular issues. Moringa is an excellent source of Vitamin B, Vitamin C, Vitamin A, magnesium, protein, iron, calcium, and essential amino acids (Saa et al., 2019). Many studies have shown Moringa's ability to fight off fungal and viral infections and alleviate depression and inflammation. Using Moringa to prevent cancer and treat digestive issues and prevent obesity, seizure prevention, and enhance the animal's immune system is beneficial to animals. Salmonella typhimurium, E. coli, Candida, and Helicobacter pylori have all been inhibited by Moringa (H. pylori). Moringa oleifera leaf aqueous extract is beneficial in treating high blood pressure in both animal and human studies (high BP). Moringa oleifera extract (MOE) lowers blood pressure by relaxing small resistance arteries, activating the eNOS-NO-sGC pathway (Xiao et al., 2011). Endothelial dysfunction and hyperactive vasoconstriction are effective treatments for hypertension in rats, but Moringa leaves (MOE) on endothelial NO production about the reduction of blood pressure (BP) remains unclear.

Moringa oleifera: Research development

The edible medicinal herb Moringa oleifera alleviates malnutrition in Africa. The phenolic profiles and bioactivities of M. oleifera flowers, fruits, and seeds from Guinea-Bissau were examined using hydroethanolic and aqueous extracts. This research was carried out. Fruits and flowers (31 g/100 g dw) showed more significant concentrations of proteins, fats, carbs, citric acid, and glycosylated flavonoids than seeds (11 g/100 g dw). Researchers found hitherto undiscovered polyphenols in M. oleifera. Hydroxyethanolic extracts included more polyphenols and were better able to combat NO and tumour cell proliferation formation than aqueous or methanolic extracts. Antimicrobial activity against bacteria
and fungi was observed in both aqueous and hydro-ethanolic extracts (Fernandes et al., 2021).

In cruciferous vegetables such as broccoli, cabbage, and Brussels sprouts, sulfur-containing phytochemicals known as glucosinolates can be found in abundance. According to recent research, Moringa, also known as the drumstick tree or the horseradish tree, has been found to contain high levels of these beneficial compounds. Many of the plant's medicinal properties can be attributed to its unique glucosinolates, which are found in abundance in Moringa, according to research published in the journal Scientific Reports in May 2018.

Myrosinase converts glucosinolates, which are inert, into bioactive isothiocyanates (Nguyen et al., 2020). Moringin, formed by hydrolysis of glucomoringin, is the primary isothiocyanate in Moringa and is responsible for many of the plant's health benefits (Borgonovo et al., 2020). 4-(alpha-L-rhamnopyranosyl)ox)benzyl isothiocyanate (also known as 4RBITC) is a common name for moringin. Anti-inflammatory and cytoprotective properties of moringin are similar to those of sulforaphane found in broccoli.

Because the Moringa plant can withstand drought, researchers looked into the role of heat shock transcription factors (HSFs) in regulating plant responses to abiotic stress. Orthologous groups critical to plant growth and survival were discovered through high-quality genome sequencing in M oleifera.

CONCLUSION

The pharmacological activities of Moringa oleifera, a member of the Moringaceae family, are diverse. As a result, the majority of the plant's parts are employed to treat a wide variety of illnesses. In addition to being able to help restore degraded soil, it is a tropical tree that requires little water. The environment benefits from it in numerous ways. Rural people benefit financially from it, and it also helps fight starvation while also cleaning up the environment and reversing deforestation.

REFERENCES


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Figure 1 Schematic representation of hemolysis of an RBC releasing haemoglobin and heme from the cell

Figure 2 Moringa oleifera can be used in a variety of ways in food systems and agro-processing
Figure 3 Morphological of M. oleifera plant

Figure 4 Phytoconstituents present in M. oleifera plant
**Table 1** Active constituents found in M. oleifera plant

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Chemical structure</th>
<th>Plant part</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flavonoids and Flavanol glycosides</td>
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<tr>
<td>Rutin</td>
<td><img src="image" alt="Rutin structure" /></td>
<td>Leaves</td>
<td>Leone et al., 2015b</td>
</tr>
<tr>
<td>Quercetin</td>
<td><img src="image" alt="Quercetin structure" /></td>
<td>Leaves</td>
<td>Elbatran et al., 2005</td>
</tr>
</tbody>
</table>
Isoquercetin

Astragalin

Isorhamnetin

Kaempferol

Apigenin
Sirajunisa Talath et al.: A Review on Significance of Moringa oleifera in the Treatment of Heme-Related Disorders and Malnutrition

Luteolin

Genistein

Diadzein

Myricetin

Epicatechin
Sirajunisa Talath *et al.*: A Review on Significance of Moringa oleifera in the Treatment of Heme-Related Disorders and Malnutrition

Procyanidins

![Procyanidins](image)

Vicenin-2

![Vicenin-2](image)

Quercetin-3-O-glucoside

![Quercetin-3-O-glucoside](image)

Glucosinolate and Isothiocyanate

- **Glucomoringin**
  - ![Glucomoringin](image)
  - Leaves, seeds
  - Tumer *et al.*, 2015

- **Glucotropaeolin**
  - ![Glucotropaeolin](image)
  - Seed
  - Saini *et al.*, 2016

Phenolic acid
Sirajunisa Talath et al: A Review on Significance of Moringa oleifera in the Treatment of Heme-Related Disorders and Malnutrition

Gallic acid

Leaves  Verma et al., 2009

Salicylic acid

Leaves  Leone et al., 2015a

Gentisic acid

Leaves  Leone et al., 2015a

Syringic acid

Leaves  Leone et al., 2015a

Ellagic acid

Leaves  Verma et al., 2009;

Ferulic acid

Leaves  Verma et al., 2009;
Caffeic acid

![Caffeic acid](image)

Leaves  Leone et al., 2015a

Coumaric acid

![Coumaric acid](image)

Leaves  Leone et al., 2015a

Sinapic acid

![Sinapic acid](image)

Leaves  Leone et al., 2015a

Clorogenic acid

![Clorogenic acid](image)

Leaves  Verma et al., 2009;

Cryptochlorogenic acid

![Cryptochlorogenic acid](image)

Leaves  Vongsak et al., 2014

Terpene

![Terpene](image)

Pods  Saini et al., 2017

Alkaloid and Sterol
Sirajunisa Talath et al: A Review on Significance of Moringa oleifera in the Treatment of Heme-Related Disorders and Malnutrition

Marumoside A

Leaves

Sahakitpichan et al., 2011

Marumoside B

Leaves

Sahakitpichan et al., 2011

N, α-L-Rhamnopyranosyl vincosamide

Leaves

Panda et al., 2013
Aurantiamide acetate

Roots

Sashidara et al., 2009

Niazimicin

Leaves, seeds

Jung, 2014

Beta-sitosterol

Leaves, seeds

Abdel-Rahman Tahany et al., 2010;

**Table 2 Biological activity of M. oleifera**

<table>
<thead>
<tr>
<th>Extract</th>
<th>Part</th>
<th>Biological activity</th>
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<tbody>
<tr>
<td>Aqueous</td>
<td>Leaf</td>
<td>Lipid-lowering and antiatherosclerotic activities</td>
<td>Chumark et al., 2008</td>
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<tr>
<td>Aqueous</td>
<td>Fruit, leaf and seeds</td>
<td>Antioxidant activity</td>
<td>Singh et al., 2009</td>
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<td>Leaf</td>
<td>Antioxidant and cardioprotective activities</td>
<td>Nandave et al., 2009</td>
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<td>Leaf</td>
<td>Anticancer and antioxidant properties</td>
<td>Sreelatha et al., 2011</td>
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<td>Hydro-alcoholic extract</td>
<td>Fruit, leaf and seeds</td>
<td>Liver tonic</td>
<td>Fakurazi et al., 2012, Ujah et al., 2013</td>
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<td>Anticancer activity</td>
<td>Lea et al., 2012</td>
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<td>Reducing nuclear factor-kappaB activity reduces inflammation.</td>
<td>Berkovich et al., 2013</td>
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<tr>
<td>Ethanol</td>
<td>Leaf</td>
<td>Upregulation of TNF-α</td>
<td>Akanni et al., 2014</td>
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<td>Ethanol</td>
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<td>Decrease lipid and cholesterol levels in rats</td>
<td>Atsukwei et al., 2014</td>
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<td>Solvent</td>
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<td>Methanol</td>
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<td>Anti-inflammatory, antioxidant, and anticancer activities</td>
<td>Adedapo et al., 2014</td>
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<tr>
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<td>Leaf</td>
<td>Antioxidant and antimicrobial activities</td>
<td>Ratshilivha et al., 2014</td>
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<td>Seeds</td>
<td>Antimicrobial activity</td>
<td>Emmanuel et al., 2014</td>
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<td>Ethanol</td>
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<td>Chuang et al., 2007</td>
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<td>Ethanol and chloroform</td>
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<td>Antimicrobial activity against Pseudomonas aeruginosa, Staphylococcus aureus, Enterobacter aerogenes and Escherichia coli</td>
<td>Bukar et al., 2010</td>
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<td>Antimicrobial activity against Escherichia coli and Staphylococcus aureus</td>
<td>Ferreira et al., 2011</td>
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<td>Chloroform, aqueous</td>
<td>Pod husks</td>
<td>Klebsiella pneumoniae, Salmonella typhimurium and Escherichia coli are all antimicrobial targets for this compound.</td>
<td>Arora and onsare, 2014</td>
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<td>Acetone</td>
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<td>A broad spectrum of antimicrobial activity against Aspergillus fumigatus, Candida albicans, Staphylococcus aureus, Enterococcus faecalis, Escherichia coli, Pseudomonas septica and Cryptococcus neoformans</td>
<td>Ratshilivha et al., 2014</td>
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<td>Methanol, aqueous and</td>
<td>Seeds</td>
<td>Inhibition of E. coli, Klebsiella pneumonia, Proteus mirabilis, P. aeruginosa, and Staphylococcus aureus microbiological activity.</td>
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