Original Article

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

Sirajunisa Talath[1]*, Hemalatha K[2], Adil Farooq Wali[3]

[1,3]Department of Pharmaceutical Chemistry, RAK College of Pharmacy, RAKMHSU, POB 11172, Ras Al Khaimah, UAE

[2]Department of Pharmacognosy, Acharya & BM Reddy College of Pharmacy, Bangalore-560 107, Karnataka, India.

Email: sirajunisa@rakmhsu.ac.ae

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).

Access this article online

Quick Response Code:

Website: www.pnrjournal.com

DOI: 10.47750/pnr.2022.13.04.061

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.

Address for correspondence: Sirajunisa Talath, Department of Pharmaceutical Chemistry, RAK College of Pharmacy, RAKMHSU, POB 11172, Ras Al Khaimah, UAE, Email: sirajunisa@rakmhsu.ac.ae

Received date: 10 August 2022 Accepted: 23 September, 2022

Published: 07 October, 2022

How to cite this article: Talath S, K H, Wali F A, A Review on Significance of Moringa oleifera in the Treatment of Heme-Related Disorders and Malnutrition, J Pharm Negative Results 2022;13(4):473-491.

previous studies have found that 97 percent of women do not get enough iron in their diets (Milman et al., 2019). Iron depletion, including through menstruation, may also cause iron deficiency (Moschonis et al., 2013). Moringa oleifera has been used in low-cost, culturally acceptable recipes to boost iron intake in India (Su and Chen, 2020; Thurber and Fahey, 2009; Meireles et al., 2020). Moringa oleifera Lam, a native Indian medicinal herb, has gained popularity in tropical and subtropical regions. The Brassicaceae family includes Moringa oleifera, a vegetable in the Brassica genus. Moringa oleifera leaves are a good source of iron and other nutrients essential for iron metabolism (Islam et al., 2021; Sultana, 2020; Saini et al., 2014). M. oleifera helps relieve blackheads, conjunctivitis (which includes a runny nose), bronchitis (includes catarrh), cholera (which includes diarrhoea), ear infections, fever, swelling of the glands as well as abnormal blood pressure (Vergara-Jimenez et al., 2017; Chaudhary and Chaurasia, 2017; Suresh and Sisodia, 2018).

Moringa oleifera, a plant native to Africa, is an effective remedy for malnutrition (Alegbeleye, 2017; Dhakar et al., 2011). There are numerous phytochemicals in the Moringa plant, including pods, leaves, and seeds, making it an excellent nutrition source. A long-term solution to malnutrition can be found in the easy-to-grow Moringa tree. Deficiency in breast milk can lead to signs of malnutrition in children. Lactogogues are commonly used by lactating mothers to boost milk production (NLM et al., 2006; Raguindin et al., 2014; Yuliastuti, 2018). Lactogogue, which contains phytosterols, aids in reproductive growth (Bekoe, 2019; Saeed and Saeed, 2020; Maurya et al., 2021). Even though Moringa leaf and other products are widely used in food and medicine, few clinical trials support their efficacy in humans, despite their many uses (Brilhante et al., 2017). This paper focuses on the iron deficiency disorders and malnutrition that can be alleviated by using M. oleifera Lam. as a food source and the phytosterols like zeatin, stigmasterol, caffeoylquinic acid, sitosterol, and kampesterol found in Moringa's phytosterols (Gopalakrishnan et al., 2016). Moringa's nutritional value, cultivation, therapeutic benefits, and pharmacological properties are all included in this study.

Pathophysiology of hemolytic disorders

Endothelial dysfunction in hemolytic diseases can be caused by increased circulating free heme or increased enzyme activity that produces reactive species. Haemoglobin, or Hb, can be released from red blood cells when Fe2+/Fe3+ heme is oxidized (RBCs). Blood plasma is swiftly destroyed or transferred to tissues like the liver for the breakdown of heme or haemoglobin under normal physiologic conditions. These reactive species, responsible for the oxidation of lipids, proteins, and DNA, cause endothelial dysfunction and a decrease in vascular homeostasis. Haptoglobin binds to hb so that it can be degraded (Hp).In the liver, the enzyme heme oxygenase-1 (HO-1) breaks down hemopexin (Hx) into iron, carbon monoxide (CO), and biliverdin, which can then be stored or redistributed. The high amounts of hemolysis in hemolytic disorders cause Hx and HO-1 to become saturated. An immunological response is generated when these pathways are depleted, activating the Toll-like receptor-4 (TLR4). ROS can be generated in two different ways, involving heme (Figure 1). If an individual has sickle cell disease (SCD), he/she may have elevated xanthine oxidase levels in their blood. However, the role of this enzyme in these diseases is still unknown (Schmidt and Kelley, 2019).

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-Minero 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 oblong 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 papery 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 anxiety 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 (Fer) 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

Niazirin A and Niaziminin 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-hydroxyphenylethanamide (marumoside A and B) and the pyrrole alkaloid (pyrrolemarumine 400-O-aL-rhamnopyranoside) in particular Niazimicin and niazimicin 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-dibenzylurea, alpha-phellandrene, 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 (Oyeyinka and Oyeyinka, 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,

anti-inflammatory, and cardioprotective properties are only some of the other benefits. As an example, it is a good source of iron and zinc and provides a wide range of health advantages. The seeds vitamin C and E content have antidiabetic, anti-cholesterolemic, and antimicrobial characteristics. The common populace has dubbed it "the miracle tree" because of its miraculous healing abilities (Table 2).

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 Bhanger, 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 (36529.41±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 phytonutrients. When pregnant women are given Moringa oleifera leaf flour biscuits, does their haemoglobin level, iron intake, and zinc intake improve? It was addressed by Manggul 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 olifera 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-rhamnopyranopyranosyloxy)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

Abd El-Hack ME, Alagawany M, Elrys AS, Desoky E-SM, Tolba HMN, Elnahal ASM, et al. Effect of Forage Moringa oleifera L. (Moringa) on Animal Health and Nutrition and Its Beneficial Applications in Soil, Plants and Water Purification. Agriculture. 2018;8.

Abdull Razis AF, Ibrahim M, Kntayya S. Health Benefits of Moringa oleifera. Asian Pac J Cancer Prev. 2014;15:8571–6.

Abdull Razis AF, Ibrahim MD, Kntayya SB. Health benefits of Moringa oleifera. Asian Pac J Cancer Prev. 2014;15(20):8571-6.

Abou-zaid AA, Nadir AS. Quality evaluation of nutritious chocolate and halawa tahinia produced with Moringa (Moringa oleifera) leaves powder. Middle East J. Appl. Sci.2014;4:1007-1015

Adedapo A, Falayi O, Oyagbemi A. The antioxidant, anti-inflammatory and antinociceptive activities of the methanol leaf extract of Moringa oleifera in some laboratory animals (657.19) FASEB J. 2014;28(1):657.19.

Adejumo O.E., Kolapo A.L., Folarin A.O. Moringa oleifera Lam. (Moringaceae) grown in Nigeria: in vitro antisickling activity on deoxygenated erythrocyte cells. J. Pharm. Bioall. Sci., 2012;4:118-122

Ahmad WA. A Review of Moringa Oleifera Lam Seed Oil Prospects in Personal Care Formulations. J Pharm Nanotechnol. 2014;2:31–4.

Akanni OE, Adedeji AL, Oloke KJ. Upregulation of TNF-α by ethanol extract of Moringa oleifera leaves in benzene-induced leukemic Wister rat: a possible mechanism of anticancer property. Cancer Res. 2014;74(19):3792–3792.

Akter T, Rahman MA, Moni A, Apu MA, Fariha A, Hannan MA, et al. Prospects for Protective Potential of Moringa oleifera against Kidney Diseases. Plants. 2021; 10.

Alegbeleye OO. How Functional Is Moringa oleifera? A Review of Its Nutritive, Medicinal, and Socioeconomic Potential. Food Nutr Bull. 2017;39(1):149–70.

Aluko O., Brai M.R., Adelore A.O. Materials evaluation of sensory attributes of snack from maize-Moringa seed flour blends. Int. J. Innov. Res. Sci. Eng. Technol., 2013;7:597-599

Anwar F, Latif S, Ashraf M, Gilani AH. Moringa oleifera: a food plant with multiple medicinal uses. Phytother Res. 2007;21(1):17-25.

Anwar, F., & Bhanger, M. I. (2003). Analytical characterization of Moringa oleifera seed oil grown in temperate regions of Pakistan . Journal of Agricultural and Food Chemistry, 51, 6558-6563.

Arise A, Arise R, Sanusi M, Esan O, Oyeyinka S. Effect of Moringa oleifera flower fortification on the nutritional quality and sensory properties of weaning food. Croat J Food Sci Technol. 2014;6:65–71.

Arise A.K., Arise R.O., Sanusi M.O., Esan O.T., Oyeyinka S.A. Effect of Moringa oleifera flower fortification on the nutritional quality and sensory properties of weaning food. Croat. J. Food Sci. Technol. 2014;6:65-71

Arora DS, Onsare JG. In vitro antimicrobial evaluation and phytoconstituents of Moringa oleifera pod husks. Ind Crops Prod. 2014;52:125–135.

Atsukwei D, Eze ED, Adams MD, et al (2014) Hypolipidaemic Effect of Ethanol Leaf Extract of Moringa oleifera Lam. in Experimentally induced Hypercholesterolemic Wistar Rats. Int J Nutr Food Sci 3:355.

Bekoe EO. Medicinal Plants Used as Galactagogues. In: Kitcher C, editor. Rijeka: Intech Open; 2019. p. Ch. 4.

Berkovich L, Earon G, Ron I, et al. Moringa oleifera aqueous leaf extract down-regulates nuclear factor-kappaB and increases cytotoxic effect of chemotherapy in pancreatic cancer cells. BMC Complement Altern Med. 2013;13:212.

Borgonovo G, De Petrocellis L, Schiano Moriello A, Bertoli S, Leone A, Battezzati A, et al. Moringin, A Stable Isothiocyanate from Moringa oleifera, Activates the Somatosensory and Pain Receptor TRPA1 Channel In Vitro. Molecules. 2020;25(4):976.

Brilhante RS, Sales JA, Pereira VS, Castelo-Branco D de SC, Cordeiro R de A, de Souza Sampaio CM, et al. research advances on the multiple uses of Moringa oleifera: A sustainable alternative for socially neglected population. Asian Pac J Trop Med. 2017;10(7):621–30.

Bukar A, Uba A, Oyeyi T. Antimicrobial profile of Moringa oleifera lam. Extracts against some food—borne microorganisms. Bayero J Pure Appl Sci. 2010.

Chaudhary K, Chaurasia S. Neutraceutical Properties of Moringa oleifera: A Review. Eur J Pharm Med Res. 2017;4:646–55.

Chiabrando D, Vinchi F, Fiorito V, Mercurio S, Tolosano E. Heme in pathophysiology: a matter of scavenging, metabolism and trafficking across cell membranes. Frontiers in Pharmacology. 2014;5.

Chuang PH, Lee CW, Chou JY. Antifungal activity of crude extracts and essential oil of Moringa oleifera Lam. Bioresour Technol. 2007;98:232–236

Chumark P, Khunawat P, Sanvarinda Y, et al. The in vitro and ex vivo antioxidant properties, hypolipidaemic and antiatherosclerotic activities of water extract of Moringa oleifera Lam. leaves. J Ethnopharmacol. 2008;116:439–446.

Cordovil K. Sickle Cell Disease: A Genetic Disorder of Beta-Globin. Edited by AL-Zwaini I. In Rijeka: IntechOpen; 2018. p. Ch. 7.

Dailey HA, Meissner PN. Erythroid heme biosynthesis and its disorders. Cold Spring Harb Perspect Med. 2013;3(4):011676.

Devkota S, Bhusal KK. Moringa oleifera: A miracle multipurpose tree for agroforestry and climate change mitigation from the Himalayas – A review. Yildiz F, editor. Cogent Food Agric. 2020;6(1):1805951.

Dhakad AK, Ikram M, Sharma S, Khan S, Pandey VV, Singh A. Biological, nutritional, and therapeutic significance of Moringa oleifera Lam.

Phytother Res. 2019;33(11):2870-2903.

Dhakar RC, Maurya S, Pooniya B, Bairwa N, Gupta M, Sanwarmal. Moringa: The herbal gold to combat malnutrition. Chronicles Young Sci. 2011;2:119–26.

Dukhi N. Global Prevalence of Malnutrition: Evidence from Literature. In Rijeka: IntechOpen; 2020. p. Ch. 6.

Emmanuel SA, Olajide OO, Abubakar S, et al. Phytochemical and antimicrobial studies of methanol, ethyl acetate, and aqueous extracts of Moringa oleifera seeds. Am J Ethnomedicine. 2014;1:346–354.

Fahey J, Olson M, Wade K, Chodur G, Odee D, et al. The Diversity of Chemoprotective Glucosinolates in Moringaceae (Moringa spp.). Sci Rep. 2018;8.

Fakurazi S, Sharifudin SA, Arulselvan P. Moringa oleifera hydroethanolic extracts effectively alleviate acetaminophen-induced hepatotoxicity in experimental rats through their antioxidant nature. Molecules. 2012;17:8334–8350.

Falowo AB, Mukumbo FE, Idamokoro EM, Lorenzo JM, Afolayan AJ, Muchenje V. Multi-functional application of Moringa oleifera Lam. in nutrition and animal food products: A review. Food Res Int. 2018;106:317–34.

Fernandes Â, Bancessi A, Pinela J, Dias MI, Liberal Â, Calhelha RC, Ćirić A, Soković M, Catarino L, Ferreira ICFR, Barros L. Nutritional and phytochemical profiles and biological activities of Moringa oleifera Lam. edible parts from Guinea-Bissau (West Africa). Food Chem. 2021;341(1):128229.

Ferreira RS, Napoleão TH, Santos AFS, et al. Coagulant and antibacterial activities of the water-soluble seed lectin from Moringa oleifera. Lett Appl Microbiol. 2011;53:186–192.

Fuglie L.J. The Moringa Tree: A local solution to malnutrition Church World Service in Senegal. 2005.

González-Minero FJ, Bravo-Díaz L. The Use of Plants in Skin-Care Products, Cosmetics and Fragrances: Past and Present. Cosmetics . 2018;5.

Gopalakrishnan L, Doriya K, Kumar DS. Moringa oleifera: A review on nutritive importance and its medicinal application. Food Sci Hum Wellness. 2016;5(2):49–56.

Grygorczyk R, Orlov SN. Effects of Hypoxia on Erythrocyte Membrane Properties—Implications for Intravascular Hemolysis and Purinergic Control of Blood Flow. Frontiers in Physiology. 2017;8.

Inusa BP, Hsu LL, Kohli N, Patel A, Ominu-Evbota K, Anie KA, et al. Sickle cell disease—genetics, pathophysiology, clinical presentation and treatment. Int J Neonatal Screen. 2019;5(2).

Irfan HM, Asmawi MZ, Khan NAK, Sadikun A. Effect of ethanolic extract of Moringa oleifera Lam. leaves on body weight and Hyperglycemia of diabetic rats. Pak J Nutr. 2016;15:112.

Islam Z, Islam SMR, Hossen F, Mahtab-Ul-Islam K, Hasan MR, Karim R. Moringa oleifera is a Prominent Source of Nutrients with Potential Health Benefits. Int J food Sci. 2021:6627265.

Kiranawati TM, Nurjanah N. Improvement of noodles recipe for increasing breastmilk: design of the Moringa noodles. Am. J. Food Sci. Technol. 2014;2:88-92

Kurokawa M, Wadhwani A, Kai H, et al. Activation of cellular immunity in herpes simplex virus type 1-infected mice by the oral administration of aqueous extract of Moringa oleifera Lam, Leaves. Phytother Res. 2016;30:797–804.

Lea MA, Akinpelu T, Amin R, et al. Inhibition of growth and induction of differentiation of colon cancer cells by extracts from okra (Abelmoschus esculentus) and drumstick (Moringa oleifera) Cancer Res. 2012.

Liang L, Wang C, Li S, Chu X, Sun K. Nutritional compositions of Indian Moringa oleifera seed and antioxidant activity of its polypeptides. Food Sci Nutr. 2019;7(5):1754–60.

Liu J, Qiang Y, Alvarez O, Du E. Electrical Impedance Characterization of Erythrocyte Response to Cyclic Hypoxia in Sickle Cell Disease. ACS Sensors. 2019;4(7):1783–90.

Manggul MS, Hidayanty H, Arifuddin S, Ahmad M, Hadju V, Usman AN. Biscuits containing Moringa oleifera leaves flour improve conditions of anemia in pregnant women. Gac Sanit. 2021;35:S191–5.

Maurya P, Yadav P, Yadav PN, Singh S. A miracle phytomedicine: Moringa oleifera. IJCRT, 2021;9(1):1306-1321

Mbikay M. Therapeutic Potential of Moringa oleifera Leaves in Chronic Hyperglycemia and Dyslipidemia: A Review. Frontiers in Pharmacology. 2012;3.

Meireles D, Gomes J, Lopes L, Hinzmann M, Machado J. A review of properties, nutritional and pharmaceutical applications of Moringa oleifera: integrative approach on conventional and traditional Asian medicine. Adv Tradit Med. 2020;20(4):495–515.

Milla PG, Peñalver R, Nieto G. Health Benefits of Uses and Applications of Moringa oleifera in Bakery Products. Plants. 2021;10.

Milman NT. Dietary Iron Intake in Women of Reproductive Age in Europe: A Review of 49 Studies from 29 Countries in the Period 1993–2015. Schiavo L, editor. J Nutr Metab. 2019:7631306.

Morris AL, Mohiuddin SS. Biochemistry, Nutrients. In: Stat Pearls. Treasure Island (FL): StatPearls Publishing; 2022

Moschonis G, Papandreou D, Mavrogianni C, Giannopoulou A, Damianidi L, Malindretos P, et al. Association of iron depletion with menstruation and dietary intake indices in pubertal girls: the healthy growth study. Biomed Res Int. 2013:423263.

Moyo B, Masika PJ, Hugo A, Muchenje V. Nutritional characterization of Moringa (Moringa oleifera Lam.) leaves. AFRICAN J Biotechnol. 2011;10:12925–33.

Mpanga I, Tiimob G, Tiimob R, Baani I, Tiimob E. Effect of Moringa oleifera Feed Supplements on All-Male Tilapia Growth Performance at Tano-Dumasi Pilot Aquaculture Centre. 2020;2:1–17.

Nadeem M, Imran M. Promising features of Moringa oleifera oil: recent updates and perspectives. Lipids Health Dis. 2016;15(1):212.

Nandave M, Ojha SK, Joshi S, et al. Moringa oleifera leaf extract prevents isoproterenol-induced myocardial damage in rats: evidence for an antioxidant, antiperoxidative, and cardioprotective intervention. J Med Food. 2009;12:47–55.

Nandimath P, S U. Interventional study to improve the haemoglobin level using Moringa oleifera powder on anaemic children in selected district of Karnataka. Indian J Forensic Community Med. 2021;8:39–44.

Nguyen VP, Stewart J, Lopez M, Ioannou I, Allais F. Glucosinolates: Natural Occurrence, Biosynthesis, Accessibility, Isolation, Structures, and Biological Activities. Molecules 2020, 25, 4537

Nice FJ. Selection and Use of Galactogogues. ICAN Infant, Child, Adolesc Nutr. 2015;7(4):192–4.

NLM. Drugs and Lactation Database (LactMed). Bethesda (MD): National Library of Medicine (US); 2006

Nova E, Redondo-Useros N, Martínez-García RM, Gómez-Martínez S, Díaz-Prieto LE, Marcos A. Potential of Moringa oleifera to Improve Glucose Control for the Prevention of Diabetes and Related Metabolic Alterations: A Systematic Review of Animal and Human Studies. Nutrients. 2020;12(7):2050.

Nwaoguikpe R, Ujowundu C, Igwe C, Dike P. The Effects of Moringa oleifera Leaves Extracts on Sickle Cell Hemoglobin. J Sci Res Reports. 2015;4(2):123–32.

Olugbemi T.S., Mutayoba S.K., Lekule F.P. Effect of Moringa (M. oleifera) inclusion in cassava based diets fed to broiler chickens. Int. J. Poult. Sci., 2010;9:363-367

Onsare JG, Arora DS. Antibiofilm potential of flavonoids extracted from Moringa oleifera seed coat against Staphylococcus aureus, Pseudomonas aeruginosa and Candida albicans. J Appl Microbiol. 2015;118:313–325

Owusu D., Oduro I. Development of crackers from cassava and sweetpotato flours using Moringa oleifera and Ipomoea batatas leaves as fortificant. Am. J. Food Nutr., 2011;1:114-122

Oyeyinka AT, Oyeyinka SA. Moringa oleifera as a food fortificant: Recent trends and prospects. J Saudi Soc Agric Sci. 2018;17(2):127–36.

Paikra BK, Dhongade HK, Gidwani B. Phytochemistry and Pharmacology of Moringa oleifera Lam. J pharmacopuncture. 2017;20(3):194–200.

Palanog AD, Calayugan MIC, Descalsota-Empleo GI, Amparado A, Inabangan-Asilo MA, Arocena EC, et al. Zinc and Iron Nutrition Status in the Philippines Population and Local Soils Frontiers in Nutrition. 2019; 6.

Pasini E, Corsetti G, Romano C, Aquilani R, Scarabelli T, Chen-Scarabelli C, et al. Management of Anaemia of Chronic Disease: Beyond Iron-Only Supplementation. Nutrients . 2021; 13.

Raguindin PF, Dans L, King J. Moringa oleifera as a Galactagogue. Breastfeed Med. 2014;9.

Raja R, A MS, B SV, Navyasri DM, C GS, D SG. Moringa oleifera -An Overview. RA J Appl Res. 2016.

Ramsay LC. Review of Iron Supplementation and Fortification. In: Claborn CVCE-D, editor. Rijeka: IntechOpen; 2015. p. Ch. 8.

Raphaël K.J. Effects of substituting soybean with Moringa oleifera meal in diets on laying and eggs quality characteristics of KABIR chickens. J. Anim. Nutr., 2015;1:1-6

Ratshilivha N, Awouafack MD, du Toit ES, Eloff JN. The variation in antimicrobial and antioxidant activities of acetone leaf extracts of 12 Moringa oleifera (Moringaceae) trees enables the selection of trees with additional uses. South Afr J Bot. 2014;92:59–64.

Renaudier P. Physiopathologie de la drépanocytose [Sickle cell pathophysiology]. Transfus Clin Biol. 2014;21(4-5):178-81.

Roganović J. Iron Deficiency Anemia in Children. In: Khan KSE-J, editor. Rijeka: IntechOpen; 2018. p. Ch. 3.

Saa RW, Fombang EN, Ndjantou EB, Njintang NY. Treatments and uses of Moringa oleifera seeds in human nutrition: A review. Food Sci Nutr. 2019;7(6):1911–9.

Saeed M, Saeed A, Iqbal M, Adnan M. Nutritional and Medicinal Importance of Moringa -A Review. Curr. Rese. Agri. Far. 2020;1(4):31-34

Saini RK, Prabhakaran M, Shetty N, Srinivasan K, Giridhar P. Dietary iron supplements and Moringa oleifera leaves influence the liver hepcidin mRNA expression and biochemical indices of iron status in rats. Nutr Res. 2014;34.

Sawicki KT, Chang HC, Ardehali H. Role of heme in cardiovascular physiology and disease. J Am Heart Assoc. 2015;4(1):e001138.

Schmidt HM, Kelley EE, Straub AC. The impact of xanthine oxidase (XO) on hemolytic diseases. Redox Biol. 2019;21:101072.

Shank L.P., Riyathong T., Lee V.S., Dheeranupattana S. Peroxidase activity in native and callus culture of Moringa oleifera Lam. J. Med. Bioeng.,2013;2:163-167

Shija AE, Rumisha SF, Oriyo NM, Kilima SP, Massaga JJ. Effect of Moringa oleifera leaf powder supplementation on reducing anemia in children below two years in Kisarawe District, Tanzania. Food Sci Nutr. 2019;7(8):2584–94.

Shija AE, Rumisha SF, Oriyo NM, Kilima SP, Massaga JJ. Effect of Moringa oleifera leaf powder supplementation on reducing anemia in children below two years in Kisarawe District, Tanzania. Food Sci Nutr. 2019;7(8):2584–94.

Singh BN, Singh BR, Singh RL, et al. Oxidative DNA damage protective activity, antioxidant and anti-quorum sensing potentials of Moringa oleifera. Food Chem Toxicol. 2009;47:1109–1116.

Sreelatha S, Jeyachitra A, Padma PR. Anti-proliferation and induction of apoptosis by Moringa oleifera leaf extract on human cancer cells. Food Chem Toxicol. 2011 Jun; 49(6):1270-5.

Su B, Chen X. Current Status and Potential of Moringa oleifera Leaf as an Alternative Protein Source for Animal Feeds. Front Vet Sci. 2020;7:53.

Sultana S. Nutritional and functional properties of Moringa oleifera. Metab Open. 2020;8:100061.

Suresh S, Sisodia S. Phytochemical and Pharmacological Aspects of Cucurbita moschata and Moringa oleifera. UK J Pharm Biosci. 2018;6:45.

Sutalangka C, Wattanathorn J, Muchimapura S, Thukham-mee W. Moringa oleifera mitigates memory impairment and neurodegeneration in animal model of age-related dementia. Oxid Med Cell Longev. 2013:695936.

Suzana D, Suyatna FD, Azizahwati, Andrajati R, Sari SP, Mun'im A. Effect of Moringa oleifera leaves extract against hematology and blood biochemical value of patients with iron deficiency anemia. J Young Pharm. 2017;9(1):S79–84.

Thurber MD, Fahey JW. Adoption of Moringa oleifera to combat under-nutrition viewed through the lens of the "Diffusion of innovations" theory. Ecol Food Nutr. 2009;48(3):212–25.

Ujah OF, Ujah IR, Johnson JT, et al. Hepatoprotective property of ethanolic leaf extract of Moringa oleifera on carbon tetrachloride (CCl4) induced hepatotoxicity. Scholar Research Library. J Nat Prod Plant. 2013;3:15–22.

Umashankar S, Nandimath PT. Interventional study to improve the haemoglobin level using Moringa oleifera powder on anaemic children in selected district of Karnataka. Indian J Forensic Community Med. 2021;8(1):39–44.

UNICEF. The State of Food Security and Nutrition in The World : Transforming Food Systems For Affordable Healthy Diets. Rome FAO. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing. 2020. 320 p.

Vergara-Jimenez M, Almatrafi MM, Fernandez ML. Bioactive Components in Moringa oleifera Leaves Protect against Chronic Disease. Antioxidants (Basel, Switzerland). 2017;6(4):91.

Vlasova II. Peroxidase Activity of Human Hemoproteins: Keeping the Fire under Control. Molecules. 2018;23(10):1–27.

Wells JCK, Marphatia AA, Amable G, Siervo M, Friis H, Miranda JJ, et al. The future of human malnutrition: rebalancing agency for better nutritional health. Global Health. 2021;17(1):119.

Xiao X, Wang J, Meng C, Liang W, Wang T, Zhou B, et al. Moringa oleifera Lam and its Therapeutic Effects in Immune Disorders. Frontiers in Pharmacology. 2020.11

Xu T, Lizarralde-Iragorri MA, Roman J, Ghasemi R, Lefèvre J-P, Martincic E, et al. Characterization of red blood cell microcirculatory parameters using a bioimpedance microfluidic device. Sci Rep. 2020;10(1):9869.

Yang Z, Keel SB, Shimamura A, Liu L, Gerds AT, Li HY, et al. Delayed globin synthesis leads to excess heme and the macrocytic anemia of Diamond Blackfan anemia and del(5q) myelodysplastic syndrome. Sci Transl Med. 2016;8(338):338.

Yuliastuti S. KELOR (Moringa oleifera) as an Alternative in Increasing Breast Milk Production. J Med Sci Clin Res. 2018;6(2):1192–6.

Zivot A, Lipton JM, Narla A, Blanc L. Erythropoiesis: insights into pathophysiology and treatments in 2017. Mol Med. 2018;24(1):11.

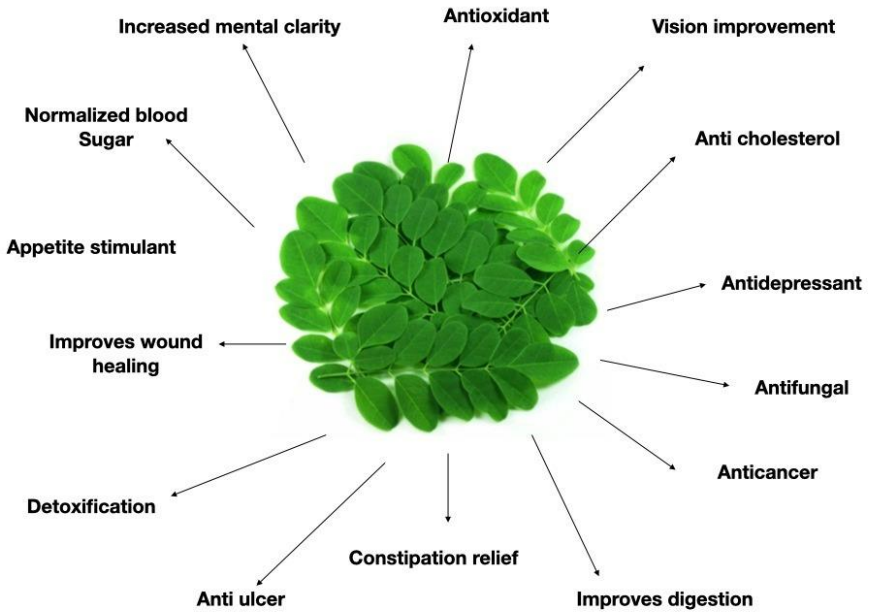


Figure 1 Schematic representation of hemolysis of an RBC releasing haemoglobin and heme from the cell

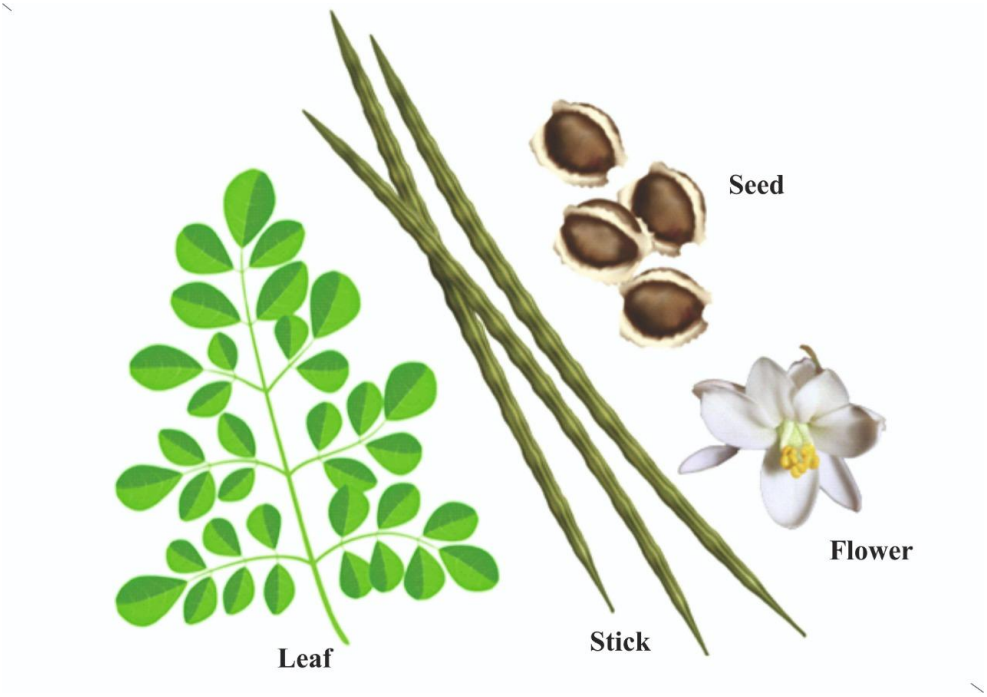


Figure 2 Moringa oleifera can be used in a variety of ways in food systems and agro-processing

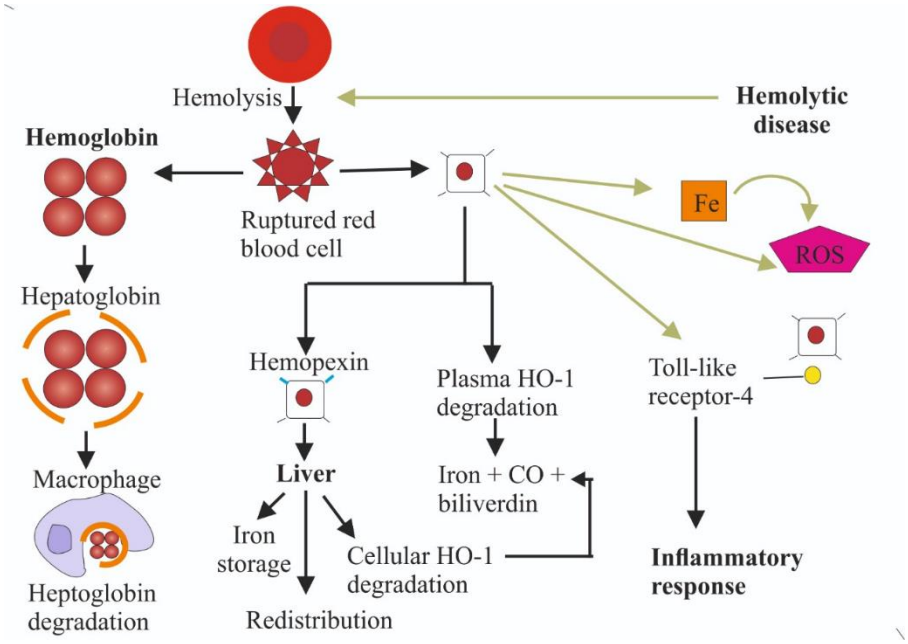


Figure 3 Morphological of M. oleifera plant

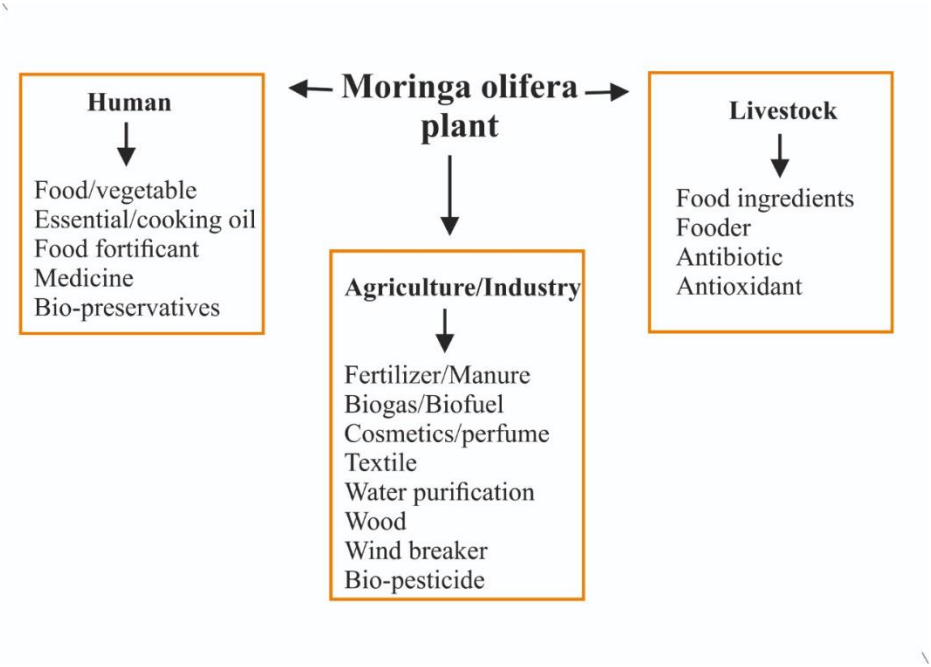


Figure 4 Phytoconstituents present in M. oleifera plant

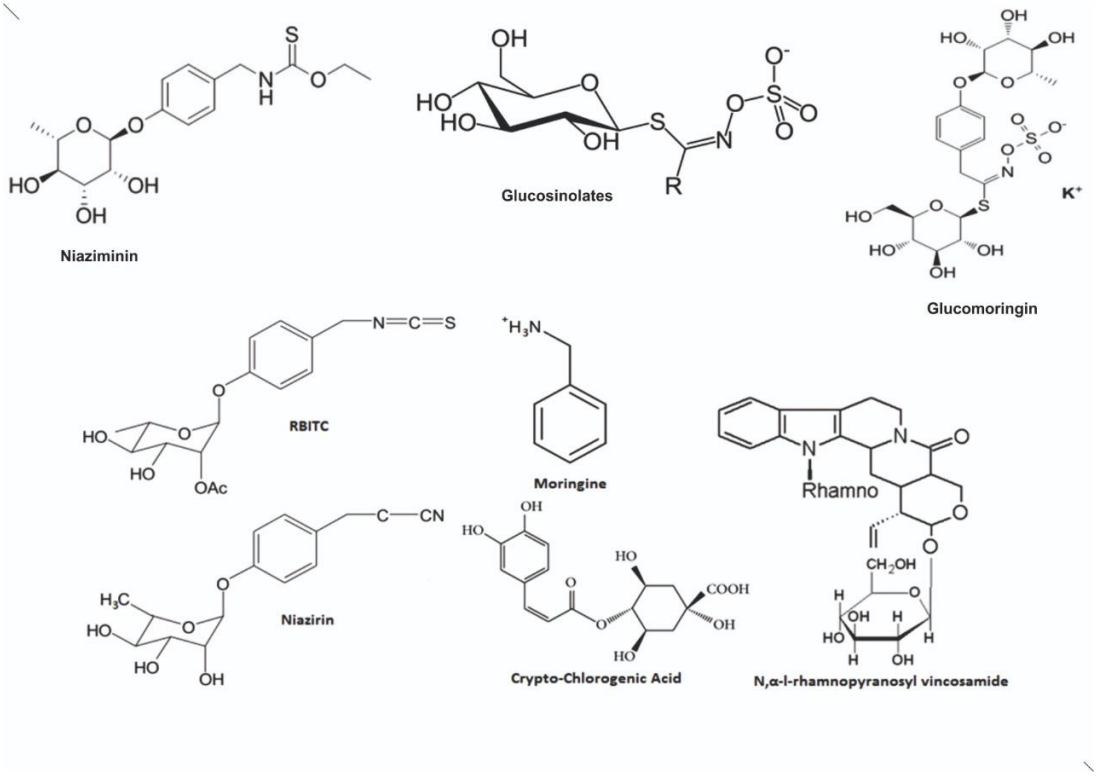
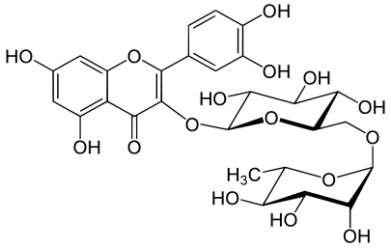
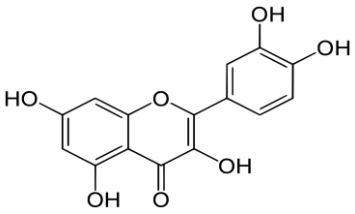
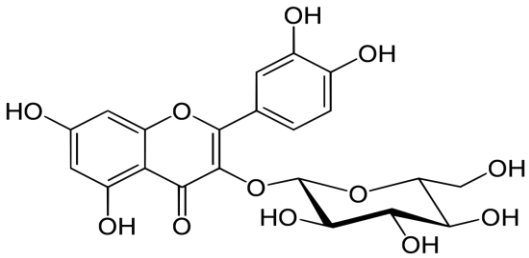
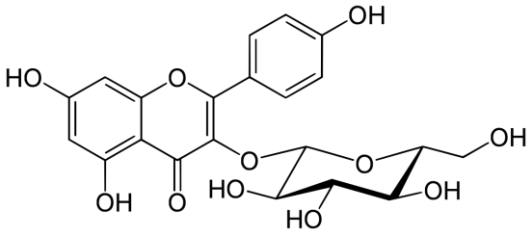
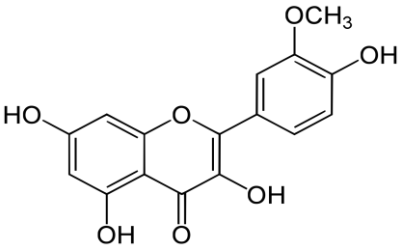
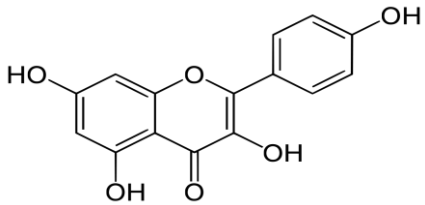
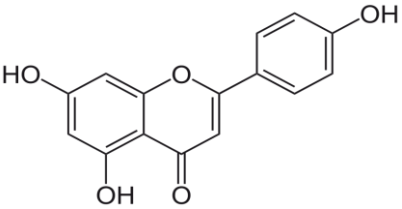
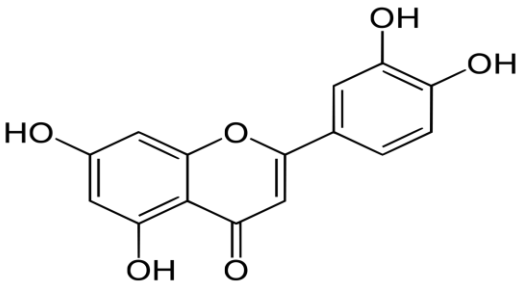
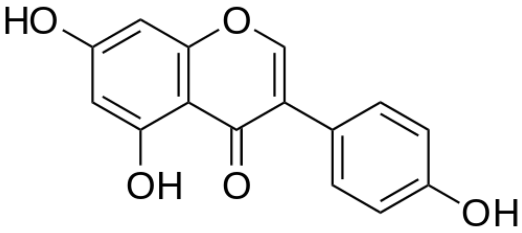
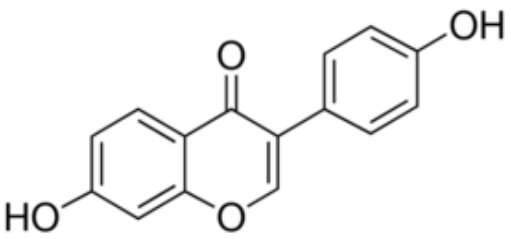
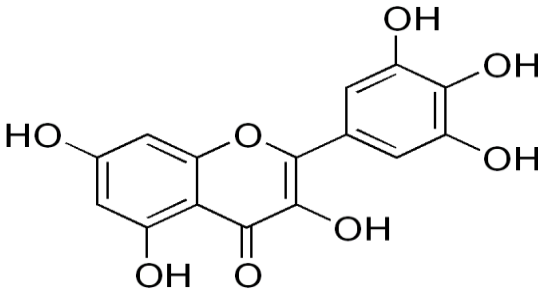
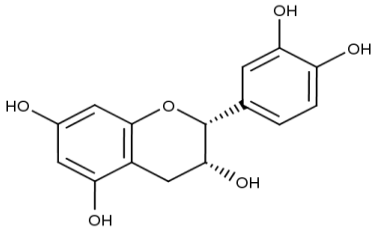
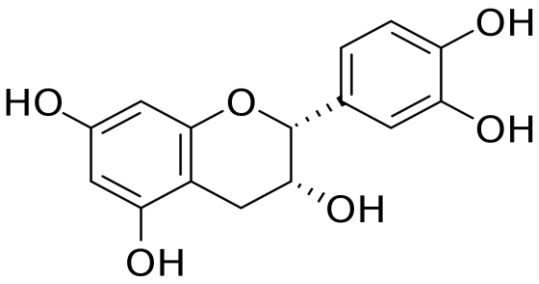
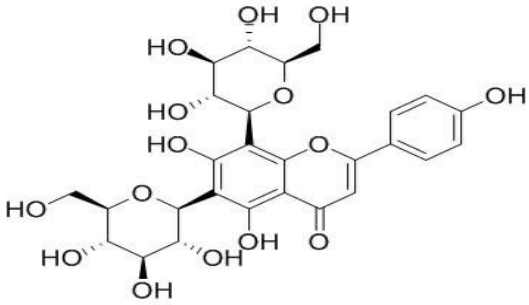
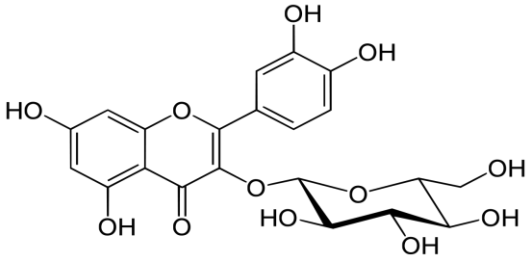
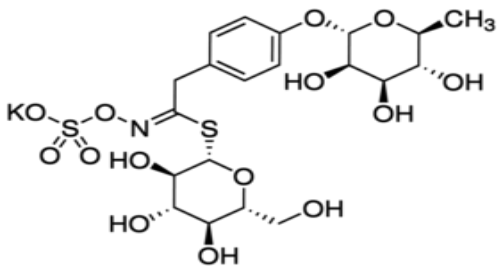
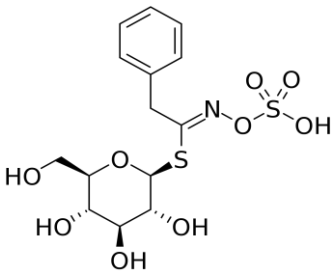


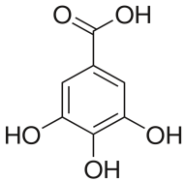
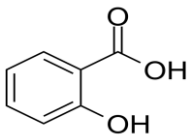
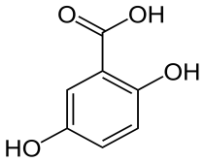
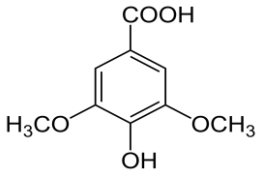
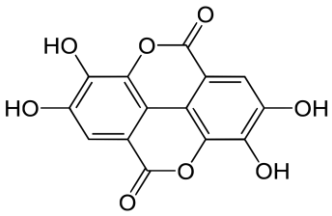
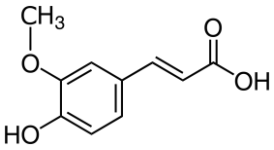
Table 1 Active constituents found in M. oleifera plant

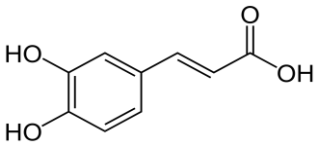
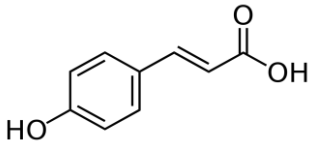
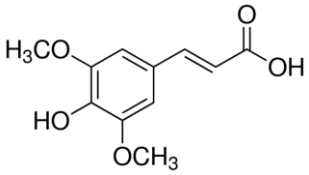
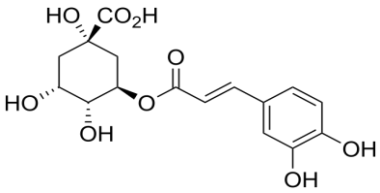
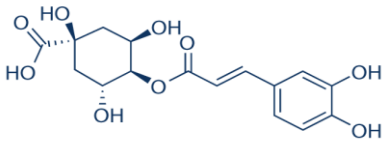
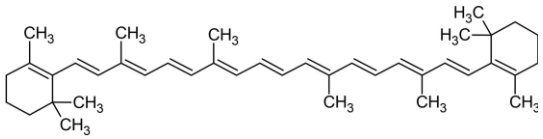
Compounds	Chemical structure	Plant part	References
Flavonoids and Flavanol glycosides			
Rutin		Leaves	Leone et al., 2015b
Quercetin		Leaves	Elbatran et al., 2005

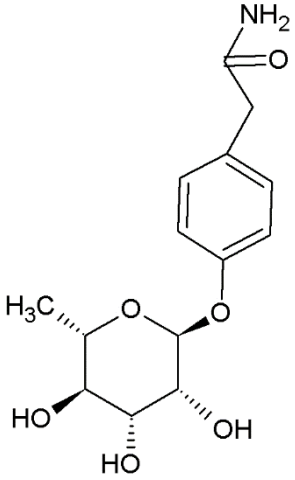
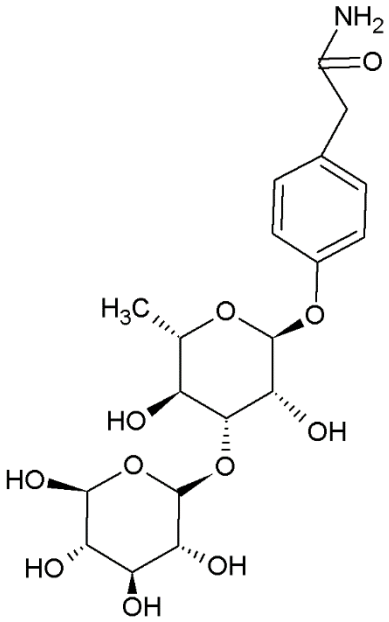
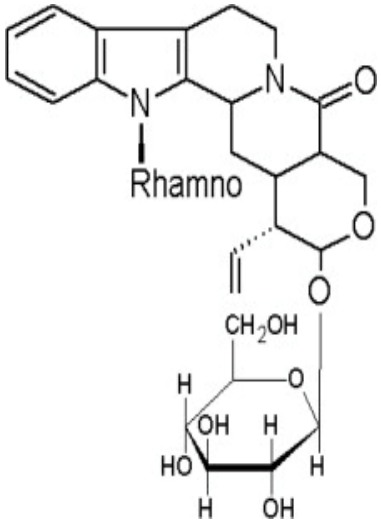
Isoquercetin		Leaves	Vongsak et al., 2014
Astragalin		Leaves	Vongsak et al., 2014
Isorhamnetin		Leaves	El-Alfy et al., 2011
Kaempferol		Leaves	Manguro and Lemmen, 2007;
Apigenin		Leaves	Abdel-Rahman Tahany et al., 2010;

Luteolin		Leaves	Elbatran et al., 2005
Genistein		Leaves	Leone et al., 2015a
Diadzein		Leaves	Leone et al., 2015a
Myricetin		Leaves, seed	Leone et al., 2015a
Epicatechin		Leaves	Leone et al., 2015a

Procyanidins		Root, stem barks	Atawodi et al., 2010
Vicenin-2		Leaves	Muhammad et al., 2016
Quercetin-3-O-glucoside		Leaves, seeds	Maiyo et al., 2016
Glucosinolate and Isothiocyanate			
Glucomoringin		Leaves, seeds	Tumer et al., 2015
Glucotropaeolin		Seed	Saini et al., 2016
Phenolic acid			

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		Leaves	Leone et al., 2015a
Coumaric acid		Leaves	Leone et al., 2015a
Sinapic acid		Leaves	Leone et al., 2015a
Clorogenic acid		Leaves	Verma et al., 2009;
Cryptochlorogenic acid		Leaves	Vongsak et al., 2014
Terpene			
Carotene		Pods	Saini et al., 2017
Alkaloid and Sterol			

Marumoside A		Leaves	Sahakitpichan et al., 2011
Marumoside B		Leaves	Sahakitpichan et al., 2011
N, α-L-Rhamnopyranosyl vincosamide		Leaves	Panda et al., 2013

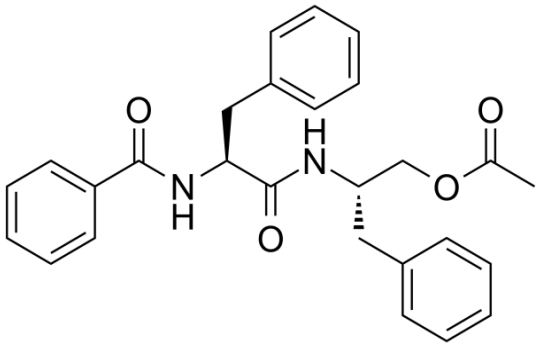
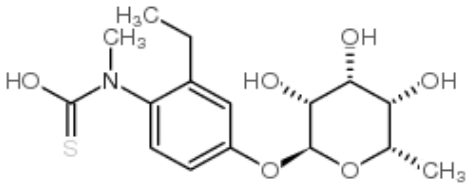
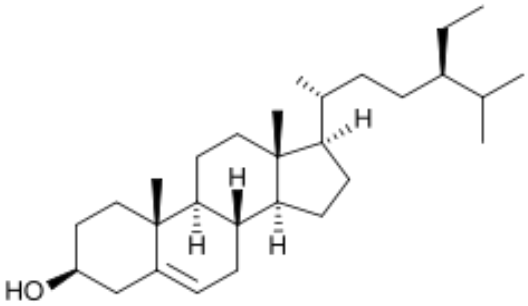
Aurantiamide acetate		Roots	Sashidara et al., 2009
Niazimicin		Leaves, seeds	Jung, 2014
Beta-sitosterol		Leaves, seeds	Abdel-Rahman Tahany et al., 2010;

Table 2 Biological activity of M. oleifera

Extract	Part	Biological activity	References
Aqueous	Leaf	Lipid-lowering and antiatherosclerotic activities	Chumark et al., 2008
Aqueous	Fruit, leaf and seeds	Antioxidant activity	Singh et al., 2009
Hydro-alcoholic extract	Leaf	Antioxidant and cardioprotective activities	Nandave et al., 2009
Aqueous	Leaf	Anticancer and antioxidant properties	Sreelatha et al., 2011
Hydro-alcoholic extract	Fruit, leaf and seeds	Liver tonic	Fakurazi et al., 2012, Ujah et al., 2013
Methanol and ethanol	Leaf	Anticancer activity	Lea et al., 2012
Aqueous	Leaf	Reducing nuclear factor-kappaB activity reduces inflammation.	Berkovich et al., 2013
Ethanol	Leaf	Upregulation of TNF-α	Akanni et al., 2014
Ethanol	Leaf	Decrease lipid and cholesterol levels in rats	Atsukwei et al., 2014

Methanol	Leaf	Anti-inflammatory, antioxidant, and anticancer activities	Adedapo et al., 2014
Acetone	Leaf	Antioxidant and antimicrobial activities	Ratshilivha et al., 2014
Methanol and aqueous	Seeds	Antimicrobial activity	Emmanuel et al., 2014
Ethanol	Leaf	Antidiabetic and lipid-lowering activities	Irfan et al., 2016
Aqueous	Leaf	Immunomodulatory and antiviral activities	Kurokawa et al., 2016
Ethanol	Seeds a leaf	Antimicrobial activity against Epidermophyton floccosum, Trichophyton rubrum, Microsporum canis and T. mentagrophytes	Chuang et al., 2007
Ethanol and chloroform	Seeds and leaf	Antimicrobial activity against Pseudomonas aeruginosa, Staphylococcus aureus, Enterobacter aerogenes and Escherichia coli	Bukar et al., 2010
Aqueous	Seed	Antimicrobial activity against Escherichia coli and Staphylococcus aureus	Ferreira et al., 2011
Chloroform, aqueous and hexane extract	Pod husks	Klebsiella pneumoniae, Salmonella typhimurium and Escherichia coli are all antimicrobial targets for this compound.	Arora and onsare, 2014
Acetone	Leaf	A broad spectrum of antimicrobial activity against Aspergillus fumigatus, Candida albicans, Staphylococcus aureus, Enterococcus faecalis, Escherichia coli, Pseudomonas septica and Cryptococcus neoformans	Ratshilivha et al., 2014
Methanol, aqueous and ethyl acetate extract	Seeds	Inhibition of E. coli, Klebsiella pneumonia, Proteus mirabilis, P. aeruginosa, and Staphylococcus aureus microbiological activity.	Emmanuel et al., 2014