

Moringa oleifera: The Science Behind its Extraordinary Health Benefits

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ABSTRACT

Moringa oleifera Lam., which is commonly known as the “drumstick tree,” is a beautiful plant that has been used for many years in traditional ways and is now being studied by scientists. This thorough review covers a lot of different areas of *M. oleifera*, from its botanical features to the many ways it is used in medicine, nutrition, and protecting the environment. In the introduction, it is explained that *M. oleifera* is found all over the world and does well in tropical and subtropical areas in places like Asia, Africa, and the Americas. There are many names for *M. oleifera*, including the drumstick tree, the ginger tree, and the ben oil tree. It is known for being useful and adaptable. This review goes into more detail about *M. oleifera*'s health benefits and nutritional value, focusing on how full it is of natural antioxidants, vitamins, and minerals. People all over the world have used *M. oleifera* for hundreds of years as a food source and herbal medicine because its leaves, seeds, flowers, and pods are full of important nutrients. This review looks at how *M. oleifera* can be used as a medicine, focusing on its antibacterial properties and ability to reduce pain and inflammation. Modern research backs up its traditional uses and suggests that it could be useful in treating diabetes, high blood pressure, and skin problems. Besides being good for people's health, *M. oleifera* is also a great plant for protecting the environment. Because it grows quickly, doesn't die from drought, and improves the soil, it is very useful in agroforestry and land restoration. It can also do well in a variety of climates, which shows how useful it could be for reducing climate change and promoting biodiversity. The review ends by talking about the bigger effects that growing *M. oleifera* has on society, like how it helps with food security, economic empowerment, and protecting the environment.

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INTRODUCTION

The tree *Moringa oleifera* lam. grows in many tropical and subtropical places. India, Africa, South and Central America, Mexico, Hawaii, and all of Asia and Southeast Asia grow it for business. It is called the drumstick tree because of the way its young fruit pods look, the ginger tree because of how ground root preparations taste, and the ben oil tree because of the oils that come from the seed. For example, *M. oleifera* Lam, or *M. oleifera*, is a green plant in the *Moringaceae* family.¹ Locals call *M. oleifera* the horseradish tree or the drumstick tree, and it is a common food source in many places around the world. Individuals eat *M. oleifera* for both its health benefits and nutritional value. They have a lot of natural antioxidants, including a substance called beta vitamin C, vitamin E, and antioxidants. People like to eat this plant's leaves, seeds, flowers, and pods, which are all high in chemical compounds and important nutrients. Some people have used *M. oleifera* for thousands of years as a food source and in herbal treatment.²

The “miracle tree,” *M. oleifera* (*M. oleifera*), grows well in almost all tropical and subtropical areas of the world. It is thought to have originated in Afghanistan, Bangladesh, India, and Pakistan. There are 13 species in the *Moringa* family: *M. oleifera*, *M. arborea*, *M. rivae*, *M. ruspoliana*, *M. drouhardii*, *M. hildebrandtii*, *M. concanensis*, *M. borziana*, *M. longituba*, *M. pygmaea*, *M. ovalifolia*, *M. peregrina*, and *M. stenopetala*. *M. oleifera* is famous for being used in food, biogas production, fertilizer, and other things.³ The *M. oleifera* tree is native to the Indian subcontinent. It is a fast-growing, drought-resistant member of the *Moringaceae* family. It is grown in many places because its young seed pods and green leaves can be used as both food and medicine. People think it is a great supplement since it has a lot of protein. As it is, it's called the “miracle tree” because it has so many health benefits. For example, it has 17 times more calcium than milk, 15 times more potassium than bananas, and 10 times more vitamins than vegetables.⁴ Therapeutic phytochemicals are making medicinal plant

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research and use grow every day. These chemicals can speed up the development of new medicines. Most phytochemicals found in plants, like carotenoids, phenolic acids, flavonoids, tannins, saponins, acids, and glucose, are good for your health and can help you avoid getting cancer. Three to four percent of the body's mass is made up of skeletal muscles, which are very important to the health of the whole body. Their main job is to keep blood sugar levels stable and the body's energy balance in check. They help with breathing, moving, and making heat. At rest, skeletal muscles did not require much energy, but after a hard contraction, they need a lot of energy.⁵ For the body to get the energy it needs, hemoglobin releases more oxygen, and a process known makes cells work better by making more ATP. *M. oleifera* is the name of an Indian tree that has been used as both a food supplement and a medicine. The leaves, seeds, and roots of the moringa plant have antibacterial properties, according to our own (unknown) research and the research of other groups. Researchers have also found that garlic or *Allium* can kill bacteria. A lot of harmful chemicals are in cigarette smoke. Some examples are acroleine, nitrogen oxides, and hydrocarbons that are poly and oxygen-derived reactive species (ODRS). The ODRS that cigarette smoke makes also turns on immune cells and membrane lining cells, which damages the lungs and other organs through oxidative stress. When people breathe in cigarette smoke, alveolar macrophages are the first immune cells that react to oxidative stress.⁶ The *M. oleifera* Lam. plant, which is also called the magical radish or drumstick tree, is in the Moringaceae family and can grow into a short, thin tree. The *M. oleifera* plant is native to places in Asia and the Middle East, like the Himalayas, India, Pakistan, Asia Minor, Africa, and Arabia. However, it is now found in many other countries as well, because it can grow in a wide range of conditions. The plant can grow in dry, desert soils and in areas with little to no rain because its roots can go deep into the ground and hold water for a long time. It grows best in temperatures between 25 and 40°C, but it can also survive in temperatures as low as -1°C and as high as 48°C.⁷ It can survive in a wide range of conditions. Specifically, over the past ten years, a lot of interesting and easy research has been done on the creation of effective bioprocesses that use biomaterials like Moringa to remove organic and inorganic metal contaminants from industrial wastewater by absorbing water. In addition to being good for you, *M. oleifera* has a lot of healing properties that have scientists and healers interested for hundreds of years. Moringa is highly valued in traditional medicine systems in Asia, Africa, and Latin America for its ability to reduce inflammation, kill germs, and ease pain.⁸ Modern research has supported many of these claims, showing that Moringa may be able to help with a wide range of health problems, from diabetes and high blood pressure to skin problems and digestive problems. More and more people are looking for natural remedies, and Moringa is one of the most powerful plants that hasn't been used for medicine yet. These days, when the environment is getting worse and the weather is unpredictable, *M. oleifera* plays a bigger role than

just being good for you. Moringa shows us how to be strong in the face of environmental problems because it is a supporter of sustainable farming and agricultural forestry. It has deep taproots that keep the soil from washing away and improve its structure.⁹ Its fast-growing leaves provide shade and food for animals. The Moringa's ability to grow well in dry and damaged environments is encouraging for efforts to plant trees and fix up land all over the world. Communities can build a greener, safer future for future generations by using the power of Moringa. The benefits of *M. oleifera* go far beyond its health benefits and ability to survive in harsh environments. They also have huge effects on the health and sustainability of the whole world. In places where there is a lack of food and people aren't getting enough nutrients, Moringa is a cheap and culturally appropriate way to improve diet diversity and fight malnutrition. Its growth can also help people get ahead financially, especially small farmers in developing countries. The environmental benefits of growing Moringa, like storing carbon and protecting biodiversity, are also in line with larger efforts to stop climate change and protect the environment.¹⁰

Historical and cultural significance

Original Indian medicine (Ayurveda) and Greek-Islamic traditional medicine (Unani, also known) have used *M. oleifera* for hundreds of years. Different cultures have used different parts of the tree (leaves, seeds, roots, bark) to treat various illnesses, such as inflammation, digestive problems, infections, and more. Local food often includes the tree's healthy leaves and pods, which add important vitamins and minerals to diets. Possible topics for the review include how *M. oleifera* is cooked and eaten in various cultures. In some cultures, *M. oleifera* may be a religious or cultural symbol.¹¹ Folklore or religious traditions may view it as a sign of fertility, healing, or protection, for example. The history of how *M. oleifera* got to other parts of the world from its home in South Asia might be covered in the review. Furthermore, the review could talk about the renewed interest in *M. oleifera* recently because of its known health benefits and potential for long-term farming and economic growth in poor areas. Lastly, the review could bring together the latest scientific research on *M. oleifera*, confirming its traditional uses and giving new uses and benefits found through thorough study.¹²

Nutritional content

The nutritional value of *M. oleifera* is very high, which helps to explain why it is known as a very valuable plant for human nutrition. The *Moringa* tree's leaves, seeds, and pods are just a few of the parts that are full of important nutrients. Here is a list of the nutrients that *M. oleifera* has. The leaves of the moringa tree are very healthy because they have a lot of vitamins, minerals, and antioxidants. They have a lot of vitamin C—a lot more than oranges do. Also, moringa leaves have a lot of beta-carotene, a type of vitamin A that is good for your eyes and immune system.¹³ They have a lot of vitamin E, which is an enzyme that helps keep cells from getting hurt. Vitamin K, which is found in moringa leaves, is important for bone health

and blood clotting. Some B vitamins, like folate (vitamin B9), which helps cells divide and grow, are found in large amounts in them. Moringa leaves are high in protein and contain all nine essential amino acids, making them a complete source of protein. For people on vegetarian or vegan diets who may have trouble getting enough protein from plants, this is particularly helpful. Minerals like calcium, magnesium, potassium, and phosphorus are found in large amounts in Moringa leaves. These minerals are important for bone health, muscle function, and the overall functioning of cells. They also have iron and zinc in them, which are needed for the immune system and for moving oxygen around in the blood.¹⁴ Flavonoids, quercetin, and chlorogenic acid are just a few of the antioxidants that are found in moringa leaves. These help protect the body from oxidative stress and inflammation. Cellulose in moringa leaves helps keep blood sugar levels steady and supports digestive health. They give you essential fatty acids, like omega-3 and omega-6 fatty acids, which are good for your heart and brain. *Moringa seeds* have a lot of protein and good fats, like omega-9 fatty acid and oil. They are traditionally used to clean water because they contain antioxidants and are good for you. The drumsticks (seeds) of the moringa plant are a good source of vitamins and minerals, but not quite as much as the leaves and seeds. They have a lot of minerals, like calcium and magnesium, and a lot of vitamins, like C and A.¹⁵

Vitamins and Minerals

Moringa leaves contain a lot of a substance called beta which is a substance that helps make vitamin A. Vitamin A is very important for skin health, vision, and immune system health. A healthy amount of vitamin A is important for growth and development in general. The amount of vitamin C in *Moringa* leaves is higher than that in oranges. Vitamin C is an extremely strong vitamin that helps the immune system work and makes protein. A very important part of wound healing, it also helps protect against oxidative stress. Vitamin E is a fat-soluble antioxidant that can be found in large amounts in moringa leaves.¹⁶ To keep your skin healthy and protect cells from free radical damage, vitamin E is important. It's important for the immune system and many other organs to work right. Vitamin K is found in Moringa leaves and is important for bone health and blood clotting. Vitamin K is also good for your heart because it controls how calcium is used in the body. Moringa leaves have thiamine (B1), riboflavin (B2), niacin (B3), pyridoxine (B6), and folate (B9) in them. The production of red blood cells, the use of energy, and nerve function depend on these vitamins.¹⁷ Folate is very important for the development of the baby while the mother is pregnant. Calcium is important for bone health and muscle function, and Moringa leaves have a lot of it. Sufficiently calcium in the diet helps nerves send messages and hormones be released.

Iron, found in *Moringa* leaves, is important for carrying oxygen through the blood (as part of hemoglobin) and making energy in general. Still getting enough iron can cause anemia and tiredness. Magnesium, which is found in Moringa leaves, is used by the body in hundreds of chemical reactions.

Magnesium is good for bone health, muscle function, and nerve transmission. You can get a lot of potassium from moringa leaves. Potassium is important for keeping your fluid balance and heart working well. Keeping blood pressure in check and helping muscles contract are two things that potassium does. The phosphorus in *moringa* leaves is good for your bones and helps your body use energy. A part of DNA and cell membranes is phosphorus. Moringa leaves have zinc in them, which is important for making proteins, keeping your immune system healthy, and healing wounds. Zinc also helps with brain and reproductive health.¹⁸

Protein and Amino Acids

Moringa leaves are a good source of plant-based protein because they have a lot of protein in them. When it comes to dry weight, Moringa leaves can have anywhere from 20 to 30% protein, which is pretty high compared to other green vegetables. Moringa protein is a complete protein because it has the right amounts of all eight essential amino acids. This is particularly useful for vegans and vegetarians who get most of their protein from plants. There are nine essential amino acids in moringa leaves. The body is unable to generate these acids itself, so they have to come from food. A substance called valine, amino acids, tryptophan, a compound called leucine, isoleucine, lysine, and histidine are some of the essential amino acids.¹⁹ The *Moringa leaf* gives you essential amino acids as well as non-essential amino acids that your body can make itself. The amino acids a substance called aspartic acid, cysteine, glutamic acid, glycine, proline, serine, and tyrosine, are some amino acids that are not necessary for life. Moringa provides enough protein to help muscles grow, repair, and stay healthy. Proteins are made up of amino acids, which are necessary for tissue repair and muscle health in general. Amino acids are very important for enzymes to work, which makes biochemical reactions easier in the body.²⁰ They help with metabolism, making hormones, and moving nutrients around the body. Some amino acids in moringa, like arginine and lysine, help the immune system work and wounds heal. It is possible for immune cells and antibodies to be made with these amino acids. Nerve chemicals like serotonin and dopamine are made from amino acids like protein and a compound called using enough of these amino acids helps keep your mood stable and your brain working well.²¹

Health Benefits

The leaves, pods, and seeds of the moringa plant are full of minerals and vitamins that are good for you. These minerals and vitamins include calcium, iron, magnesium, potassium, and zinc. Flavonoids, polyphenols, and vitamin C are just a few of the many antioxidants found in moringa. These help to fight free radicals and lower oxidative stress in the body. This can keep cells from getting hurt and lower the risk of getting long-term illnesses. Alcohols, substances and phenolic acids are some of the compounds found in moringa that have strong anti-inflammatory properties (Camilleri and Blundell, 2024). Moringa may help reduce inflammation and ease the

symptoms of inflammatory conditions if you eat it regularly. Researchers have found that moringa can lower sugar and keep blood pressure in check, which is good for heart health. Moringa may also help protect against heart disease because it has compounds that fight inflammation and free radicals. Moringa's vitamins, minerals, and phytochemicals make the immune system stronger and make it easier for the body to fight off infections.²³ Compounds in moringa leaves, such as quercetin and chlorogenic acid, help the immune system. Researchers have looked into how moringa might lower blood sugar and make insulin work better. This means that people with diabetes or who are at risk of getting diabetes can benefit from eating it. Moringa may help keep your brain healthy and sharp by having compounds that protect neurons and fight free radicals. Moringa has been looked at to see if it might lower the risk of neurological conditions like Parkinson's and Alzheimer's. There is fiber in moringa that helps your digestive health by keeping your gut microbiota healthy and encouraging regular bowel movements. It might also help with digestive problems like bloating and constipation.²⁴ Moringa has minerals and vitamins that help keep your skin and hair healthy. The seeds of the moringa plant are used to make oil that is used in skin care products because it moisturizes and slows down the aging process. Some chemicals in Moringa have been shown to kill bacteria, viruses, and parasites. This means that it is used in traditional medicine to treat infections caused by these things.²⁵

Anti-inflammatory Properties

A big part of *M. oleifera*'s health benefits is that it reduces inflammation. This property has been studied a lot in recent years. Because it has many bioactive compounds that are strong anti-inflammatory, moringa is a great natural way to treat conditions that are caused by inflammation. Here is a summary of how *M. oleifera* works to reduce inflammation. These compounds (quercetin, kaempferol), phenolic acids (chlorogenic acid), and isothiocyanates are some of the bioactive compounds that can be found in moringa leaves, seeds, and other parts of the plant. These chemicals are very good at reducing inflammation because they stop the body's inflammatory pathways. TNF- α and interleukins (IL-1 β and IL-6) are two examples of pro-inflammatory cytokines that are stopped from being made by extracts from the *Moringa plant*.²⁶ Moringa helps control the inflammatory response and ease the symptoms of inflammation by lowering the production of these inflammatory mediators. Moringa can help reduce inflammation because it contains antioxidants. Free radicals and oxidative stress can cause inflammation and tissue damage. Antioxidants get rid of them. It has been found that moringa extracts can stop the nuclear factor-kappa B (NF- κ B) pathway, which is a key regulator of inflammation.²⁷ By stopping NF- κ B from working, Moringa helps lower the production of genes and enzymes that cause inflammation. Moringa can help reduce inflammation and protect tissues and organs from damage caused by long-term inflammation. Because it lowers inflammation, moringa may help stop or lessen conditions

like arthritis, inflammatory bowel diseases, and heart diseases. Putting Moringa oil or extracts on skin conditions that cause inflammation, such as eczema, dermatitis, and psoriasis, has shown promise.²⁸ Moringa can help soothe and heal skin that is inflamed because it reduces inflammation and moisturizes. Moringa may help relieve pain because it reduces inflammation. This is especially true for conditions like arthritis and muscle soreness, where pain is caused by inflammation. Moringa improves health and well-being by lowering chronic inflammation. It does this by helping the immune system, heart health, and brain health.²⁹

Antioxidant Effects

There are a lot of antioxidants in moringa, such as antioxidants, polyphenols, and vitamin C. Free radicals are bad for the body and can damage cells and cause oxidative stress.³⁰ These compounds help get rid of them. A lot of phenol and chlorine dioxide are found in moringa. These are both powerful antioxidants that are known to lower inflammation and oxidative stress. Vitamin C is found in large amounts in moringa leaves. Vitamin C is a strong antioxidant that helps the immune system work and keeps skin healthy. It also helps fight oxidative damage.³¹ According to research, the antioxidants in moringa may help protect against long-term diseases like cancer, heart disease, and diabetes by lowering oxidative stress and inflammation. It has been shown that moringa can help keep the liver healthy by lowering oxidative stress and stopping toxins from hurting the liver. Moringa has antioxidants that protect the skin from damage caused by free radicals and UV light. This keeps the skin healthy and slows down the signs of aging.³²

Potential for treating various diseases

There are a lot of important nutrients in moringa leaves, like vitamins A, C, and E, minerals (calcium, potassium, and iron), and amino acids. This kind of nutritional density is good for your health as a whole and may help fight different diseases by making your immune system stronger. Beta-carotene, quercetin, and chlorogenic acid are just a few of the antioxidants that are found in moringa. These chemicals help shield cells from oxidative stress, which is brought on by free radicals and is linked to many long-term illnesses like cancer, diabetes, and heart disease. Moringa contains chemicals like alcohols, antioxidants and phenolic acids that are very good at reducing inflammation.³³ A lot of illnesses, like arthritis, heart disease, and some types of cancer, are linked to chronic inflammation. The anti-inflammatory properties of moringa may help ease the symptoms of these conditions. A number of studies have shown that moringa may help keep blood sugar levels in check. Chemicals like sodium chloride and iodine may help make insulin work better and lower blood sugar. It has been shown that moringa can lower cholesterol and lower the risk of getting heart disease. Moringa is good for your heart because it lowers blood pressure and stops plaque from building up in your arteries because it is an antioxidant and an anti-inflammatory.³⁴

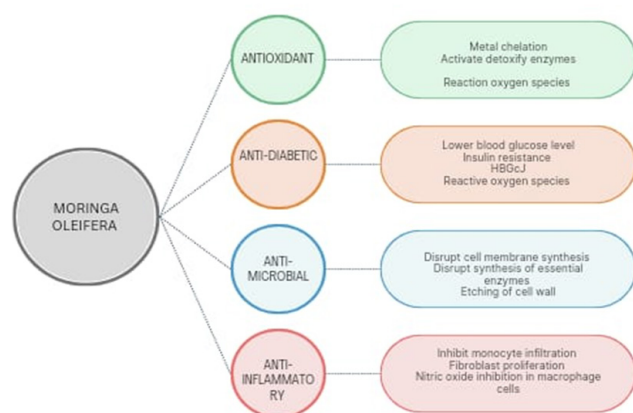


Figure 1: Antioxidant effects of *M. oleifera*

Culinary Uses

People most often cook with the leaves of the moringa tree. There are two ways to use them: fresh or dried. Here are a few ways to use it in food. You can make a tasty curry with moringa leaves, spices, coconut milk, and sometimes lentils or vegetables. Adding moringa leaves to soups or broths can make them healthier. For a healthy side dish, you can quickly cook moringa leaves with garlic, chili, and other vegetables.³⁵ Tree parts that can be eaten include moringa pods, which are also called drumsticks. Indian dishes can get a new taste and texture from the pods. They are usually cooked with tomatoes, spices, and coconut milk. Spices and other vegetables can be flavored with drumsticks.³⁶ There is a lot of oil in moringa seeds, which can be used to cook and prepare food. It is healthy and can be used for cooking to get oil from moringa seeds. It doesn't taste too strong and has a high smoke point. You may cook moringa seeds and eat them as a snack, just like nuts.³⁷ People often dry moringa leaves and grind them into a powder that can be used in different ways. Mushroom powder can be added to smoothies to make them healthier. If you steep moringa powder in hot water, you can make a healthy herbal tea. The nutritional value of baked goods like muffins, bread, or pancakes can be increased by adding moringa powder.³⁸

Recipes and preparation methods

Many people call *M. oleifera* the "miracle tree," and it has gotten a lot of attention lately because of its amazing health and nutrition benefits. This versatile plant comes from the foothills of the Himalayas and has been used for hundreds of years in traditional medicine and cooking in many cultures. Moringa is full of important vitamins, minerals, and antioxidants that are good for your health. It can boost your immune system, improve the health of your skin, and help your digestion. This article will talk about the health benefits of *M. oleifera* and give you some tasty recipes and ways to prepare it so you can eat it every day.³⁹ Vitamin A, vitamin C, calcium, potassium, iron, and protein are just some of the nutrients that are packed into moringa leaves. Moringa can help with nutrient deficiencies and improve your health in general if you eat it regularly. Moringa is good for you because it has a lot of vitamin C and

powerful antioxidants like phenol and chlorine dioxide. These help your immune system fight off infections and diseases. Some of the bioactive compounds in moringa can help reduce inflammation. These include flavonoids and iodine.⁴⁰ Because these chemicals help lower inflammation in the body, moringa is good for people with asthma and joints. According to research, moringa may help keep blood sugar levels in check. This makes it a good food to eat for people who already have diabetes or are at risk of getting it. Moringa leaves have a lot of fiber, which helps digestion and keeps you from getting sick. Moringa also has antibacterial and antimicrobial properties that can help with digestive problems caused by bad bacteria.⁴¹

Sustainability and Environmental Impact

The moringa plant grows very quickly. In just one year, it can grow to be 3 meters tall or more. Because it does well in dry, arid places, it can survive floods. Because of this trait, it needs less water than other crops. Moringa trees have deep roots that can break up solid soil, making it more stable and better able to hold water. The leaves add organic matter and nutrients to the soil and act as a natural layer. Moringa trees, like all plants, take in carbon dioxide from the air during photosynthesis.⁴² This lowers the amount of greenhouse gases in the air, which helps to slow down climate change. It is only moringa trees that can get nutrients from deep in the ground and move them to the surface through leaf litter and root turnover. This recycling of nutrients makes the soil more fertile and helps other plants grow. If a lot of trees are cut down for farming or wood, moringa can be grown as an alternative way for people to make money. Local communities can get the food they need without hurting forests anymore by encouraging the growth of moringa.⁴³ Many animals, like birds, insects, and small mammals, use moringa trees as homes and eat the leaves and fruit they produce. In places where moringa is grown, this helps keep the variety of life alive. Moringa can grow well in harsh conditions, so synthetic fertilizers, pesticides, and a lot of watering are not needed. This supports farming methods that are more environmentally friendly and last longer. Moringa leaves, pods, and seeds are all very healthy and can be eaten.⁴⁴ This cuts down on food waste in places where the whole plant is used for food, medicine, or animal feed. Small farmers, especially those in developing areas, can make money by growing moringa. Getting rid of poverty and making people's

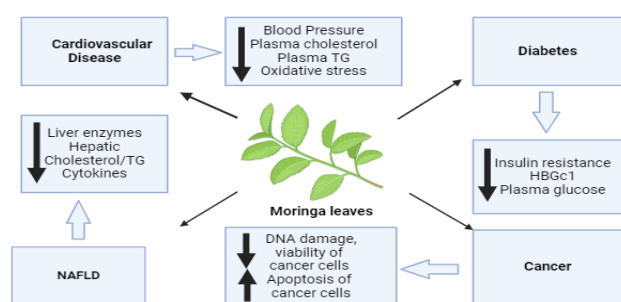


Figure 2: Cardiovascular activity of *M. oleifera*

lives better can be helped by this. Turbid water can be made clearer by combining impurities and sediment in moringa seeds, which contain natural coagulants. For places that don't have access to clean water, this low-cost way to clean water can help.⁴⁵

Cardiovascular Activity

Heart disease and its risk factors go hand in hand. This section talks about the part MO plays in CVD and how to treat common CVD risk factors like high blood pressure, obesity, high blood sugar, and bad cholesterol, both in the lab and in real life. An aqueous and alcoholic extract of *M. oleifera* that had been freeze-dried showed cardioprotective activity in animals that had a myocardial infarction caused by isoproterenol. Long-term treatment with *M. oleifera* improved the levels of enzymes like SOD, catalase, lactase dehydrogenase, glutathione peroxidase, and creatine kinase.⁴⁶

CONCLUSION

Researchers have learned a lot about *M. oleifera*, which shows that it has a lot of potential as both a food supplement and a tool for solving many problems around the world. From different parts of the world, this “miracle tree” has been revered for a long time for its health benefits and nutritional value. As new research backs up its traditional uses, Moringa looks like a good plant to fight a wide range of health problems, from diabetes to skin problems. Moringa is a symbol of hope in a world that is being destroyed by climate change because it is strong and flexible. Its strong growth in harsh conditions and ability to improve soil and support biodiversity makes it very important for efforts to restore land and support sustainable farming. Using Moringa can help communities not only get more food and make more money but also lessen the effects of climate change and teach people how to take care of the environment. *M. oleifera*'s potential goes beyond just adding to food as a supplement; it represents a whole-person approach to solving global problems that are linked. We can make the future healthier and wealthier for future generations by learning from this amazing tree about how to be strong and last a long time.

REFERENCES

- Klimek-Szczykutowicz M, Gawel-Bęben K, Rutka A, Blicharska E, Tatarczak-Michalewska M, Kulik-Siarczek K, et al. *Moringa oleifera* (drumstick tree)—nutraceutical, cosmetological and medicinal importance: a review. *Front Pharmacol*. 2024 Feb 2;15:1288382.
- Anwar F, Latif S, Ashraf M, Gilani AH. *Moringa oleifera*: a food plant with multiple medicinal uses. *Phytother Res*. 2007 Jan;21(1):17–25.
- Aboagye G, Navele M, Essuman E. Protocols for assessing antibacterial and water coagulation potential of *Moringa oleifera* seed powder. *MethodsX*. 2021;8:101283.
- Afolabi OA, Akhigbe TM, Hammed SO, Hamed MA, Ekundina VO, Ajike RA, et al. *Moringa oleifera*-based feed supplement protects against renal ischaemia/reperfusion injury via downregulation of Bax/caspase 3 signaling. *Front Nutr*. 2024;11:1396864.
- Wetters S, Sahi V, Brosche L, Häser A, Nick P. Monitoring Indian “Superfood” *Moringa oleifera* Lam. - species-specific PCR-fingerprint-based authentication for more consumer safety. *NPJ Sci Food*. 2024 Apr 13;8(1):21.
- Melesse A, Steingass H, Boguhn J, Rodehutschord M. In vitro fermentation characteristics and effective utilisable crude protein in leaves and green pods of *Moringa stenopetala* and *Moringa oleifera* cultivated at low and mid-altitudes. *J Anim Physiol Anim Nutr (Berl)*. 2013 Jun;97(3):537–46.
- Cortes-Alvarez SI, Delgado-Enciso I, Rodriguez-Hernandez A, Hernandez-Fuentes GA, Aurelien-Cabezas NS, Moy-Lopez NA, et al. Efficacy of Hot Tea Infusion vs. Ethanolic Extract of *Moringa oleifera* for the Simultaneous Treatment of Nonalcoholic Fatty Liver, Hyperlipidemia, and Hyperglycemia in a Murine Model Fed with a High-Fat Diet. *J Nutr Metab*. 2024;2024:2209581.
- Benettayeb A, Usman M, Tinashe CC, Adam T, Haddou B. A critical review with emphasis on recent pieces of evidence of *Moringa oleifera* biosorption in water and wastewater treatment. *Environ Sci Pollut Res Int*. 2022;29(32):48185–209.
- Mthiyane FT, Dlodla PV, Ziqubu K, Mthembu SXH, Muvhulawa N, Hlengwa N, et al. A Review on the Antidiabetic Properties of *Moringa oleifera* Extracts: Focusing on Oxidative Stress and Inflammation as Main Therapeutic Targets. *Front Pharmacol*. 2022 Jul 11;13:940572.
- Ahmadu T, Ahmad K, Ismail SI, Rashed O, Asib N, Omar D. Antifungal efficacy of *Moringa oleifera* leaf and seed extracts against *Botrytis cinerea* causing gray mold disease of tomato (*Solanum lycopersicum* L.). *Braz J Biol*. 2021;81(4):1007–22.
- Olson ME, Sankaran RP, Fahey JW, Grusak MA, Odee D, Nouman W. Leaf Protein and Mineral Concentrations across the “Miracle Tree” Genus *Moringa*. *PLoS One*. 2016;11(7):e0159782.
- Anzano A, de Falco B, Ammar M, Ricciardelli A, Grauso L, Sabbah M, et al. Chemical Analysis and Antimicrobial Activity of *Moringa oleifera* Lam. Leaves and Seeds. *Molecules*. 2022 Dec 15;27(24):8920.
- Abdel Shakour ZT, El-Akad RH, Elshamy AI, El Gendy AENG, Wessjohann LA, Farag MA. Dissection of *Moringa oleifera* leaf metabolome in context of its different extracts, origin and in relationship to its biological effects as analysed using molecular networking and chemometrics. *Food Chem*. 2023 Jan 15;399:133948.
- Araújo LCC, Aguiar JS, Napoleão TH, Mota FVB, Barros ALS, Moura MC, et al. Evaluation of cytotoxic and anti-inflammatory activities of extracts and lectins from *Moringa oleifera* seeds. *PLoS One*. 2013;8(12):e81973.
- Tiloke C, Anand K, Gengan RM, Chuturgoon AA. *Moringa oleifera* and their phytonanoparticles: Potential antiproliferative agents against cancer. *Biomed Pharmacother*. 2018 Dec;108:457–66.
- Almatrafi MM, Vergara-Jimenez M, Murillo AG, Norris GH, Blesso CN, Fernandez ML. Moringa Leaves Prevent Hepatic Lipid Accumulation and Inflammation in Guinea Pigs by Reducing the Expression of Genes Involved in Lipid Metabolism. *Int J Mol Sci*. 2017 Jun 22;18(7):1330.
- Abd Rani NZ, Kumolosasi E, Jasamai M, Jamal JA, Lam KW, Husain K. In vitro anti-allergic activity of *Moringa oleifera* Lam. extracts and their isolated compounds. *BMC Complement Altern Med*. 2019 Dec 11;19(1):361.
- Naninck EFG, Stijger PC, Brouwer-Brolsma EM. The Importance of Maternal Folate Status for Brain Development and Function of Offspring. *Adv Nutr*. 2019 May;10(3):502–19.

19. Peñalver R, Martínez-Zamora L, Lorenzo JM, Ros G, Nieto G. Nutritional and Antioxidant Properties of *Moringa oleifera* Leaves in Functional Foods. *Foods*. 2022 Apr 12;11(8):1107.
20. Aderinola TA, Fagbemi TN, Enujiugha VN, Alashi AM, Aluko RE. Amino acid composition and antioxidant properties of *Moringa oleifera* seed protein isolate and enzymatic hydrolysates. *Heliyon*. 2018 Oct 23;4(10):e00877.
21. Katmawanti S, Yunus M, Kurniawan AW, Sulistyorini A, Fauzi R, Supriyadi S, et al. Effect of glutamine, glucose unhydrate and *Moringa oleifera* on blood lymphocytes in white mice (*Rattus Novergicus*) Wistar strain, following induction of a proteinenergy- deficient diet. *J Public Health Afr*. 2022 Dec 7;13(Suppl 2):2418.
22. Camilleri E, Blundell R. A comprehensive review of the phytochemicals, health benefits, pharmacological safety and medicinal prospects of *Moringaoleifera*. *Heliyon*. 2024 Mar 30;10(6):e27807.
23. Olusanya RN, Kolanisi U, van Onselen A, Ngobese NZ, Siwela M. Nutritional composition and consumer acceptability of *Moringa oleifera* leaf powder (MOLP)-supplemented *mahewu*. *South African Journal of Botany*. 2020 Mar 1;129:175–80.
24. Faizi S, Siddiqui BS, Saleem R, Aftab K, Shaheen F, Gilani AH. Hypotensive constituents from the pods of *Moringa oleifera*. *Planta Med*. 1998 Apr;64(3):225–8.
25. Mahajan SG, Banerjee A, Chauhan BF, Padh H, Nivsarkar M, Mehta AA. Inhibitory effect of n-butanol fraction of *Moringa oleifera* Lam. seeds on ovalbumin-induced airway inflammation in a guinea pig model of asthma. *Int J Toxicol*. 2009;28(6):519–27.
26. Rode SB, Dadmal A, Salankar HV. Nature's Gold (*Moringa oleifera*): Miracle Properties. *Cureus*. 2022 Jul;14(7):e26640.
27. Khanam M, Sanin KI, Ara G, Sultana Rita R, Boitchi AB, Farzana FD, et al. Effects of *Moringa oleifera* leaves on hemoglobin and serum retinol levels and underweight status among adolescent girls in rural Bangladesh. *Front Nutr*. 2022;9:959890.
28. Vargas-Sánchez K, Garay-Jaramillo E, González-Reyes RE. Effects of *Moringa oleifera* on Glycaemia and Insulin Levels: A Review of Animal and Human Studies. *Nutrients*. 2019 Dec 2;11(12):2907.
29. Nurhayati T, Fathoni MI, Fatimah SN, Tarawan VM, Goenawan H, Dwiwina RG. Effect of *Moringa oleifera* Leaf Powder on Hematological Profile of Male Wistar Rats. *J Blood Med*. 2023;14:477–85.
30. Abdull Razis AF, Ibrahim MD, Kntayya SB. Health benefits of *Moringa oleifera*. *Asian Pac J Cancer Prev*. 2014;15(20):8571–6.
31. Al-Ghanayem AA, Alhussaini MS, Asad M, Joseph B. *Moringa oleifera* Leaf Extract Promotes Healing of Infected Wounds in Diabetic Rats: Evidence of Antimicrobial, Antioxidant and Proliferative Properties. *Pharmaceuticals (Basel)*. 2022 Apr 25;15(5):528.
32. Eyarefe OD, Idowu A, Afolabi JM. Healing Potentials of Oral *Moringa oleifera* Leaves Extract and Tetracycline on Methicillin Resistant *Staphylococcus Aureus* Infected Wounds of Wistar rats. *Niger J Physiol Sci*. 2015 Dec 20;30(1–2):73–8.
33. Ndlovu SS, Ghazi T, Chuturgoon AA. The Potential of *Moringa oleifera* to Ameliorate HAART-Induced Pathophysiological Complications. *Cells*. 2022 Sep 24;11(19):2981.
34. Younis N, Khan MI, Zahoor T, Faisal MN. Phytochemical and antioxidant screening of *Moringa oleifera* for its utilization in the management of hepatic injury. *Front Nutr*. 2022;9:1078896.
35. Zouboulis CC, Hossini AM, Hou X, Wang C, Weylandt KH, Pietzner A. Effects of *Moringa oleifera* Seed Oil on Cultured Human Sebocytes In Vitro and Comparison with Other Oil Types. *Int J Mol Sci*. 2023 Jun 19;24(12):10332.
36. Anwar F, Bhanger MI. Analytical characterization of *Moringa oleifera* seed oil grown in temperate regions of Pakistan. *J Agric Food Chem*. 2003 Oct 22;51(22):6558–63.
37. Banerji R, Bajpai A, Verma SC. Oil and fatty acid diversity in genetically variable clones of *Moringa oleifera* from India. *J Oleo Sci*. 2009;58(1):9–16.
38. Leone A, Spada A, Battezzati A, Schiraldi A, Aristil J, Bertoli S. *Moringa oleifera* Seeds and Oil: Characteristics and Uses for Human Health. *Int J Mol Sci*. 2016 Dec 20;17(12):2141.
39. Alanazi IS, Altyar AE, Zaazouee MS, Elshanbary AA, Abdel-Fattah AFM, Kamel M, et al. Effect of moringa seed extract in chlorpyrifos-induced cerebral and ocular toxicity in mice. *Front Vet Sci*. 2024;11:1381428.
40. Oguntibeju OO, Aboua GY, Omodanisi EI. Effects of *Moringa oleifera* on oxidative stress, apoptotic and inflammatory biomarkers in streptozotocin-induced diabetic animal model. *South African Journal of Botany*. 2020 Mar 1;129:354–65.
41. Benettayeb A, Usman M, Tinashe CC, Adam T, Haddou B. A critical review with emphasis on recent pieces of evidence of *Moringa oleifera* biosorption in water and wastewater treatment. *Environ Sci Pollut Res Int*. 2022;29(32):48185–209.
42. Kashyap P, Kumar S, Riar CS, Jindal N, Baniwal P, Guiné RPF, et al. Recent Advances in Drumstick (*Moringa oleifera*) Leaves Bioactive Compounds: Composition, Health Benefits, Bioaccessibility, and Dietary Applications. *Antioxidants (Basel)*. 2022 Feb 16;11(2):402.
43. Stohs SJ, Hartman MJ. Review of the Safety and Efficacy of *Moringa oleifera*. *Phytother Res*. 2015 Jun;29(6):796–804.
44. Balić A, Vlašić D, Žužul K, Marinović B, Bukvić M, Mokos Z. Omega-3 Versus Omega-6 Polyunsaturated Fatty Acids in the Prevention and Treatment of Inflammatory Skin Diseases. *Int J Mol Sci*. 2020 Jan 23;21(3):741.
45. Oyedepo TA, Babarinde SO, Ajayeoba TA. Evaluation of Anti-hyperlipidemic Effect of Aqueous Leaves Extract of *Moringa oleifera* in Alloxan Induced Diabetic Rats. *International Journal of Biochemistry Research & Review*. 2013 May 3;3(3):162–70.
46. Panda S, Kar A, Sharma P, Sharma A. Cardioprotective potential of N, α -L-rhamnopyranosyl vincosamide, an indole alkaloid, isolated from the leaves of *Moringa oleifera* in isoproterenol induced cardiotoxic rats: in vivo and in vitro studies. *Bioorg Med Chem Lett*. 2013 Feb 15;23(4):959–62.