Chapter 25

The Pharmacological Potential of *Moringa oleifera* Reviews of its Bioactive Compounds and Therapeutic Effects

Samia Samar[1], Attiqa Sajid[2], Faisal Yousaf[3], Hira Shair[4], Atiqa Nudrat[3], Fatima Ijaz[5], Laiba Naeem[6] , Hassan Ali[7] and Anum Zulfiqar*[3]

[1]Department of Pharmacology, Faculty of Basic Medical Sciences, King Edward Medical University, Pakistan
[2]Department of Zoology, Wildlife and Fisheries, Faculty of Sciences, University of Agriculture, Faisalabad, Pakistan
[3]Department of Biochemistry, Faculty of Sciences, University of Agriculture, Faisalabad, Pakistan
[4]National Institute of Food Science and Technology, Faculty of Food, Nutrition and Home Sciences, University: University of Agriculture, Faisalabad, Pakistan
[5]Centre of Agricultural Biochemistry and Biotechnology, Faculty of Agriculture, University of Agriculture, Faisalabad, Pakistan
[6]Department of Chemistry, Faculty of Sciences, University of Agriculture, Faisalabad, Pakistan
[7]Department of Pharmacy, Government College University Faisalabad, Pakistan
*Corresponding author: missanum36@gmail.com

ABSTRACT

The tropical periodic deciduous plant *Moringa oleifera*, which is a member of the Moringaceae family, is abundant in biologically active compounds like phytochemicals, vitamins, electrolytes, and minerals. Every part of *Moringa* has a different composition but most commonly powder of dried leaves of moringa is used as functional ingredients in our food. Moringa is also thought to be a treatment for malnutrition and many other disorders. It has numerous pharmacological qualities, including antioxidant, anti-inflammatory, anti-anemic, antibacterial, anti-diabetic, and anti-cancer effects. It improves liver and brain health. Probably, the presence of flavonoids and other bioactive chemicals in moringa is directly related to the plant's pharmacological qualities. To serve as a reference for Moringa's possible use as a functional food, this chapter will include a summary of its bioactive chemicals and therapeutic qualities.

KEYWORDS
Moringa oleifera, Phytochemicals, Therapeutic, Nutritional, Bioactive compounds

Received: 07-Jun-2024
Revised: 24-Jul-2024
Accepted: 15-Aug-2024

A Publication of Unique Scientific Publishers

Cite this Article as: Samar S, Sajid A, Yousaf F, Shair H, Nudrat A, Ijaz F, Naeem L Ali H and Zulfiqar A, 2024. The pharmacological potential of *Moringa oleifera* reviews of its bioactive compounds and therapeutic effects. In: Abbas RZ, Khan AMA, Qamar W, Arshad J and Mehnaz S (eds), Complementary and Alternative Medicine: Botanicals/Homeopathy/Herbal Medicine. Unique Scientific Publishers, Faisalabad, Pakistan, pp: 222-229. https://doi.org/10.47278/book.CAM/2024.284

INTRODUCTION

Among the monogenetic family Moringaceae, *Moringa oleifera* Lam (syn. M. ptreygosperma Gaertn.) is one of the most well-known, extensively distributed, and naturally occurring species. It is incredibly useful so there has been a lot of research done on this plant, one of the 13 species of the Moringaceae family (Boopathi and Abubakar, 2021). And as the "kelor tree" in others. Shagara al Rauwaq, which translates to "tree for purifying," is the name of the tree in the Nile Valley while it is cultivated and grown throughout Pakistan under the native name "Sohanjna." The tree is between five and ten meters tall. The tropical *Moringa oleifera* is local to Asia Minor, Africa, Arabia, India, Pakistan, and the western and sub-Himalayan areas. It can tolerate poor soil conditions, grows well in hot, dry, and humid tropical climates, and is not greatly affected by drought. With an estimated yearly demand of between 250 and over 3000 mm, it can tolerate various rainfall. *Moringa oleifera* can be found in Central America, the Caribbean Islands, South and North America, Cambodia, and the Philippines (Anwar et al., 2007).

M. oleifera ranges in five to ten meter heightened rapidly growing plant. The pale green, soft leaves of *M. oleifera* measure between 30 and 60 cm and have several tiny leaflets. The fragrant, bisexual flowers of *M. oleifera* have five uneven, milky, or white petals. After being planted, they flower within the first six months. Furthermore, the flowers typically develop into anthem, which is a structure that is between 12 and 30 centimeters in length, between April and June on the hairy, thin pedicels. In geographically chilly areas, flowering occurs once a year; in areas with more consistent seasonal temperatures and persistent rainfall, it blooms twice a year or even year-round. Fruit yields are typically modest in the initial years. A tree can produce as many as 1000 grains of pods after three years of planting (Liu et al., 2018).

Because practically every portion of the *M. oleifera* tree has some use, it is regarded as one of the most multipurpose

plants on the planet. Because of its abundance in some macro and micronutrients that are crucial to human nutrition, this tree is known as a miracle. Different components of *M. oleifera* are prepared differently and used as vegetables or dietary supplements in many underdeveloped nations. Furthermore, practically every component of this tree has already been used to successfully treat a range of illnesses. Forage uses include leaves, tree trunks for gums, flower nectar in honey, and ground seeds used to purify water. A substitute food supply for malnutrition, particularly in young children and newborns, is *M. oleifera* leaf (Oyeyinka and Oyeyinka, 2018).

Fig. 1: Moringa 'drumstick' plant leaves

Table 1: Moringa species are widely cultivated in different countries(Boopathi and Abubakar, 2021)

Series:	Species of Moringaceae:	Most widely cultivated in:
01	*M. oleifera*	Pakistan, India
02	*M. peregrina*	Red Sea Area, Arabia
03	*M. concanensis*	Pakistan, Bangladesh, India
04	*M. drouhardii*	Madagasar
05	*M. stenopetala*	Ethiopia, Kenya
06	*M. hildebrandtii*	Madagasar
07	*M. ovalifolia*	Angolia, Namibia
08	*M. rivae*	Ethiopia, Kenya
09	*M. longituba*	Somalia, Kenya
10	*M. arborea*	Kenya
11	*M. pygmaea*	Somalia
12	*M. borziana*	Somalia, Kenyya
13	*M. ruspoliana*	Ethiopia, Kenya, Somalia

Bioactive Compounds Present in *M. oleifera*

The benefits of the moringa tree for the environment, water sanitation, health, and nutrition have led to its designation as a tree of life. Moringa is a tree of great diversity that is prized in many tropical regions and used in a wide range of traditional remedies. Because it contains a variety of bioactive chemicals, moringa is a useful traditional medicinal plant. It contains a variety of nutrients, including protein, vitamins, minerals, and phytonutrients like tannins, alkaloids, flavonoids, polyphenols, and carotenoids. In some locations where there are nutritional issues, this plant is utilized as a nutritional supplement for young children (Duranti et al., 2021). Moringa leaf's nutritive and bioactive composition is affected by agroclimatic factors, plant age, genotype, and harvest timing (Managa et al., 2021; Rébufa et al., 2021).

Phytochemicals Present in Moringa

Phytochemicals are organic molecules that are physiologically active and present in plants that humans eat. Although they have not been linked to any particular human deficiency illness, they may have health benefits. Generally speaking,

phytochemicals are plant-derived secondary metabolites i.e., materials produced by plant cells that support the survival of the entire plant. Numerous phytochemicals are thought to have the same properties as natural pesticides. Some phytochemicals provide color or aroma, while others serve as signaling molecules within the plant or in connection to other organisms. Even in Western countries, that cultivate and eat relatively few plant species as food, thousands of phytochemicals that are found in food are ingested in substantial amounts. Phytochemicals have been used by humans as medication to treat and prevent a variety of illnesses, especially cancer or illness related to old age (Johnson and extraction, 2013). Plant-based phytochemicals are classified into five types depending on their chemical structures: carotenoids, polyphenols, terpenoids, alkaloids, and compounds containing sulfur (Bøhn et al., 2012). Moringa trees have almost all these types of phytochemicals due to which Moringa has vast medicinal uses. The phytochemicals called alkaloids are produced when amino acids are broken down. The predominant alkaloid found in Moringa leaves is N, α-l-rhamnopyranosyl vincosamide (VR), which possesses a cardioprotective function (Panda et al., 2013).

The Moringa has polyphenols that include high concentrations of tannins, lignans, and phenolic acids. Comparatively speaking, the plant's leaves have a higher concentration of polyphenols than its flowers or seeds do. It has been discovered that they have antifungal, antibacterial, and antioxidant properties (Leone et al., 2015). Studies have shown that *M. peregrina* leaves have a roughly 22 percent greater total phenolic content than *M. oleifera* leaves (Al Juhaimi et al., 2017). Furthermore, the concentration of phenolic compounds is contingent upon many parameters, including the variety, time of year, and geographical position. For instance, compared to cultivars grown in India, America, and Africa, those grown in Pakistan had a higher phenolic content (Saini et al., 2016).

Flavonoids make up the majority of the polyphenols found in moringa. Since the human body is unable to synthesize flavonoids, this class of diphenyl propane molecules must be obtained through diet. Furthermore, because they are quickly digested, regular supplementation is required (Wang et al., 2017). Anthocyanidins, chalcones, flavanones, flavones, and flavanols are some of the substituents of flavonoids. The flavonoids quercetin, about 47 percent, and kaempferol, approximately 30 percent, are prominently found throughout the Moringa tree, except its roots and seeds. While kaempferol is linked to a decreased risk of cancer, including epithelial ovarian cancer, quercetin has strong antioxidant activity and possesses anti-diabetic, hypotensive, and hypolipidemic qualities. There are also other flavonoids present, such as luteolin, epicatechin, myricetin, and apigenin (Rodríguez-Pérez et al., 2015).

Chlorogenic Acid is another important phenolic acid found in moringa. It is a dihydro cinnamic acid ester that is involved in glucose control. It is discovered to exhibit anti-dyslipidemic action by lowering the level of triglycerides and total cholesterol in plasma (Amaglo et al., 2010). These are the pigments that give fruits and vegetables their color and are typically found in them. One of the best sources of α-tocopherol and other carotenoids is the leaves of *Moringa oleifera*. There are six main types of carotenoids found in *M. oleifera's* vegetative components, including its leaves, flowers, and fruits. All-E-zeaxanthin, all-E-lutein, 13-Z-lutein, all-E-luteoxanthin, 15-Z-β-carotene, and all-E-β-carotene are some of these molecules. All-E-lutein makes up the majority of these, making up roughly 53%. Additionally, they suggested that the high concentration of carotenoids found in moringa will aid in avoiding or lessening vitamin A insufficiency (Saini et al., 2014).

Antioxidant in Moringa

The antioxidant activity of different parts of the moringa tree has been done by in vitro and in vivo analysis. Moringa Leaves have ascorbic acids, β-carotene, glucoside, quercetin, kaempferol, chlorogenic acid, phenolic acids, isothiocyanates, polyphenols and rutin (Tumer et al., 2015). Moringa Flowers have Phytosterols, palmitic acid, and 9-octadecenamide while Moringa seeds are rich in oil and contain oleic acid, mono palmitic acid, tri-oleic triglycerides, tocopherols, Myricetin, and lectins(Mahajan et al., 2007). Moringa Pods has glucosinolates, Procyanidins, flavonoids, isothiocyanates, and thiocarbamates. These all show high antioxidant activity (Singh and Navneet, 2018).

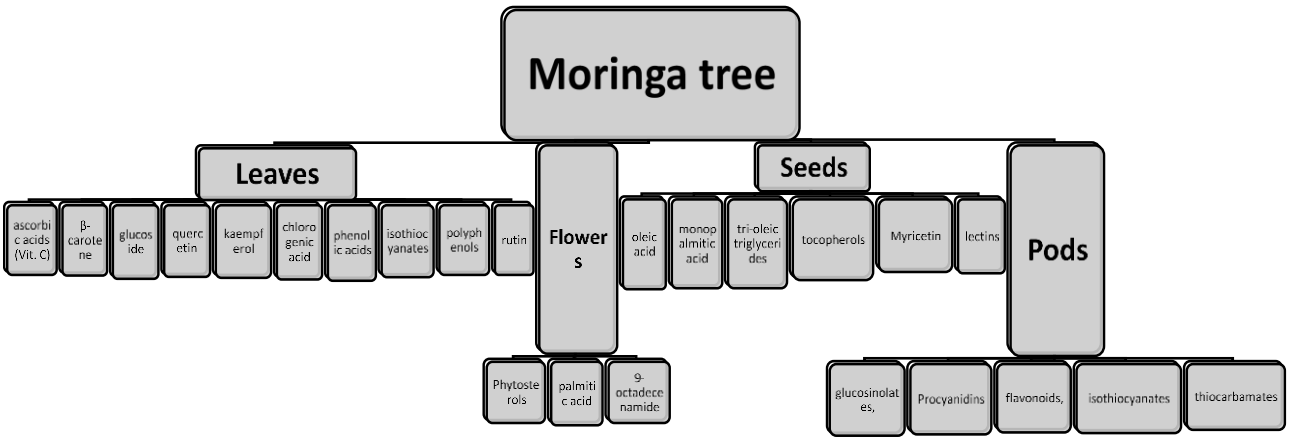

Fig. 2: Composition of different parts of Moringa tree.

Vitamins and Minerals present in Moringa

By consuming moringa, vitamin deficiency can be cured (Olson and Fahey, 2011). The dried powdered leaves of Moringa contain a high vitamin E and βeta-carotene content. Betacarotene, ascorbic acid, niacin, riboflavin pyridoxine, thiamine, cholecalciferol, biotin, tocopherol, and vit. K have all been found to be abundant in moringa powder. These vitamins are necessary for normal body functioning as Vit. A is necessary for vision, and Vit D is compulsory for bone development, without Vit. K blood clotting is impossible, Vit C is required for skin as well as maintains iron levels in the blood, etc.(Isitua et al., 2015). The leaves are a valuable source of minerals and vitamins. Indeed, compared to citrus fruits, carrots, yogurt, dairy products, spinach and bananas, and, moringa is believed to provide seven times more vitamin C, ten times more vitamin A, seventeen times more calcium, nine times more protein, fifteen times more potassium, and twenty-five times more iron (Rockwood et al., 2013).

As compared to bananas and green leafy vegetables like spinach, moringa has more iron and potassium (Gómez et al., 2014). The fact that dried moringa leaves have a significant mineral element deposit is also really intriguing. It was found that the amount of calcium was greater than in other plant sources. Calcium is necessary for bones and teeth, preventing osteoporosis, and required for blood clotting, nervous system, immunity, and muscle movement. Thus, moringa is a rich source of this valuable mineral (Nkafamiya et al., 2010). The leaves of this plant were discovered to be highly abundant in iron, a mineral that is frequently lacking in diets based on plants. Iron plays a vital part in energy metabolism by facilitating the transmission of electrons in the electron transport chain, which is important for the synthesis of ATP. Iron is a component of myoglobin and hemoglobin for oxygen transport (Kozat, 2007).

Cu, thought to have profound impacts on the immune system, was present in the dried leaves of the moringa plant. Zn and copper work together to support superoxide dismutase function and the elimination of oxygen-free radicals. As a result, it plays a crucial role in the cellular membranes' defense mechanism against the damage caused by superoxide free radicals. Furthermore, it has been demonstrated that the copper-containing enzyme ceruloplasmin has anti-inflammatory action, which may be helpful in mastitis situations (Kozat, 2007). Studies revealed that dried Moringa leaves are said to contain higher amounts of zinc. Zinc is necessary for the creation of insulin, RNA, DNA, and many enzymes' structures and/or functions. Additionally, zinc is necessary for the growth and reproduction of cells, particularly sperm cells. Furthermore, zinc has been linked to anti-viral, antimicrobial, anti-fungal properties, and anti-cancer effects. The sulfur found in moringa is essential for the rumen microbes' efficient growth and function. Thus, the mineral makeup of moringa is important for its therapeutic, pharmacological, and nutritional benefits (Busani et al., 2011).

Protein Content

Since amino acids are chemical substances that combine to produce proteins, they have an impact on both the amount and type of protein. The classification of amino acids into essential and non-essential categories varies depending on the type of animal and how it is produced. Essential Amino acids are that are not produced by the body. It must be necessary to take them by food while non-essential amino acids are not necessary in the diet (Swanepoel et al., 2010). The protein content level is especially important nutritionally because it may help animals meet their needs for protein and energy while also strengthening their immune systems against illness. According to reports, moringa contains high-quality, readily digested protein that is influenced by the quality of its amines. Nineteen amino acids were present in the dried Moringa leaves. Out of the typical 20 amino acids, only glutamine was not found; however, glutamine may be produced from glutamic acid. Of the 19 amino acids found, 10 were identified as essential amino acids as includes, phenylalanine, threonine, lysine, methionine, leucine, tyrosine, valine, isoleucine, tryptophan and histidine (Sánchez-Machado et al., 2010).

The Healthy Fat Present in Moringa

The dried leaves of Moringa were found to contain 17 different fatty acids, 11 of which were classed as saturated fatty acids despite having lower values. The compounds with the greatest and lowest values were henicosanoic, palmitic, and capric. There were three types of polyunsaturated fatty acids found: α-linolenic, linoleic, and g-linolenic. Of these, α-linolenic had the highest value. The value of α-linolenic acid is higher, at 56.87 percent. α-linolenic acid, an n-3 fatty acid that falls under the category of essential fatty acids, caught our attention (Sánchez-Machado et al., 2010).

Dietary polyunsaturated fatty acids are present in greater amounts in moringa than saturated fatty acids. Because Polyunsaturated FA has a higher content and a lower level of Saturated FA, it is recommended to include more of it in the diet as it helps to avoid diseases and promote overall health. Increased intake of α-linolenic acid is advised as it supports the body's natural production of long-chain omega-3 fatty acids. Total omega 3 fatty acids are almost 45 percent more in moringa leaves as compared to omega 6 fatty acids which are mostly present in our diet. But generally, our diet is deficient in omega-3 fatty acids so by incorporating moringa leaves in our diet we can get healthy fats (Wood et al., 2008).

Therapeutic Effects of Moringa

Many researchers have used the leaves, seeds, and pods of Moringa to report on a variety of pharmacological qualities. It addresses undernourishment, acts as an antidiabetic, reduces inflammation, and treats a variety of conditions affecting the bones, muscles, liver, etc. (Paikra et al., 2017).

Antidiabetic Effects

Diabetes is a degenerative blood glucose system disease that is characterized by insufficient or absent pancreatic beta cell production of insulin, leading to chronic hyperglycemia. This condition is linked to long-term microvascular complications such as retinopathy, nephropathy, and neuropathy, as well as macrovascular complications such as cardiovascular problems. Additionally, oxidative stress brought on by hyperglycemia is a serious side effect of diabetes (Forbes and Cooper, 2013). Previous research found that MO can prevent the development and adverse effects of diabetic-induced damage to the kidney by way of its beneficial impact on oxidative damage and cytokines associated with inflammation in the kidneys of diabetic rats. *M. oleifera* has a high antioxidant amount and broad medicinal properties. Abilities (Fahey, 2005). Strong phytochemical components found in MO protect against inflammation, reactive oxygen species (ROS), and renal damage caused by diabetes. As a result, MO may help prevent diabetic complications, especially in developing nations like Africa where most people cannot afford orthodox medicine (Fahey, 2005). The decrease in insulin resistance, enhanced insulin secretion, and suppression of intestinal glucose were found to be the mechanisms underlying Moringa's ability to lower blood sugar (Muhammad et al., 2016).

Anti-anemic Effects

Anemia is characterized by a drop in the blood's erythrocyte mass or hemoglobin concentration, which lowers the blood's capacity to carry oxygen. Anemia affects both physical and mental health when hemoglobin levels in the blood fall under the normal range, which is below twelve g/dL for female and less than 13 g/dL for male(Dary et al., 2006). Moringa leaves have anti-anemic effects as a study was conducted on rats. After inducing hydrolysis, treatment of moringa's dried leaves powder was given and parameters to check anemia were then improved, including RBC count, MCV, Hb, HCV etc. The normal spleen showed typical white and red pulps with few megakaryocytes and little hemosiderin pigment deposition; the anemic group showed hyperplasia of megakaryocytes with significant hemosiderin deposition; the best results were observed in the groups treated with *Moringa oleifera* flower extract; the other treated groups indicated ranging degrees of improvement as indicated by a decrease in the number of megakaryocytes and accumulation of hemosiderin pigments. The effect of *M. oleifera* flower extract might be attributed to the presence of vitamins and iron content in them(MANJEGOWDA et al.).

Antibacterial Activity of Moringa

Moringa oleifera has been shown to have antibacterial activity against several bacteria, including *Bacillus subtilus, Escherichia coli, Staphylococcus aureus, Proteus vulgaris, Pseudomonas aeroginosa,* and *Streptococcus mutans* greatest action against *Streptococcus* mutant was demonstrated by the ethanol leaf extract, whereas greatest activity against *P.vulgarisas* was demonstrated by the aqueous extract(Patel et al., 2014). In another study, bacteria's ability to proliferate is inhibited by the plant leaves' aqueous, ethanol, and methanol extracts. Escherichia coli was substantially more susceptible to the inhibitory effects of water, ethanol, and methanol extracts compared to *Staphylococcus aureus* and *Pseudomonas aeruginosa*, respectively. Furthermore, at a greater dose of 120 mg/ml, the inhibitory impact of both ethanol and methanol extract was significantly larger. Thus, the gram-positive bacteria *Staphy aureus* and the gram negative bacteria *E. coli* and *Pseudomonas aeruginosa* that were examined were susceptible to the powder made from the leaves of the moringa plant(Singh and Tafida, 2014).

In another study, Methanol leaf extract inhibited *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* same as *P. aeruginosa* and it is more effective than water leaf extract(van den Berg and Kuipers, 2022).

Anti-inflammatory Activity

The Ethanol extract from boiling *M. oleifera* pods on the expression of inflammatory mediators released by the macrophage cell line stimulated by lipopolysaccharide (LPS). The extract from the pod demonstrates a strong anti-inflammatory effect by inhibiting LPS-induced NO generation, iNOS, COX-2 protein expression, and TNF-α and IL-6 secretion in a dose-dependent manner. Additionally, this food extract dramatically lowers levels of its mRNA cognates, which could have an impact on their transcription process or mRNA stability, according to the RT-PCR study. The findings also showed that by preventing the activation of all three MAPKs and reducing IκB-α phosphorylation, this dietary extract reduced the production of these proinflammatory mediators. As a result, the extract inhibited the production of pro-inflammatory genes, which are MAPKs and NF-κB's downstream targets, by acting on the upstream signaling pathway(Muangnoi et al., 2012). In LPS-stimulated murine macrophages, isothiocyanates derived from Moringa seed extract demonstrated anti-inflammatory efficacy by reducing NO generation and inflammatory gene expression as iNOS, cytokines such as IL-1 and IL-6. Moringa basically targets inflammatory cytokines such as IL-1, IL-6, etc. (Jaja-Chimedza et al., 2017)

Anti-cancer Activity

Many research studies showed that moringa has anticancer effects on human cancer cells. Glucosinolates may be able to decrease the development of carcinogenesis through some molecular targets as part of *M. oleifera's* chemoprevention strategy. It also involves anti-inflammatory, anti-tumor expansion of cells, induction of the death of cells, prevention of tumor angiogenesis, and inhibition of carcinogen activation and detoxification. Because glucosinolate is present in *M. oleifera* and has been shown in anticancer trials to trigger apoptosis, its chemopreventive benefits are expected.

Additionally, investigations using *M. oleifera* leaf extract to stop the expansion of human cancer cell lines have shown the plant's chemopreventive efficacy(Karim et al., 2016). In human malignant lung cells (A549), an aqueous extract of moringa leaves suppresses cancer proliferation and development by triggering apoptosis, DNA breakage, and increased oxidative stress. The level of p53 increased significantly(Tiloke et al., 2013). In another investigation, human peripheral blood mononuclear cells were exposed to an aqueous extract of moringa seeds, which had cytotoxic effects on them but had no influence on the hemolytic activity of erythrocytes (Araújo et al., 2013).

Hepatoprotective Effects

Eating a high-fat diet causes nonalcoholic fatty liver disease and can have several negative health effects. It has been documented that moringa leaf extract helps mice with liver damage in a high-fat diet. The liver homogenate was used to quantify liver histology, serum activity of hepatic enzyme markers such as reduced glutathione, ferric reducing antioxidant power, aspartate aminotransferase, and alanine aminotransferase, as well as lipid peroxidation. It's interesting to note that moringa also reduced the early symptoms of fatty liver brought on by HFD. Additionally, all Moringa-treated groups' livers showed a significant decrease in lipid peroxidation and a rise in endogenous antioxidant characteristics. The study's findings showed that moringa has hepatoprotective effects that are both preventative and curative(Das et al., 2012). The rats that were given antitubercular medications (isoniazid, rifampicin, and pyrazinamide) also demonstrated hepatoprotective action against liver damage caused by the ethanolic extract of Moringa leaves. This was achieved by preventing hepatic LPO and lowering serum levels of ALT, ALT, ALP, and bilirubin (Pari and Kumar, 2002).

Effect on Skin

Glutathione, the pigment melanin, and enzymatic antioxidants are examples of endogenous antioxidants found in skin (Weschawalit et al., 2017). The skin can become exposed to chemicals, air pollution, ultraviolet radiation, psychological stress, alcohol consumption, smoking, free radicals, and reactive oxygen species. However, to minimize oxidative stress and improve DNA repair, the overproduction of free radicals necessitates the topical use of exogenous antioxidants (Pham-Huy et al., 2008). Antioxidants lessen photodamage, which stops the production of skin pigment. Antioxidants have also been demonstrated to improve skin moisture, which helps to revive the skin. Unsaturated fatty acid-containing natural oils are frequently utilized as natural moisturizers and antioxidants to stop dry, aging skin (Montenegro et al., 2017).

The seed oil of *Moringa oleifera* is pale yellow and has a subtle nutty scent. Studies have indicated that *M. oleifera* seed oil has a protective impact on the skin. Because *M. oleifera* seed oil has a slight sun protection effect, it was recommended to preserve the natural skin pigmentation. There have been reports of *M. oleifera* seed oil's anti-fungal properties (Chuang et al., 2007). When compared to those utilizing the cream base, the skin moisture level of those applying moringa seed oil cream was much higher. By preventing dehydration and forming a hydrophobic barrier on the skin, moringa seed oil improves skin hydration. The presence of oleic acid in moringa seed oil caused the skin barrier to be disturbed, increased the oil's molecular interactions with lipids in the stratum corneum, and improved the oil's penetration effectiveness into the epidermis (Lin et al., 2017).

Role in Weight Loss

One of the main epidemic issues endangering people's health globally is obesity. An active endocrine organ, visceral adipose tissue secretes adipokines such as resistin, adiponectin, and leptin which are critical for metabolism, inflammation, endothelial function, insulin secretion and insulin sensitiveness, energy expenditure, and food intake. Insulin resistance and anomalies in the cardiovascular system resulted from this (Catalano et al., 2010). In a different study, compared to untreated obese control rats, *M. oleifera* extract increased the expression of the adiponectin gene and down-regulated the mRNA expression of resistin and leptin in obese rats. In comparison to the obese control group that did not get treatment, this improvement in gene expression was accompanied by a decrease in body weight, improvements in the atherogenic indices and coronary artery index, as well as improvements in glucose levels and insulin resistance values (Metwally et al., 2017).

Decrease Muscle Pain

It has been confirmed that consuming Moringa reduces joint, muscle, and stiff shoulder or neck discomfort effectively. Those with relatively high levels of oxidative stress showed substantial impacts based on the indicators of oxidative stress. Among female individuals with MSE intake, there was also a larger reduction in physical discomfort, decreased weariness, and improved quality of sleep. Consuming moringa has demonstrated promise in reducing fatigue-related physical discomfort, enhancing general quality of life, and enhancing sleep (Abe et al., 2023). Through improving energy consumption in adult skeletal muscle and upregulating the expression of important metabolic markers, such as those related to glycolysis, ATP synthesis, mitochondrial biogenesis, and angiogenesis, *M. oleifera* has the potential to be an ergogenic aid (Eze, 2020).

REFERENCES

Abe, A., Kapoor, M. P., Morishima, S., Timm, D., Nakajima, A., Ozeki, M., and Disease, (2023). Alleviating the physical discomfort in healthy individuals with Moringa seed extract: a randomized, double-blind, placebo-controlled, parallel-

group trial. *13*(10), 459-475.

Al Juhaimi, F., Ghafoor, K., Ahmed, I. M., Babiker, E., Özcan, M. and Characterization. (2017). Comparative study of mineral and oxidative status of Sonchus oleraceus, Moringa oleifera and Moringa peregrina leaves. *11*, 1745-1751.

Amaglo, N. K., Bennett, R. N., Curto, R. B. L., Rosa, E. A., Turco, V. L., Giuffrida, A., and Timpo, G. M. J. F. C. (2010). Profiling selected phytochemicals and nutrients in different tissues of the multipurpose tree Moringa oleifera L., grown in Ghana. *122*(4), 1047-1054.

Anwar, F., Latif, S., Ashraf, M., Gilani, A. and Derivatives, T. (2007). Moringa oleifera: a food plant with multiple medicinal uses. *21*(1), 17-25.

Araújo, L. C. C., Aguiar, J. S., Napoleão, T. H., Mota, F. V. B., Barros, A. L. S., Moura, M. C., and Paiva, P. (2013). Evaluation of cytotoxic and anti-inflammatory activities of extracts and lectins from Moringa oleifera seeds. *8*(12), e81973.

Bøhn, S. K., Ward, N. C., Hodgson, J. M., Croft, K. D. J. F., and Function (2012). Effects of tea and coffee on cardiovascular disease risk. *3*(6), 575-591.

Boopathi, N. M., and Abubakar, B. (2021). Botanical Descriptions of Moringa spp. 11-20.

Busani, M., Patrick, J. M., Arnold, H., and Voster, M. (2011). Nutritional characterization of Moringa (Moringa oleifera Lam.) leaves. *10*(60), 12925-12933.

Catalano, K. J., Stefanovski, D., and Bergman, R. N. J. D. (2010). Critical role of the mesenteric depot versus other intra-abdominal adipose depots in the development of insulin resistance in young rats. *59*(6), 1416-1423.

Chuang, P.-H., Lee, C.-W., Chou, J.-Y., Murugan, M., Shieh, B.-J., and Chen, H.-M. J. B. t. (2007). Anti-fungal activity of crude extracts and essential oil of Moringa oleifera Lam. *98*(1), 232-236.

Dary, O., Hurrell, R. J. W. H. O., Food, and Agricultural Organization of the United Nations: Geneva, S. (2006). Guidelines on food fortification with micronutrients. *2006*, 1-376.

Das, N., Sikder, K., Ghosh, S., Fromenty, B., and Dey, S. (2012). Moringa oleifera Lam. leaf extract prevents early liver injury and restores antioxidant status in mice fed with high-fat diet.

Duranti, G., Maldini, M., Crognale, D., Sabatini, S., Corana, F., Horner, K., and Ceci, R. J. P. P. (2021). Moringa oleifera leaf extract influences oxidative metabolism in C2C12 myotubes through SIRT1-PPARα pathway. *1*(1), 100014.

Eze, S. M. (2020). Moringa oleifera Improves Skeletal Muscle Metabolism and Running Performance in Mice.

Fahey, J. (2005). Moringa oleifera: a review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Part 1. *1*(5), 1-15.

Forbes, J. M., and Cooper, M. E. J. P. r. (2013). Mechanisms of diabetic complications. *93*(1), 137-188.

Gómez, A. V., Angulo, K. J. O. J. I., and desarrollo. (2014). Revisión de las características y ususde la planta moringa oleífera. *22*(2), 309-330.

Isitua, C. C., Lozano, M., Jaramillo, C., and Dutan, F. (2015). Phytochemical and nutritional properties of dried leaf powder of Moringa oleifera Lam. from machala el oro province of ecuador. *5*(2), 8-16.

Jaja-Chimedza, A., Graf, B. L., Simmler, C., Kim, Y., Kuhn, P., Pauli, G. F., and Raskin, I. (2017). Biochemical characterization and anti-inflammatory properties of an isothiocyanate-enriched moringa (Moringa oleifera) seed extract. *12*(8), e0182658.

Johnson, I., Stability, and extraction. (2013). Phytochemicals and health. 49-67.

Karim, N. A. A., Ibrahim, M. D., Kntayya, S. B., Rukayadi, Y., Hamid, H. A., and Razis, A. (2016). Moringa oleifera Lam targeting chemoprevention. *17*(8), 3675-3686.

Kozat, S. (2007). Serum T3 and T4 concentrations in lambs with nutritional myodegeneration. *21*(5), 1135-1137.

Leone, A., Spada, A., Battezzati, A., Schiraldi, A., Aristil, J., and Bertoli, S. (2015). Cultivation, genetic, ethnopharmacology, phytochemistry and pharmacology of Moringa oleifera leaves: An overview. *16*(6), 12791-12835.

Lin, T.-K., Zhong, L., and Santiago, J. (2017). Anti-inflammatory and skin barrier repair effects of topical application of some plant oils. *19*(1), 70.

Liu, Y., Wang, X.-y., Wei, X.-m., Gao, Z.-t., and Han, J. (2018). Values, properties and utility of different parts of Moringa oleifera: An overview. *10*(4), 371-378.

Mahajan, S. G., Mali, R. G., and Mehta, A. (2007). Protective effect of ethanolic extract of seeds of Moringa oleifera Lam. against inflammation associated with development of arthritis in rats. *4*(1), 39-47.

Managa, L. R., du Toit, E. S., Prinsloo, G. J. B. S., and Ecology. (2021). Variations in the leaf metabolite profile between hydroponic and field grown Moringa oleifera Lam. genotypes. *97*, 104302.

Manjegowda, N., Kumar, M. R., Raghunathanaidu, B. D., Anjali, B., Sridhara, K., Ramesh, B., and Ahmed, S. Anti-anemic potential of Moringa oleifera flower extract against phenylhydrazineinduced anemia in rats. *62*(2).

Metwally, F. M., Rashad, H. M., Ahmed, H. H., Mahmoud, A. A., Raouf, E. R. A., and Abdalla, A. (2017). Molecular mechanisms of the anti-obesity potential effect of Moringa oleifera in the experimental model. *7*(3), 214-221.

Montenegro, L., Parenti, C., Turnaturi, R., and Pasquinucci, L. J. P. (2017). Resveratrol-loaded lipid nanocarriers: correlation between in vitro occlusion factor and in vivo skin hydrating effect. *9*(4), 58.

Muangnoi, C., Chingsuwanrote, P., Praengamthanachoti, P., Svasti, S., and Tuntipopipat, S. J. I. (2012). Moringa oleifera pod inhibits inflammatory mediator production by lipopolysaccharide-stimulated RAW 264.7 murine macrophage cell lines. *35*, 445-455.

Muhammad, H. I., Asmawi, M. Z., and Khan, N. (2016). A review on promising phytochemical, nutritional and glycemic

control studies on Moringa oleifera Lam. in tropical and sub-tropical regions. *6*(10), 896-902.
Nkafamiya, I. I., Osemeahon, S., Modibbo, U., and Aminu, A. (2010). Nutritional status of non-conventional leafy vegetables, Ficus asperifolia and Ficus sycomorus. *4*(3), 104-108.
Olson, M. E., and Fahey, J. (2011). Moringa oleifera: un árbol multiusos para las zonas tropicales secas. *82*(4), 1071-1082.
Oyeyinka, A. T., and Oyeyinka, S. (2018). Moringa oleifera as a food fortificant: Recent trends and prospects. *17*(2), 127-136.
Panda, S., Kar, A., Sharma, P., Sharma, A. J. B., and letters, m. C. (2013). 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. *23*(4), 959-962.
Pari, L., and Kumar, N. (2002). Hepatoprotective activity of Moringa oleifera on antitubercular drug-induced liver damage in rats. *5*(3), 171-177.
Patel, N., Patel, P., Patel, D., Desai, S., Meshram, D. and Sciences, P. (2014). Phytochemical analysis and antibacterial activity of Moringa oleifera. *4*(2), 27-34.
Pham-Huy, L. A., He, H., and Pham-Huy, C. (2008). Free radicals, antioxidants in disease and health. *4*(2), 89.
Rébufa, C., Dupuy, N., and Bombarda, I. J. V. S. (2021). AComDim, a multivariate tool to highlighting impact of agroclimatic factors on Moringa oleifera Lam. leaf's composition from their FTIR-ATR profiles. *116*, 103297.
Rockwood, J., Anderson, B., and Casamatta, D. (2013). Potential uses of Moringa oleifera and an examination of antibiotic efficacy conferred by M. oleifera seed and leaf extracts using crude extraction techniques available to underserved indigenous populations. *3*(2), 61-71.
Rodríguez-Pérez, C., Quirantes-Piné, R., Fernández-Gutiérrez, A., Segura-Carretero, A. and Products. (2015). Optimization of extraction method to obtain a phenolic compounds-rich extract from Moringa oleifera Lam leaves. *66*, 246-254.
Saini, R., Harish Prashanth, K., Shetty, N., and Giridhar, P. (2014). Elicitors, SA and MJ enhance carotenoids and tocopherol biosynthesis and expression of antioxidant related genes in Moringa oleifera Lam. leaves. *36*, 2695-2704.
Saini, R. K., Sivanesan, I., and Keum, Y.-S. J. B. (2016). Phytochemicals of Moringa oleifera: a review of their nutritional, therapeutic and industrial significance. *6*, 1-14.
Sánchez-Machado, D. I., Núñez-Gastélum, J. A., Reyes-Moreno, C., Ramírez-Wong, B., and López-Cervantes, J. (2010). Nutritional quality of edible parts of Moringa oleifera. *3*, 175-180.
Singh, A., and Navneet, X. (2018). Ethnomedicinal, pharmacological and antimicrobial aspects of Moringa oleifera Lam. A review. *7*(1), 45-50.
Singh, K., and Tafida, G. (2014). Antibacterial activity of Moringa oleifera (Lam) leaves extracts against some selected bacteria. *6*(9), 52-54.
Swanepoel, N., Robinson, P., Erasmus, L. and technology. (2010). Amino acid needs of lactating dairy cows: Impact of feeding lysine in a ruminally protected form on productivity of lactating dairy cows. *157*(1-2), 79-94.
Tiloke, C., Phulukdaree, A., Chuturgoon, A. and medicine, a. (2013). The antiproliferative effect of Moringa oleifera crude aqueous leaf extract on cancerous human alveolar epithelial cells. *13*, 1-8.
Tumer, T. B., Rojas-Silva, P., Poulev, A., Raskin, I., Waterman, C. and chemistry, f. (2015). Direct and indirect antioxidant activity of polyphenol-and isothiocyanate-enriched fractions from Moringa oleifera. *63*(5), 1505-1513.
van den Berg, J., and Kuipers, S. (2022). The antibacterial action of Moringa oleifera: A systematic review. *151*, 224-233.
Wang, S., Yang, C., Tu, H., Zhou, J., Liu, X., Cheng, Y., and Xu, J. J. S. R. (2017). Characterization and metabolic diversity of flavonoids in citrus species. *7*(1), 10549.
Weschawalit, S., Thongthip, S., Phutrakool, P., Asawanonda, P. J. C., cosmetic, and dermatology, i. (2017). Glutathione and its antiaging and antimelanogenic effects. 147-153.
Wood, J., Enser, M., Fisher, A., Nute, G., Sheard, P., Richardson, R., and Whittington, F. J. M. s. (2008). Fat deposition, fatty acid composition and meat quality: *A Review*, *78*(4), 343-358.