



REVIEW ARTICLE

MORINGA OLEIFERA AS A DURABLE BIOLOGICAL REFINERY AGRICULTURAL RESOURCE: INDUSTRIAL PRODUCTION, DIETARY, MEDICINAL, ALONG WITH BENEFICIAL VALUE ASSESSMENT OF THE ENTIRE CROP

KHUSHI SINGH , KRITIKA SHUKLA , IKSHITA SINGH , ARTI MISHRA , ASHUTOSH PATHAK*

Department of Pharmaceutical Chemistry, Dr. Shakuntala Misra National Rehabilitation University, Mohan Rd, Sarosa Bharosa, Lucknow, Uttar Pradesh India – 226017.

*CORRESPONDING AUTHOR

Dr. Ashutosh Pathak

ARTICLE HISTORY: 04.08.2026 RECEIVED: 11.09.2026 REVISED: ACCEPTED: 15.09.2026

ABSTRACT

A perennial irrigation deciduous tree found in many tropical along with subtropical areas, *Moringa oleifera* Lam. represents belonging of a family known as Moringaceae. In recognition of its numerous dietary and therapeutic benefits, it is commonly known as the "Medical Miracle Tree." Maintaining health, promoting normal growth, and lowering the risk of nutritional problems all depend on proper nourishment. In many regions of the world, *M. oleifera* is a plant with several uses that has long been used as a dietary supplement and in alternative and conventional health care. The plant's various parts, such as foliage, plant material, pods, flowering bodies, and rhizomes, were extensively studied for their anticipated physiological functions and potential functions in the management of health issues related to oxidative stress, such as tumours, diabetes, pulmonary hypertension, along with heart disease. The plant is notably prized for its varied nutritional makeup and has garnered a lot of attention as a possible remedy for micronutrient deficiencies, particularly in areas with limited access to a variety of nutrient-dense foods. Vital fatty acids, proteins, dietary fibre, carbs, lipids, carotenoids, vitamins, minerals, and a variety of phytochemicals are among the many nutritionally and physiologically significant components found in *M. oleifera*. *M. oleifera* has significant promise in nutritional treatments, functional foods, traditional medicine, nutraceutical development, and other health-related applications because of its rich content and variety of biological characteristics. It is a crucial plant for ongoing research and sustainable use due to its nutritional, economic, medicinal, and biological relevance.

Keywords: *Moringa oleifera*, Nutritional Composition, Medicinal Properties, Phytochemicals, Antioxidant Activity, Nutraceutical Applications.

This article is licensed under a Creative Commons Attribution-Non-commercial 4.0 International License. Copyright © 2026 Author(s) retains the copyright of this article.



INTRODUCTION

Protein and a number of vital vitamins and minerals may be found in fresh *Moringa oleifera* leaves. Freshly cut leaves contain about 2 g of protein and 13 kcal per 21 g serving. Vitamin B6 makes up the largest portion of the recommended daily intake of micronutrients (19%), followed by vitamin C (12%), iron (11%), and riboflavin (11%). Additionally, the leaves offer significant levels of provitamin A in the form of beta-carotene (9%) and magnesium (8%), underscoring their potential as a nutrient-dense component for food and functional food applications [1].

M. oleifera's chemical makeup has a significant impact on its safety profile. Because of this, more research has focused on determining its bioactive components and elucidating their pharmacological actions and underlying mechanisms. These studies are crucial for determining if *M. oleifera* is appropriate for use in the creation of food and pharmaceutical goods. For its safe and efficient use, it is especially crucial to comprehend the relationship between individual components and biological effects, identify the compounds in charge of major activities, choose suitable dosage forms, and assess possible toxicology in humans [2].

Fortunately, in-depth research on *M. oleifera* has led to the identification of several bioactive chemicals and has advanced its manufacturing methods, pharmacological uses, and toxicological evaluation. In order to gain further understanding of *M. oleifera*'s medicinal potential and safety, research has increasingly concentrated on clarifying molecular mechanisms by which it exerts its biological properties [3].

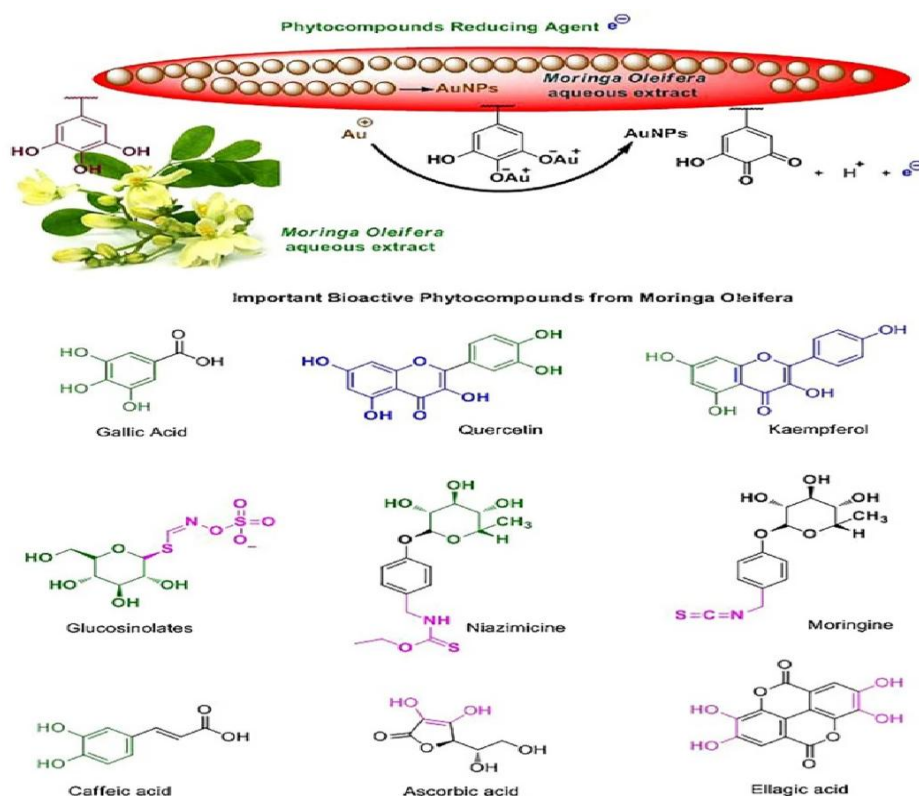


Figure 01: Phytoconstituent's of moringa

Table 01: Books and various methods of plant parts used in treatment

Name of Ayurvedic Text	Form of Plant Used	Treatment	References
Charaka Samhita (1000 BC- 4th Cent. AD)	Powder Decoction	Used for treatment of worms and headache, Ascites, oedema Hiccough and asthma, deafness, tinnitus in the ear, worm's manifestation.	[4]
Ashtanga Hridaya (7th Cent. AD)	Oil	Ear ache, deafness, and tinnitus in the ear	[5]
Kashyapa Samhita (6-7th Cent AD)	Decoction Oil	Puerperal disorder, sleeplessness Edema	[6]
Sharangadhara Samhita (13 Cent. AD)	Decoction	Conjunctivitis	[7]
Yogaratanakara (17th Cent. A.D.)	Decoction	Enlargement of spleen, worm edema, Ascites, fever, abscess.	[8]

Table 02: Comparative amino acid profile of different consumable leaf powders with Moringa leaf powder [9-14]

Essential amino acids (g/100 g of dry matter)			
Source	Anchote leaves (<i>Coccinia abyssinica</i>)	Mulberry leaves (<i>Morus alba</i>)	Moringa leaf powder
Histidine	1.59	3.59	2.1
Isoleucine	3.69	4.69	4.7
Leucine	5.37	6.90	9.1
Lysine	3.79	5.29	5.5
Methionine	0.89	1.77	1.7
Phenyl-alanine	3.09	3.36	6.1
Threonine	3.46	4.24	4.1
Tryptophan	—	—	—

Valine	4.18	5.17	5.3
Nonessential amino acids (g/100 g of dry matter)			
Tyrosine	1.62	11.41	4.1
Alanine	5.57		6.2
Arginine	4.32	4.51	7.3
Asparagine	8.95	8.25	—
Glutamic acid	8.93	—	10.6
Glycine	5.70	5.95	5.2
Proline	2.17	—	3.0
Serine	4.40	4.1	4.2
Cystine	3.26	—	0.7

Segmentation by Taxonomy [15]

Table 03: The taxonomic hierarchy Chart

Kingdom	Plantae
Sunkingdom	<i>Tracheobionta</i>
Super division	<i>Spermatophyte</i>
Division	<i>Magnoliophyta</i>
Class	<i>Magnoliopsida</i>
Subclass	<i>Dilleniidae</i>
Order	<i>Capparales</i>
Family	<i>Moringaceae</i>
Genus	<i>Moringa</i>
Species	<i>Oleifera</i>

Indigenous and Ethnomedical Features

Because of its purported medicinal properties, *Moringa oleifera* is a plant that has been used in traditional medicine and eaten for ages. Nearly every part during the plant has historically been used for a variety of medical purposes, comprising leaves, berries, pods, bark, gum, blossoms, seeds, seed oil, and root systems. *Moringa* has long been used traditionally to treat ailments like anxiety, diarrhoea, dysentery, colitis, high blood pressure, and to encourage urination [16].

Moringa leaves are also traditionally prepared as poultices and applied to inflammatory conditions, including glandular swelling, headaches, and bronchitis. The pods have been used traditionally for managing hepatitis and relieving joint discomfort. *Moringa* roots have been employed in folk medicine for kidney stones, liver disorders, inflammation, ulcers, and pain affecting the ears and teeth. In addition, the stem bark has traditionally been applied in the management of wounds and various skin infections. These traditional applications demonstrate the extensive ethnomedicinal importance of *M. oleifera* in different cultures [17].

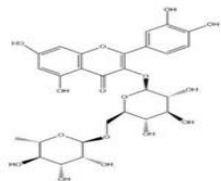
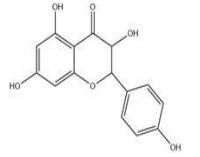
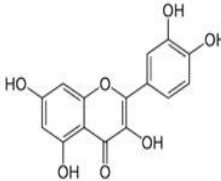
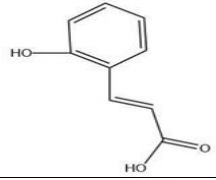
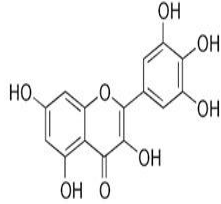
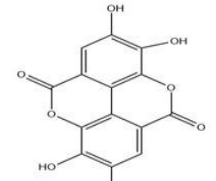
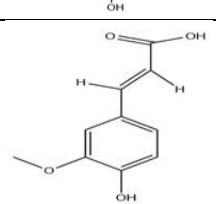
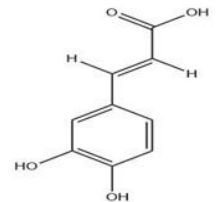
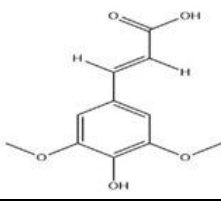
Moringa extract

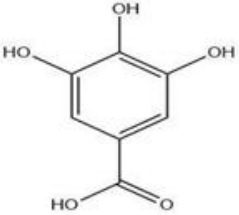
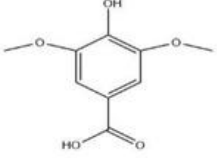
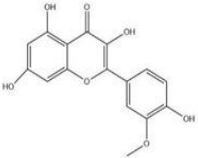
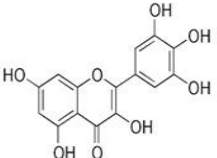
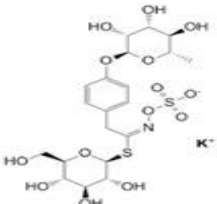
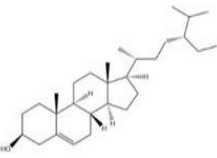
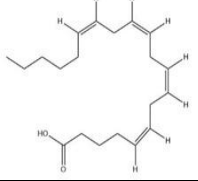


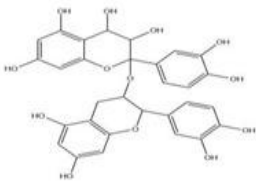
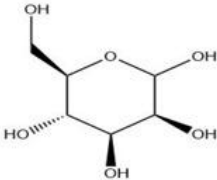
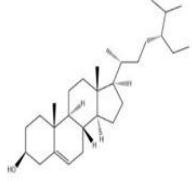
Figure 02: Various parts of moringa

Table 04: Chemical details and Therapeutic Activity

Plant	Compound	Class	Structure	Therapeutic	Referen
-------	----------	-------	-----------	-------------	---------

Part				Activity	ces
Leaves	Rutin (555.6 µg/g)	Flavonoid		Found to have maximum affinity and interaction towards BRAC-1 gene.	[18]
Leaves	Kaempferol (197.6 µg/g)	Flavonoid		Oxidative damage protective activity.	[19]
Leaves	Quercetin (2030.9 µmol/100 g)	Flavonoid		Exerts an excellent effect as anti-diabetic agent.	[20]
Leaves	O coumaric acid (0.536 mg/g)	Phenolic acid		Antioxidant and anti-microbial	[21]
Leaves	Myricetin (5.804 mg/g)	Flavonoid		Potential prevention of diabetes mellitus and other diabetic complications	[22]
Leaves	Ellagic acid (0.078 to 0.128 mg/g)	Polyphenol		Prevents viral and bacterial infections, potential antioxidant	[23]
Leaves	Ferulic acid (0.078 to 0.128 mg/g)	Phenol		Promising results as anti- cancer, antioxidant, antithrombotic, anti-arrhythmic, and anti-inflammatory.	[24]
Leaves	Caffeic acid (0.409 mg/g)	Phenol		Boosts athletic performance, reduces fatigue, helps weight loss, protects against herpes, HIV, cancer.	[25]
Leaves	Sinapic acid (trace amount)	Phenol		Cardioprotective, renoprotective, anxiolytic, neuroprotective.	[26]

Leaves	Gallic acid (1.034 mg/g)	Phenol		Anti-inflammatory, anti-neoplastic, anti-oxidant	[27]
Leaves	Syringic acid (trace amount)	Phenol		Anti-oxidant, antimicrobial.	[28]
Leaves	Isorhamnetin (0.118 mg/g)	Flavonoid		Anti-oxidant	[29]
Seeds	Myricetin (5.804 mg/g)	Flavonoid		Potential prevention of diabetes mellitus and other diabetic complications	[30]
Seeds	Glucomoringin	Glucosinolates		Anti-inflammatory, pain relieving, anti-oxidant, antihypertensive.	[31]
Seeds	β -sitosterol	Phytosterol		Anti-inflammatory	[32]
Seeds	Arachidic acid	Fatty acid		Increased breast milk production	[33]
Seeds	Oleic acid (70% w/w)	Fatty acid		Reduces blood pressure and reduces free radical damage to the cell.	[34]
Seeds	Myristic acid	Fatty acid		Anxiolytic effect, used in membrane localization of the enzyme.	[35]
Seeds	Palmitic acid	Fatty acid		Trypanocidal and anti- leukemic effect	[36]

Seeds	Procyanidin	Flavonoid		Cardioprotective	[37]
Flower	D-mannose	Carbohydrate		Treatment of deficiency caused by genetic defects, and acute urinary tract infections.	[38]
Stem	β -sitosterol	Phytosterol		Anti-oxidant, cardiovascular, immunomodulatory	[39]

REGIONAL & FLORAL DIVERSITY

Despite its original range is typically linked with the countries of India, Arabia, and the East Indies, *Moringa oleifera* is a plant variety that is grown and found around the entire globe. It is now well-established in Florida, Madagascar, Central America, Cuba, the Philippines, Ethiopia, the nation of Nigeria, African countries, Asia, the Caribbean, Latin America, and the Pacific Islands. According to historical proof, *M. oleifera* was brought from India many centuries ago to a number of places, including the African continent, Southeast Asia, and the Philippine islands [40].

M. oleifera is an evergreen tree that may flourish in tropical and subtropical regions all over the world given the right climatic circumstances. The plant is well suited to tropical and subtropical climates, with optimal growth often happening at temperatures ranging from around 25 to 35 °C. Long-term waterlogging can harm its development; therefore, it needs well-drained soil and sufficient yet indirect sunshine to thrive. Soils that range from slightly acidic to alkaline can be tolerated by the species. When circumstances are right, the tree might start bearing fruit six to eight months after it is established [41].

From a business point of view *M. oleifera* is grown in many places, such as portions of South America, Africa, Mexico, and Hawaii. However, because different soil properties and growth circumstances can affect a plant's nutrient profile, its nutritional makeup may vary significantly between geographical areas [42].

PHYTOCHEMICAL CONSTITUENTS

The therapeutic and pharmacological properties of *Moringa oleifera* are closely associated with the diverse phytochemicals present in the plant. Research has demonstrated that the distribution and composition of these bioactive substances vary among different parts of the plant. The flowers contain several classes of phytochemicals, including flavonoids, alkaloids, sucrose, and various amino acids. Among the reported flavonoid compounds are kaempferitrin, isoquercitrin, and rhamnetin [43].

PHENOLIC SUBSTANCES

After being extracted using ethanol and butanol, niazirin (1) was separated from the seeds and leaves of *M. oleifera*. According to reports, this chemical has α -glucosidase inhibitory action, with an IC_{50} value of 382.2 μ M. *M. oleifera* leaves were also used to isolate caffeoylquinic acid (2), 4-O-caffeoylquinic acid (3), 4-O-(3'-O- α -D-glucopyranosyl)-caffeoylquinic acid (4), 4-O-(4'-O- α -D-glucopyranosyl)-caffeoylquinic acid (5), 4-O- β -D-glucopyranoside benzoic acid (6), benzaldehyde 4-O-L-rhamnopyranoside [44].

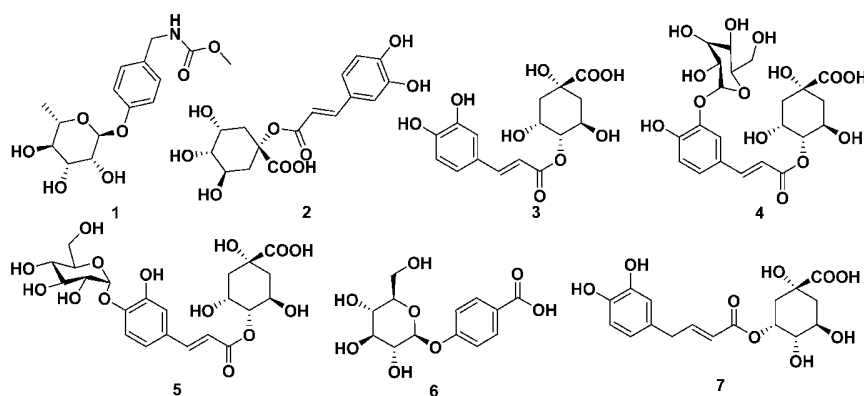


Figure 03: Phenolic substances of Moringa

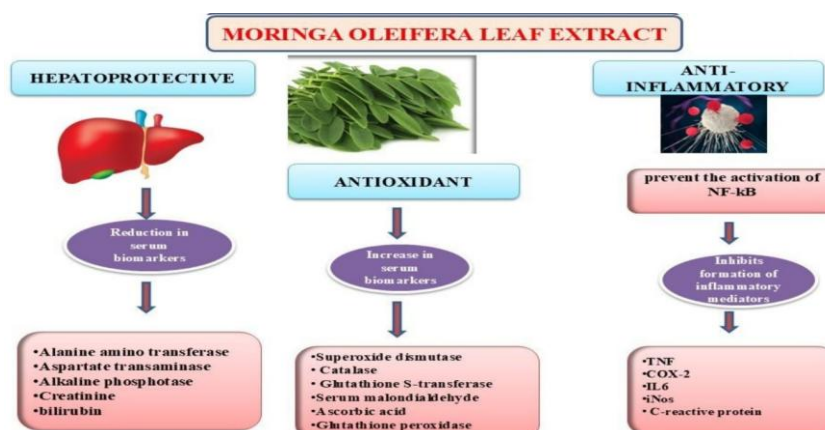


Figure 04: Pharmacological Action of Moringa Leave extract

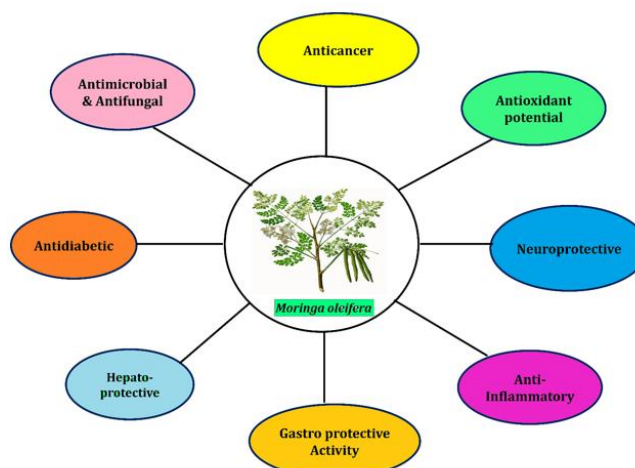


Figure 04: Pharmacological Action of Moringa

Anti-Haemorrhagic Properties

Although uncontrolled bleeding can cause life-threatening complications and even death, preventing and managing excessive blood loss are crucial therapeutic goals, especially in situations requiring severe injuries or surgical procedures. Adeyemi et al. investigated *M. oleifera* extracts' capacity to mitigate the haemorrhagic effects of *Echis ocellatus* venom. According to their research, the extract made from ethanol had the best defines against bleeding caused by venom. When tested against 2 mL of *E. ocellatus* venom containing 0.22 mg/kg of venom, the extract was efficacious at a level of 800 mg/kg. The study also looked at the significance of pre-incubation and showed that the extract's ability to neutralize bleeding was improved by letting it interact with the venom before to delivery [45].

Anti-Allergy Properties

An allergic condition arises when the immune system responds improperly to typically innocuous chemicals, causing inflammatory reactions that might affect many organs and tissues. As a result, the development of anti-allergic treatments has concentrated on both enhancing symptom control and learning more about the molecular mechanisms

behind allergic reactions. The anti-allergic properties of *M. oleifera* leaves, pods, and seeds were studied by Rani et al. Nine chemicals were recovered from the plant materials after they were macerated using 80% ethanol. Their results showed that *M. oleifera* formulations might decrease allergic reactions in both their early and late phases [46].

Antimicrobial Properties

Due to its significance in managing the microbes that cause infectious illnesses, the antibacterial potential of chemicals originating from plants has garnered significant scientific interest. The necessity to find potent antimicrobial compounds from natural sources has been further highlighted by the growing number of microbial strains that are resistant to traditional antimicrobial medications. Using the agar well diffusion method, the antibacterial activity of extracts made from various *M. oleifera* parts was assessed against *Staphylococcus aureus* and *Escherichia coli*. The highest inhibitory effects against *E. coli* were seen in the 80% methanolic extracts made from the leaves, pulp, and seeds. The 70% and 80% methanolic floral extracts shown similar levels of antibacterial activity against *S. aureus* [47].

Anthelmintic Action

Infections with parasitic helminths can impact the host's various organs and tissues, potentially leading to serious health consequences. Helminth parasite infestations in animals can result in significant financial losses in addition to their negative effects on human health. As a result, the hunt for potent anthelmintic drugs has drawn more interest as a way to manage parasitic worms in humans and animals. Nilani et al. used earthworms that were around 3–5 cm long and 0.1–0.2 cm wide as the experimental model to examine the anthelmintic activity of *M. oleifera* seed oil. 25 and 50 mg/mL concentrations of the seed oil were evaluated. Anthelmintic effects were shown by both standard concentrations, resulting in immobility after 21 and 16 minutes, respectively [48].

Treatment Against Hypertension

Persistently high blood pressure is the hallmark of hypertension, a chronic cardiovascular condition that raises the risk of major consequences like stroke, renal impairment, and cardiovascular disease. Randriamboajonvy et al. used spontaneously hypertensive rats (SHR) as an experimental model to study the cardiovascular effects of *M. oleifera* seed oil. The seed oil significantly reduced the nocturnal heart rate after ten days of therapy, while the diurnal heart rate did not significantly change [49].

The left ventricle hemodynamic ability in SHR, which was significantly reduced in these animals as compared to Wistar-Kyoto (WKY) control rats, was also enhanced by treatment with *M. oleifera* seed oil. Nonetheless, compared to the WKY controls, the ejection fraction—a measure of systolic cardiac function—remained noticeably lower in both the untreated and seed-oil-treated SHR groups. These results suggest that in antihypertensive rats, seed containing oil was unable to considerably enhance systolic ventricular function. On the other hand, after administering seed oil, the extended isovolumic - relaxation time in SHR, typically indicates poor diastolic relaxation, fully returned to normal [50]. Additionally, in comparison to untreated SHR heart tissue, medicated SHR hearts showed a decrease in cardiomyocyte size following the administration of *M. oleifera* standard seed oil. The investigators also looked into the possibility that the soybean oil's cardioprotective benefits, namely its capacity to prevent cardiac fibrosis in rats with spontaneous hypertension, may be attributed to peroxisome proliferation-activated protein (PPAR) signalling. Overall, the results imply that *M. oleifera* seed oil may improve diastolic performance and cardiac remodelling in hypertension, whereas its impact on normal systolic function seems to be minimal [51].

Activities of Neuroparmacology

Numerous potentially advantageous impacts on a central nervous system have been shown by studies looking at the neuroparmacological effects of *M. oleifera*. According to earlier research, leaf extracts may be helpful in treating neurodegenerative diseases like Alzheimer's disease as they can restore the brain's altered serotonin transmitter levels. Furthermore, in vitro studies of the ethanolic leaf extract showed anticonvulsant action in a penicillin-induced seizure model, with effects linked to changes in locomotor activity, brain dopamine, serotonin, and norepinephrine (5-HT) levels [52].

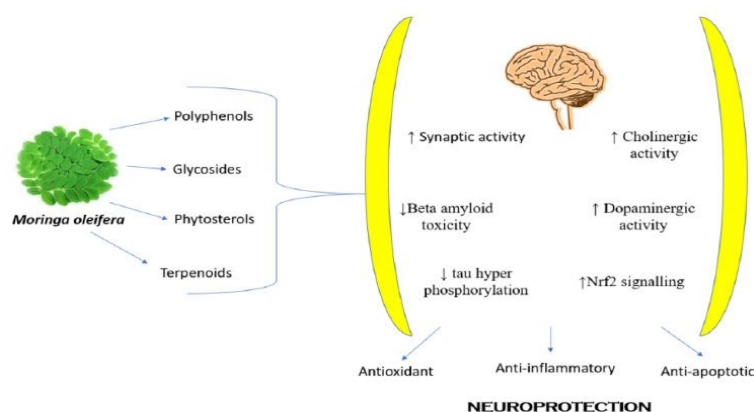


Figure 05: The various phytochemical components of *M. oleifera* are thought to have a major role in its neuroprotective qualities. These bioactive substances may improve dopaminergic and cholinergic neurotransmission as well as synaptic

function. Furthermore, activation of the nuclear factor erythroid 2-related factor 2 (Nrf2) signalling pathway, which is crucial for cellular defence against oxidative stress, has been linked to *M. oleifera*. Its components may also restrict the phosphorylation of tau proteins and lessen β -amyloid-associated neurotoxicity. When taken as a whole, these activities imply that *M. oleifera* may offer defence against the molecular mechanisms underlying neuronal malfunction and neurodegeneration [53].

Neuroprotective and antioxidant effect in neurodegenerative disorders

Moringa is recognized for its neuroprotective effects, attributed to its ability to enhance blood supply to the brain. This is crucial in preventing cerebral ischemia and reducing the ROS formation. The plant significantly reduces ROS, inducing an antioxidant response that protects the brain. Notably, *Moringa* reduces brain infarct volume in cortical and subcortical areas significantly. It also increases superoxide dismutase (SOD) activity in rodent hippocampus and striatum. The ethyl acetate fraction of *Moringa* has been studied for its impact on the molecular mechanisms of inflammation. Treatment with this fraction results in the downregulation of iNOS, COX-2, and NF- κ B expression, while upregulating I κ B α levels [54].

Anti-Obesity Activity

In a study, oral treatment with leaf powder of *M. oleifera* for a duration of nearly 49 days was found to significantly reduce body mass index (BMI) in rats suffering from hypercholesterolemia. The mechanistic approach behind this was the downregulation of mRNA expression of the hormones resistin and leptin and the concomitant increase in regulation of the gene adiponectin in rats. A recent study revealed the mechanistic approach for the anti-obesity effect of *M. oleifera*. The plant significantly improved lipid profile by reducing body weight. It also regulated adipogenesis-related genes, increased glucose tolerance, and decreased levels of hormones such as vaspin, leptin, and resistin [55].

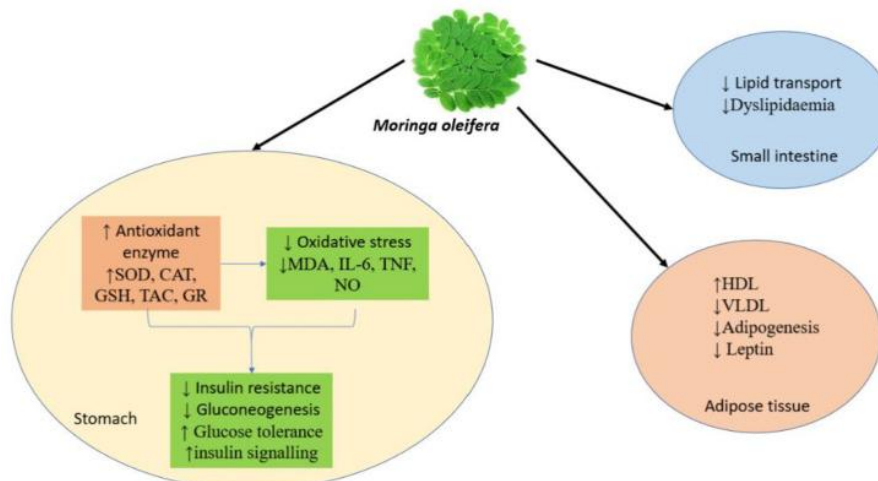


Figure 06: *M. oleifera* as a promising anti-obesity agent. Various in-vitro findings suggest that supplements of *M. oleifera* cause direct inhibition of pancreatic lipase, thus reducing the conversion of triglycerides into simple. Moringa has fat storage regulation by upregulation of lipolysis-associated protein and down-regulating the expression of protein related to fat storage. It is also effective in the improvement of antioxidant levels. Besides these, Moringa is also responsible for increasing ghrelin levels and decreasing leptin, producing a feeling of satiety [56].

Variability in composition: Plant sections, cultivars, regions, and seasons all have different amounts of nutrients and phytochemicals.

Chemical processing and storage: Oxidation, stability of bioactive compounds, and nutrient retention can all be impacted by drying, grinding, extraction, and storage.

Quality and normalization: Systematic assessment is necessary for antinutritional factors, pollutants, microbiological risks, and dose-dependent toxicity.

Inadequate clinical evidence: Rather than being supported by sufficiently powered human clinical trials, many treatment claims are based on laboratory or animal investigations.

Economic viability: Commercial profitability may be constrained by the expenses of harvesting, transportation, extraction, purification, and quality assurance.

Scale-up related challenges: It's possible that laboratory results won't immediately convert into effective manufacturing procedures.

Whole- crop integration: Further investigation is required to ascertain the optimal extraction sequence, the value of residual fractions, and the effects of integrated processing on the environment.

Future aspect

The analysis highlights different elements of *M. oleifera*, encompassing its international research, traditional ethnopharmacology, pharmacology activities, phytochemistry, pharmacological formulas, medical investigations, toxicity,

and other miscellaneous factors. The presence of alkaloids, phenolic acid, glycosides, sterols, glucosinolates, flavonoids, terpenes and fatty acids are responsible for the therapeutic actions of *M. oleifera*. Furthermore, *M. oleifera* is abundant in substances like vitamins, minerals, and carotenoids, which enhance its therapeutic benefit and superfood ingestion. Pharmacological studies demonstrate that the active ingredients of the plant have effectively healed different ailments such as neuropathic pain, cancer, hypertension, diabetes, obesity etc. However, a number of phytochemicals have not yet been investigated for potential medical advantages. Apart from its therapeutic application, farmers utilize the plant as a cost-effective bio stimulant in their fields. According to a review of the literature, a significant amount of preclinical research has been conducted in recent years. Further clinical research is needed to determine the plant's effectiveness in treating serious illnesses such coronavirus epidemics, acquired immunodeficiency syndrome (AIDS), and different types of cancer. Additionally, additional mechanism-based research is suggested to investigate the plant's mechanistic strategy for identifying and isolating active or synergistic chemicals [57].

CONCLUSION

According to the research that is now accessible, *Moringa oleifera* is a multipurpose agricultural resource with significant potential in the areas of nutrition, food processing, phytochemical extraction, seed-oil production, cosmetics, water treatment, and biomass usage. Its main benefit is the potential to extract several beneficial compounds from various areas of the same crop, rather than just its high nutritional value or any one therapeutic quality. From a dietary perspective, moringa can contribute to nutrient-rich food formulations and dietary diversification. From a medicinal perspective, its phytochemicals provide promising research opportunities, although clinical evidence is not yet sufficient to establish most therapeutic claims. From an industrial perspective, seed oil, natural coagulants, food ingredients, and selected biomass-derived products represent important avenues for value addition. Environmentally, an integrated production system could reduce waste and support a circular bioeconomy if its resource requirements and residual streams are properly managed. The general conclusion is that the genus *Moringa oleifera* has great promise as a whole-crop biological refinery resource; nevertheless, its long-term success is contingent upon the development of evidence-based products, safe processing, commercial viability, and observable environmental sustainability. To provide feasible routes from crop cultivation to commercial production, more interdisciplinary research integrating agronomy, food science, biotechnology, drug development, conventional industrial engineering, and life-cycle evaluation is required.

FINANCIAL SUPPORT

None

DECLARATION COMPETING INTEREST

Not Declared

ACKNOWLEDGEMENT

None

INFORM CONSENT AND ETHICAL CONSIDERATION

Not Applicable

REFERENCES

1. Tiloke C, Anand K, Gengan RM, Chuturgoon AA. *Moringa oleifera* and their phytonanoparticles: Potential antiproliferative agents against cancer. *Biomed Pharmacother.* 2018;108:457–66. <https://doi.org/10.1016/j.biopha.2018.09.060>.
2. Balogun T.A., Buliamimu K.D., Chukwudozie O.S., Tihamiyu Z.A., Idowu T.J. Anticancer Potential of *Moringa oleifera* on BRCA-1 Gene: Systems Biology. *Bioinform. Biol. Insights.* 2021;15:11779322211010703. doi: 10.1177/11779322211010703.
3. Alam P., Elkholy S.F., Mahfouz S.A., Alam P., Sharaf-Eldin M.A. HPLC based estimation and extraction of rutin, quercetin and gallic acid in *Moringa oleifera* plants grown in Saudi Arabia. *J. Chem. Pharm.* 2016;8:1243–1246.
4. Singh B.N., Singh B.R., Singh R.L. Oxidative DNA damage protective activity, antioxidant and anti-quorum sensing potentials of *Moringa oleifera*. *Food Chem. Toxicol.* 2009;47:1109–1116. doi: 10.1016/j.fct.2009.01.034. Ndong M., Uehara M., Katsumata S., Suzuki K. Effects of oral administration of *Moringa oleifera* Lam on glucose tolerance in Goto-Kakizaki and Wistar rats. *J. Clin. Biochem. Nutri.* 2007;40:229–233. doi: 10.3164/jcbrn.40.229.
5. Zhang M., Hettiarachchy S.N., Horax R., Kannan A., Praisoody M.D.A., Muhundan A., Mallangi C.R. Phytochemicals, antioxidant and antimicrobial activity of *Hibiscus sabdariffa*, *Centella asiatica*, *Moringa oleifera* and *Murrayakoenigii* leaves. *J. Med. Plants Res.* 2011;5:6672–6680.
6. Leone A., Spada A., Battezzati A., Schiraldi A., Aristil J., Bertoli S. Cultivation, genetic, ethnopharmacology, phytochemistry and pharmacology of *Moringa oleifera* leaves: An overview. *Int. J. Mol. Sci.* 2015;16:12791–12835. doi: 10.3390/ijms160612791.

7. Sharifi-Rad J., Quispe C., Castillo C.M.S., Caroca R., Lazo-Vélez M.A., Antonyak H., Polishchuk A., Lysiuk R., Oliynyk P., Masi L.D., et al. Phytochemicals for the Prevention and Treatment of Oxidative Stress-Induced Diseases. *World J. Gastrointest. Endosc.* 2022;22:1–9.
8. Zduńska K., Dana A., Kolodziejczak A., Rotsztein H. Antioxidant Properties of Ferulic Acid and Its Possible Application. *Skin Pharmacol. Physiol.* 2018;31:332–336. doi: 10.1159/000491755.
9. Chung T.W., Moon S.K., Chang Y.C., Ko J.H., Lee Y.C., Cho G., Kim S.H., Kim J.G., Kim C.H. Novel and therapeutic effect of caffeic acid and caffeic acid phenyl ester on hepatocarcinoma cells: Complete regression of hepatoma growth and metastasis by dual mechanism. *FASEB J.* 2004;18:1670–1681. doi: 10.1096/fj.04-2126com.
10. Pandi A., Kalappan V.M. Pharmacological and therapeutic applications of Sinapic acid—An updated review. *Mol. Biol. Rep.* 2021;48:3733–3745. doi: 10.1007/s11033-021-06367-0.
11. Alhakmani F., Kumar S., Khan S.A. Estimation of total phenolic content, in-vitro antioxidant and anti-inflammatory activity of flowers of *Moringa oleifera*. *Asian Pac. J. Trop. Biomed.* 2013;3:623–627. doi: 10.1016/S2221-1691(13)60126-4. Bennour N., Mighri H., Eljani H., Zammouri T., Akrouf A. Effect of Solvent Evaporation Method on Phenolic Compounds and the Antioxidant Activity of *Moringa oleifera* Cultivated in Southern Tunisia. *S. Afr. J. Bot.* 2020;129:181–190. doi: 10.1016/j.sajb.2019.05.005.
12. Riaz A., Rasul A., Hussain G., Zahoor M.K., Jabeen F., Subhani Z., Younis T., Ali M., Sarfraz I., Selamoglu Z. Astragalin: A Bioactive Phytochemical with Potential Therapeutic Activities. *Adv. Pharmacol. Sci.* 2018;2018:9794625. doi: 10.1155/2018/9794625.
13. Borronovo G., De Petrocellis L., Schiano Moriello A., Bertoli S., Leone A., Battezzati A., Mazzini S., Bassoli A. Moringin, A Stable Isothiocyanate from *Moringa oleifera*, activates the Somatosensory and Pain Receptor TRPA1 Channel In Vitro. *Molecules.* 2020;25:976. doi: 10.3390/molecules25040976. [DOI] [PMC free article] [PubMed] [Google Scholar]
14. Liao P.-C., Lai M.-H., Hsu K.-P., Kuo Y.-H., Chen J., Tsai M.-C., Li C.-X., Yin X.-J., Jeyashoke N., Chao L.K.-P. Identification of β -Sitosterol as in Vitro Anti-Inflammatory Constituent in *Moringa oleifera*. *J. Agric. Food Chem.* 2018;66:10748–10759. doi: 10.1021/acs.jafc.8b04555.
15. Goel F. Exploring the therapeutic role of *Moringa oleifera* in neurodegeneration: antioxidant, anti-inflammatory, and neuroprotective mechanisms: exploring the therapeutic role of *Moringa oleifera* in neurodegeneration. *Inflammopharmacology.* 2025 Jul;33(7):3653–69.
16. Gavrilas L., Păltinean R., Frumuzachi O., Mocan A. Cris, an, G. Effects of *Moringa oleifera* Lam. Supplementation on Cardiometabolic Outcomes: A Meta-Analysis of Randomized Controlled Trials with GRADE Assessment. *Nutrients* 2025, 17, 3501 [Internet]. *Food Rev. Int.* 2025
17. Zahouily M. Application of *Moringa oleifera* Plant. *Handbook of Sustainable Industrial Wastewater Treatment.* 2025 Jul 25;100.
18. Salsi G., Greco C., Laudicina VA, Lucia C., Muscarella SM, Greco G., Orlando S., Fascella G., Mammano MM. Preliminary results of *Moringa oleifera* Lam. grown in a semi-arid Mediterranean environment in a climate change scenario. *Frontiers in Sustainable Food Systems.* 2025 Jun 24;9:1576147.
19. Vega-Britez GD, Fernandes T, Ribeiro BB, Santos AB, Araujo ND, Santos RA, Silva NM, Goes ES, Vargas Junior FM. A Bibliometric Analysis of Research on *Moringa oleifera* in Sheep and Goat Production Systems in the Scopus and Web of Science Databases (2000–2025). *Ruminants.* 2026 Sep 3;6(3):77.
20. Arshad MT, Maqsood S, Ikram A, Gnedeka KT. Recent perspectives on the pharmacological, nutraceutical, functional, and therapeutic properties of *Moringa oleifera* plant. *Food Science & Nutrition.* 2025 Apr;13(4):e70134.
21. Soto JA, Gómez AC, Vásquez M, Barreto AN, Molina KS, Zuniga-Gonzalez CA. Biological properties of *Moringa oleifera*: A systematic review of the last decade. *FI000Research.* 2025 Jan 30;13:1390.
22. Kam AH, Mawooa SJ, Neergheen VS. Processed *Moringa oleifera* (Lam). *Native Crops in India: Biochemical, Processing, and Nutraceutical Aspects.* 2025 Sep 29;324.
23. Nassarawa SS, Nasiru MM, Magaji HA, Abdullahi FS. *Moringa oleifera* (Drumstick). In *Phytoadaptogenic Properties of Medicinal Plants* 2025 Nov 19 (pp. 77-95). CRC Press.
24. Salih WM, Abdallah MN, Al-Farha AA. Effects of various proportions of *Moringa oleifera* supplementation on productivity and physiological traits of ewes and lambs. *Asian Journal of Dairy and Food Research.* 2025;44(4):702–8.
25. Ogunniyi QA, Adegoke AA, Tejumade AO, Ogunlakin AD. Beyond Medicine for a Greener Future: Non-Therapeutic Applications of *Moringa oleifera*. *Istanbul Journal on Applied Biological Sciences.* 2025 Dec 29;1(2):e3-.
26. Villegas-Vazquez EY, Gómez-Cansino R, Marcelino-Pérez G, Jiménez-López D, Quintas-Granados LI. Unveiling the miracle tree: therapeutic potential of *Moringa oleifera* in chronic disease management and beyond. *Biomedicines.* 2025 Mar 5;13(3):634.
27. Safi SA, Amin MA, Nastoh NA. *Moringa Oleifera* as a Nutraceutical Resource: Nutritional Profile and Its Impact on Broiler Growth Performance. *Journal of Natural Science Review.* 2025 Oct 4;3(3):208-27.
28. Kakkar S, Dharavat N, Pammi SV. A *Moringa Oleifera*, a natural coagulant, as a potential future approach for sustainable water purification: a patent based study. *Results in Engineering.* 2025 Aug 6;106630.

29. Aleman-Ramirez JL, Okoye PU, Saldaña-Trinidad S, Torres-Arellano S, Sebastian PJ. The role of *Moringa oleifera* in the development of alternative biofuels, under the concept of an integral one-tree biorefinery: A minireview. *Biofuels, Bioproducts and Biorefining*. 2025 May;19(3):942-62.
30. El-Sherbiny GM, Alluqmani AJ, Elsehemy IA, Kalaba MH. Antibacterial, antioxidant, cytotoxicity, and phytochemical screening of *Moringa oleifera* leaves. *Scientific Reports*. 2024 Dec 16;14(1):30485.
31. Wu S, Li X, Zhou G, Pan L, Su Y, Qiu Q, Zhang J, He Q. A bibliometric analysis of *Moringa oleifera* during 2000–2024. *Open Life Sciences*. 2026 Jan 23;21(1):20251314.
32. Goel F. Exploring the therapeutic role of *Moringa oleifera* in neurodegeneration: antioxidant, anti-inflammatory, and neuroprotective mechanisms: exploring the therapeutic role of *Moringa oleifera* in neurodegeneration. *Inflammopharmacology*. 2025 Jul;33(7):3653-69.
33. El Bilali H, Dan Guimbo I, Nanema RK, Falalou H, Kiebre Z, Rokka VM, Tietiambou SR, Nanema J, Dambo L, Grazioli F, Naino Jika AK. Research on moringa (*Moringa oleifera* Lam.) in Africa. *Plants*. 2024 Jun 11;13(12):1613.
34. Mahaveerchand H, Abdul Salam AA. Environmental, industrial, and health benefits of *Moringa oleifera*. *Phytochemistry Reviews*. 2024 Oct;23(5):1497-556.
35. Gutierrez Herrera JC, Martínez Ovallos CA, Agudelo-Castañeda DM, Paternina-Arboleda CD. Exploring *Moringa oleifera*: green solutions for sustainable wastewater treatment and agricultural advancement. *Sustainability*. 2024 Oct 30;16(21):9433.
36. Xu J, Shi J, Chen Z, Liu Y, Gao X, Li J, Li L. Structural characterization of *Moringa oleifera* root polysaccharides and their protective effects on small intestinal inflammation in mice. *Food Bioscience*. 2025 Sep 30;107686.
37. Divya S, Pandey VK, Dixit R, Rustagi S, Suthar T, Atuahene D, Nagy V, Ungai D, Ahmed AE, Kovács B, Shaikh AM. Exploring the phytochemical, pharmacological and nutritional properties of *Moringa oleifera*: A comprehensive review. *Nutrients*. 2024 Oct 9;16(19):3423.
38. Divya S, Pandey VK, Dixit R, Rustagi S, Suthar T, Atuahene D, Nagy V, Ungai D, Ahmed AE, Kovács B, Shaikh AM. Exploring the phytochemical, pharmacological and nutritional properties of *Moringa oleifera*: A comprehensive review. *Nutrients*. 2024 Oct 9;16(19):3423.
39. Al-Suwailem NK, Kamel NN, Abbas AO, Nassar FS, Mohamed HS, Gouda GF, Safaa HM. The impact of dietary *Moringa oleifera* leaf supplementation on stress markers, immune responses, and productivity in heat-stressed broilers.
40. Caspersen AM, Rasmussen LV. *Moringa oleifera* as a potential avenue to improve food security in rural Malawi. *Trees, Forests and People*. 2024 Dec 1;18:100667.
41. Hamada FA, Sabah SS, Mahdy EM, El-Raouf HS, El-Taher AM, El-Leel OF, Althobaiti AT, Ghareeb MA, Randhir R, Randhir TO. Genetic, phytochemical and morphological identification and genetic diversity of selected *Moringa* species. *Scientific Reports*. 2024 Dec 16;14(1):30476.
42. Panova N, Gerasimova A, Gentscheva G, Nikolova S, Makedonski L, Velikova M, Beraich A, Talhaoui A, Petkova N, Batovska D, Nikolova K. *Moringa oleifera* Lam.: A Nutritional powerhouse with multifaceted pharmacological and functional applications. *Life*. 2025 May 29;15(6):881.
43. Baesso Moura B, Hoshika Y, Brunetti C, dos Santos Nascimento LB, Marra E, Paoletti E, Ferrini F. Stress physiology of *Moringa oleifera* under tropospheric ozone enrichment: An ecotype-specific investigation into growth, nonstructural carbohydrates, and polyphenols. *The Plant Journal*. 2024 Dec;120(5):2127-37.
44. Shah A, Manning G, Zakharova J, Arjunan A, Batool M, Hawkins AJ. Particle size effect of *Moringa oleifera* Lam. seeds on the turbidity removal and antibacterial activity for drinking water treatment. *Environmental Chemistry and Ecotoxicology*. 2024 Jan 1;6:370-9.
45. Xie R, Ponnampalam EN, Ahmadi F, Dunshea FR, Suleria HA. Antioxidant potential and characterization of polyphenol compounds in *Moringa oleifera* pods. *Food Science & Nutrition*. 2024 Dec;12(12):10881-902.
46. Egbu CF, Mulaudzi A, Motsei LE, Mnisi CM. *Moringa oleifera* products as nutraceuticals for sustainable poultry production. *Agriculture & Food Security*. 2024 Dec 28;13(1):54.
47. Azeem W, Mukhtar T, Inam-ul-Haq M, Khan MA, Ibrahim MS, Hassan A, Regmi H, Duncan LW. The nematocidal potential of *Moringa oleifera* extracts and rhizobacteria against *Meloidogyne incognita* in tomato. *Frontiers in Plant Science*. 2025 May 13;16:1562074.
48. Worku B, Tolossa N. A review on the neuroprotective effect of *Moringa oleifera*. *Oxidative medicine and cellular longevity*. 2024;2024(1):7694516.
49. Husien HM, Peng W, Essa MO, Adam SY, Ur Rehman S, Ali R, Saleh AA, Wang M, Li J. The anti-inflammatory properties of polysaccharides extracted from *Moringa oleifera* leaves on IEC6 cells stimulated with lipopolysaccharide in vitro. *Animals*. 2024 Dec 4;14(23):3508.
50. Avilés-Gaxiola S, Contreras-Angulo LA, García-Aguilar I, Heredia JB. *Moringa oleifera* Lam. leaf peptides: antioxidant and antiproliferative activity in human colon cancer caco-2 cell line. *Antioxidants*. 2024 Nov 8;13(11):1367.
51. Noreen A, Hussain M, Malik MF, Iftikhar A, Zeb U, Farid A, Alarfaj AA, Ansari MJ. *Moringa oleifera* based silver nanoparticles: Synthesis and insecticidal toxicity against fall armyworm. *NotulaeBotanicae Horti Agrobotanici Cluj-Napoca*. 2024 Dec 16;52(4):14066-.

52. Barzan G, Sacco A, Giovannozzi AM, Portesi C, Schiavone C, Salafranca J, Wrona M, Nerín C, Rossi AM. Development of innovative antioxidant food packaging systems based on natural extracts from food industry waste and *Moringa oleifera* leaves. *Food Chemistry*. 2024 Jan 30;432:137088.
53. Mwami B, Maňourová A, Hendre PS, Muchugi A, Verner V, Kariuki P, Sulaiman N, Polesny Z. Traditional knowledge, use, and management of *Moringa oleifera* among the Mijikenda Community in Kilifi, Kenya. *Plants*. 2024 Dec 19;13(24):3547.
54. Mwami B, Maňourová A, Hendre PS, Muchugi A, Verner V, Kariuki P, Sulaiman N, Polesny Z. Traditional knowledge, use, and management of *Moringa oleifera* among the Mijikenda Community in Kilifi, Kenya. *Plants*. 2024 Dec 19;13(24):3547.
55. Rajkumar C, Ramsridhar S, Veeraraghavan VP, Francis AP, Purushotham M, Mageshwari U. Anticancer effect of *Moringa oleifera* in oral squamous cell carcinoma: a systematic review. *Discover Oncology*. 2024 Nov 21;15(1):688.