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Moringa (Moringa oleifera) Antioxidant & Antihyperglycemic Activity

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Abstract : *Oxidative stress and chronic hyperglycaemia are central to the development of diabetes and its complications, and there is continuing demand for safe, inexpensive plant-based adjuncts to conventional therapy. Moringa oleifera Lam. (family Moringaceae), known as the drumstick or horseradish tree, is a fast-growing tree native to the Indian subcontinent that is now cultivated throughout the tropics. Its leaves, pods, seeds, roots and flowers are used as food and as traditional medicine, and the leaves are an unusually rich source of protein, vitamins, minerals and phenolic compounds. The leaves contain flavonoids (quercetin and kaempferol glycosides), chlorogenic acid and other phenolic acids, and glucosinolates and isothiocyanates, which are characteristic of the plant. Experimental studies report antioxidant, antihyperglycaemic, hypolipidaemic, anti-inflammatory, antimicrobial, hepatoprotective and neuroprotective activities. In diabetic and glucose-intolerant rodents, aqueous and alcoholic leaf extracts improved glucose tolerance and lowered blood glucose, and isothiocyanates from the leaves attenuated inflammatory mediators in macrophages. Small human studies are encouraging, but are limited by size, short duration and variable preparations. This review presents the history, phytochemistry, experimental protocols, mechanisms, health benefits, applications, advantages and limitations of Moringa oleifera with emphasis on antioxidant and antihyperglycaemic activity.*

Keywords: MOAAA :- Moringa oleifera, Antioxidant, Antihyperglycemic, Isothiocyanates, Phytochemicals

I. INTRODUCTION

Diabetes mellitus affects hundreds of millions of people worldwide, and chronic hyperglycaemia generates reactive oxygen species and promotes inflammation, which in turn damage blood vessels, nerves, kidneys and the eyes [1]. Oral antidiabetic drugs are widely used but are associated with side effects, cost and loss of efficacy over time. Plants with antioxidant and glucose-lowering activity are therefore of interest as adjuncts [2,3].

Moringa oleifera Lam. is called the “miracle tree” because nearly every part is useful as food, medicine, animal fodder or for water purification [4,5]. The leaves are eaten as a vegetable in India, Africa and Southeast Asia and are an important source of protein, β-carotene, vitamin C, calcium, potassium and iron [6,7]. The plant contains flavonoids, phenolic acids and glucosinolate-derived isothiocyanates with antioxidant and anti-inflammatory properties [8,9].

Aqueous leaf extract improved glucose tolerance in rats [10] and lowered glucose in hyperglycaemic rats [11], and reviews have summarised the effects on hyperglycaemia and dyslipidaemia [12]. Moringa isothiocyanates reduce inflammatory mediators in macrophages [13]. At the same time, the safety and efficacy of Moringa in humans need further study [14]. This article presents a structured review of Moringa as an antioxidant and antihyperglycaemic plant.

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II. LITERATURE SURVEY

1. Anwar, F. et al. (2007)
This review described Moringa oleifera as a food plant with multiple medicinal uses, summarising its nutritional value and its reported hypotensive, antispasmodic, antiulcer, anti-inflammatory, hepatoprotective, antimicrobial and antidiabetic activities. [5]

2. Ndong, M. et al. (2007)
Oral administration of Moringa oleifera leaf powder or extract improved glucose tolerance in Goto-Kakizaki and Wistar rats, supporting its traditional antidiabetic use. [10]

3. Jaiswal, D. et al. (2009)
Aqueous leaf extract of Moringa oleifera reduced blood glucose and improved glucose tolerance in glucose-loaded and streptozotocin-induced hyperglycaemic rats, and effects were compared with a standard drug. [11]

4. Mbikay, M. (2012)
This review summarised preclinical and clinical evidence for the use of Moringa oleifera leaves in chronic hyperglycaemia and dyslipidaemia and discussed the possible active constituents. [12]

5. Coppin, J. P. et al. (2013)
Flavonoids from Moringa oleifera were characterised by LC-MS and extracts showed anti-inflammatory activity in cell studies. [15]

6. Waterman, C. et al. (2014)
Water-extractable, stable isothiocyanates from Moringa leaves reduced inflammatory mediators in macrophage cells, indicating anti-inflammatory activity. [13]

7. Leone, A. et al. (2015)
This overview summarised the cultivation, ethnopharmacology, phytochemistry and pharmacology of Moringa leaves, with emphasis on nutritional composition and bioactive compounds. [6]

8. Stohs, S. J. & Hartman, M. J. (2015)
This review of the safety and efficacy of Moringa oleifera concluded that leaves and seeds appear to be safe at moderate doses, but that more human data are needed, and noted possible risks with root and bark. [14]

9. Vergara-Jimenez, M. et al. (2017)
The review described bioactive components of Moringa leaves, including phenolics, flavonoids and isothiocyanates, and their protective effects against chronic diseases through antioxidant and anti-inflammatory activity. [9]

10. Abd Rani, N. Z. et al. (2018)
This review of the Moringa genus summarised phytochemistry and pharmacological properties and highlighted the need for rigorous clinical studies. [16]

Historical Background of Moringa (Moringa oleifera):

Moringa oleifera is native to the sub-Himalayan regions of northern India and has been used there for thousands of years [5,17]. In Ayurveda the tree is known as Shigru, and its leaves, pods, seeds, bark and roots are recommended for inflammation, infections, digestive problems, skin disease, pain and as a general tonic [7,17]. In Indian households the pods are an important vegetable known as drumsticks, and the leaves are consumed in many regional dishes.

Moringa has spread to Africa, Southeast Asia and the Americas, where it is grown as a food crop, and it is promoted by development agencies as a source of nutrition in areas of malnutrition [4]. The seeds have been used for water purification because of cationic proteins that flocculate impurities [6]. Scientific investigation of its pharmacology intensified from the 1990s, and reviews and clinical studies have appeared in the last two decades [5,6,14].

PROTOCOL :

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III. MATERIALS

1. Plant Material

Fresh leaves of Moringa oleifera are collected from healthy trees and authenticated by a qualified botanist [18]. The leaves are washed, shade-dried for 7–14 days, powdered and stored in airtight containers away from light. A voucher specimen is deposited in the institutional herbarium. For isothiocyanate studies, fresh or carefully dried leaves are used because glucosinolate conversion depends on the plant enzyme myrosinase [13].

2. Chemicals and Reagents

Analytical-grade ethanol, methanol and distilled water are used for extraction [19]. Streptozotocin or alloxan is used to induce diabetes [20,21], and glibenclamide or metformin serves as a standard antidiabetic drug. Glucose oxidase–peroxidase kits are used for glucose estimation [22]. Folin–Ciocalteu reagent, aluminium chloride and DPPH are used for in vitro antioxidant assays [23,24]. Lipopolysaccharide is used to stimulate macrophage cells in anti-inflammatory assays [13].

3. Experimental Animals

Healthy adult Wistar or Sprague–Dawley rats (150–200 g) of either sex are acclimatised for one week under standard conditions with free access to pellet diet and water. Experiments are approved by the Institutional Animal Ethics Committee and follow national regulations and the ARRIVE guidelines [25].

4. Extraction Equipment and Methods

Leaf powder is extracted by maceration, Soxhlet extraction or hot-water infusion, and extracts are concentrated under reduced pressure in a rotary evaporator and lyophilised. Aqueous extracts are used to mimic the traditional preparation. Extracts are stored at 4 °C and protected from light.

5. Analytical Instruments

HPLC and LC-MS are used to identify and quantify flavonoids, phenolic acids and isothiocyanates [13,15]. A UV–visible spectrophotometer is used for total phenolic content, total flavonoid content and enzyme assays. A glucometer is used to monitor blood glucose in animals, and a microplate reader is used for MTT and ELISA assays.

6. Phytochemical Screening

Qualitative tests are carried out for alkaloids, flavonoids, tannins, saponins, terpenoids, glycosides and phenolic compounds [18,19]. Total phenolic and flavonoid contents are estimated by the Folin–Ciocalteu and aluminium chloride methods [23,26].

IV. METHODS

1. Preparation of Moringa Extracts

Typically 50 g of leaf powder is extracted with water, ethanol or methanol by maceration for 24–72 hours or in a Soxhlet apparatus for 6–8 hours, filtered, concentrated and dried. The yield is calculated.

2. Phytochemical Analysis

Qualitative tests, total phenolic content and total flavonoid content are determined, and quercetin, kaempferol and chlorogenic acid are quantified by HPLC [15,23,26].

3. In Vitro Antioxidant and Anti-inflammatory Assays

DPPH radical scavenging and lipid peroxidation inhibition are measured spectrophotometrically [24,27,28]. Anti-inflammatory activity is assessed by inhibition of albumin denaturation [29] and by measuring nitric oxide and cytokine release from lipopolysaccharide-stimulated RAW 264.7 macrophages, with viability confirmed by the MTT assay [13,30].

4. In Vitro Antidiabetic Assays

Inhibition of α-amylase and α-glucosidase is measured as an indicator of delay of carbohydrate digestion, and glucose uptake in muscle or adipocyte cell lines is measured to assess insulin-like or insulin-sensitising effects.

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5. In Vivo Antihyperglycaemic Studies

Oral Glucose Tolerance Test: Fasted normal rats receive extract or standard drug orally, followed by a glucose load after a defined interval, and blood glucose is measured at 0, 30, 60, 90 and 120 minutes [10,11]. Streptozotocin or Alloxan-induced Diabetes: Diabetes is induced by a single intraperitoneal injection, which selectively destroys pancreatic β-cells [20,21]. Rats with fasting blood glucose above a defined threshold are divided into diabetic control, standard (glibenclamide) and extract-treated groups and treated orally for 14–28 days. Blood glucose, body weight, lipid profile, liver and kidney function and antioxidant parameters (superoxide dismutase, catalase and lipid peroxidation) are measured [22,28,31,32].

6. In Vivo Anti-inflammatory Studies

Carrageenan-induced paw oedema in rats is used to assess anti-inflammatory activity [33].

6. Toxicity Studies

Acute oral toxicity of Moringa preparations is evaluated in rodents following OECD Guideline 423 (acute toxic class method), in which a single oral dose, commonly up to 2000 mg/kg, is administered and the animals are observed for 14 days for mortality, behavioural changes and body-weight alterations [34]. Sub-acute toxicity is evaluated by repeated daily dosing for 28 days according to OECD Guideline 407, followed by estimation of haematological and serum biochemical parameters and histopathology of vital organs [35].

7. Histopathological Analysis

At the end of an experiment the pancreas, liver and kidney is excised, fixed in 10% neutral buffered formalin, dehydrated through graded alcohols, cleared, embedded in paraffin and sectioned at about 5 µm. Sections are stained with haematoxylin and eosin (H&E) and examined under a light microscope for inflammatory cell infiltration, tissue architecture and degenerative changes by a pathologist who is blinded to the treatment groups [36].

8. Statistical Analysis

In the experimental studies summarised in this review, data are generally expressed as mean ± SEM. Group comparisons are performed by one-way analysis of variance (ANOVA) followed by a post hoc test such as Tukey's or Dunnett's test, and $p < 0.05$ is usually taken as the threshold of statistical significance. Reporting of animal experiments is expected to follow the ARRIVE guidelines [25].

V. MECHANISM OF ACTION

The antioxidant and antihyperglycaemic effects of Moringa are attributed to several groups of constituents acting together, particularly flavonoids, phenolic acids and isothiocyanates [9,12].

1. Antioxidant Mechanisms:

Phenolic acids and flavonoids scavenge free radicals, chelate metals and inhibit lipid peroxidation, and Moringa has been reported to raise the activity of endogenous antioxidant enzymes [1,9]. Isothiocyanates can activate the Nrf2 pathway, which increases cellular defence [9,13].

2. Glucose-lowering Mechanisms:

Leaf extracts improve glucose tolerance, which is attributed to reduced intestinal glucose absorption, improved insulin secretion and insulin sensitivity, and increased tissue glucose uptake [10,11,12]. Isothiocyanates and flavonoids such as quercetin and chlorogenic acid are thought to contribute [12].

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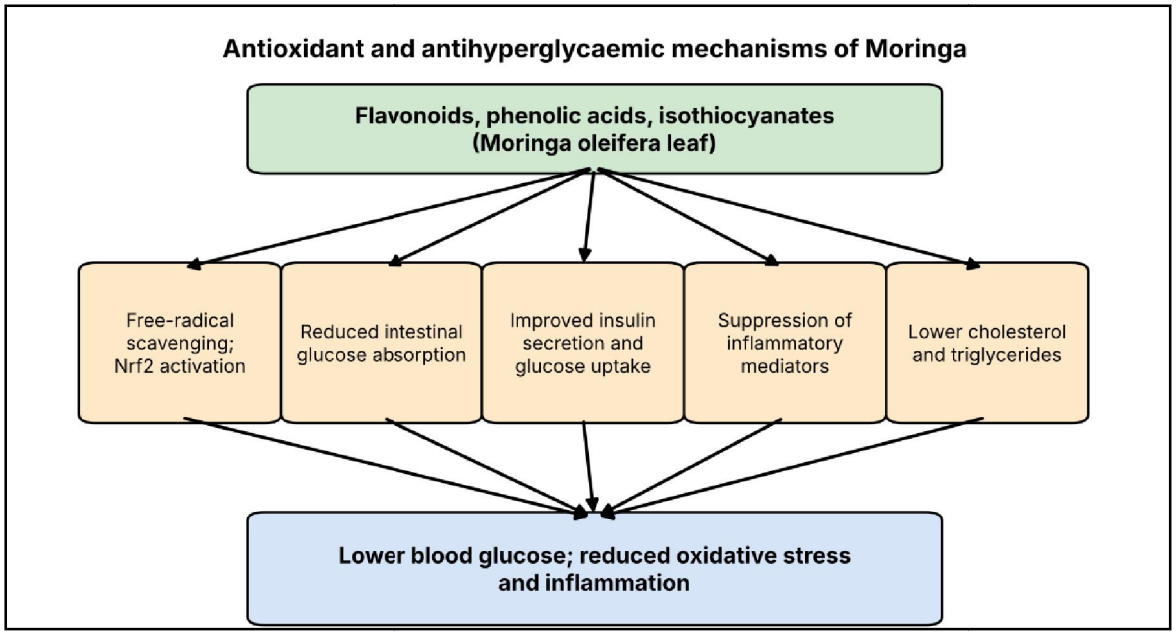


Fig.No.1. Mechanism of Action of Moringa

3. Anti-inflammatory Mechanisms:

Moringa isothiocyanates and flavonoids reduce the release of nitric oxide, pro-inflammatory cytokines and other inflammatory mediators from activated macrophages, partly through suppression of NF-κB [13,15,37].

4. Lipid-lowering Mechanisms:

Experimental studies suggest that Moringa leaf preparations lower serum cholesterol and triglycerides, possibly by reducing cholesterol absorption and by antioxidant protection of lipoproteins [6,12].

5. Protection of Pancreatic β-cells and Organs:

Antioxidant constituents may protect pancreatic β-cells, liver and kidney from oxidative injury in diabetic animals [9,11].

6. Antimicrobial Mechanisms:

Isothiocyanates and other constituents inhibit the growth of several bacteria and fungi, and cationic seed proteins have flocculating and antimicrobial properties [6,17].

VI. OVERALL MECHANISM SUMMARY:

The antioxidant and antihyperglycaemic effects of Moringa result from free-radical scavenging and Nrf2 activation, reduced carbohydrate absorption, improved insulin action and glucose uptake, suppression of inflammatory mediators and protection of tissues from oxidative damage.

Health Benefits of Moringa (Moringa oleifera)

Moringa is valued both as a highly nutritious food and as a medicinal plant [6,7].

1. Antioxidant Properties

Leaf extracts have high phenolic content and show strong radical scavenging activity [8,9].

2. Antihyperglycaemic Activity

Leaf extracts improved glucose tolerance and lowered blood glucose in experimental animals, and small human studies suggest benefit [10,11,12].

3. Anti-inflammatory Activity

Isothiocyanates and flavonoids reduce inflammatory mediators [13,15].

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4. Nutritional Value

Leaves are rich in protein, vitamins A and C, calcium, potassium and iron, and are used to combat malnutrition [4,6].

5. Lipid-lowering and Cardiovascular Benefits

Preclinical studies suggest reduced cholesterol and triglycerides, and hypotensive activity has been reported [5,12].

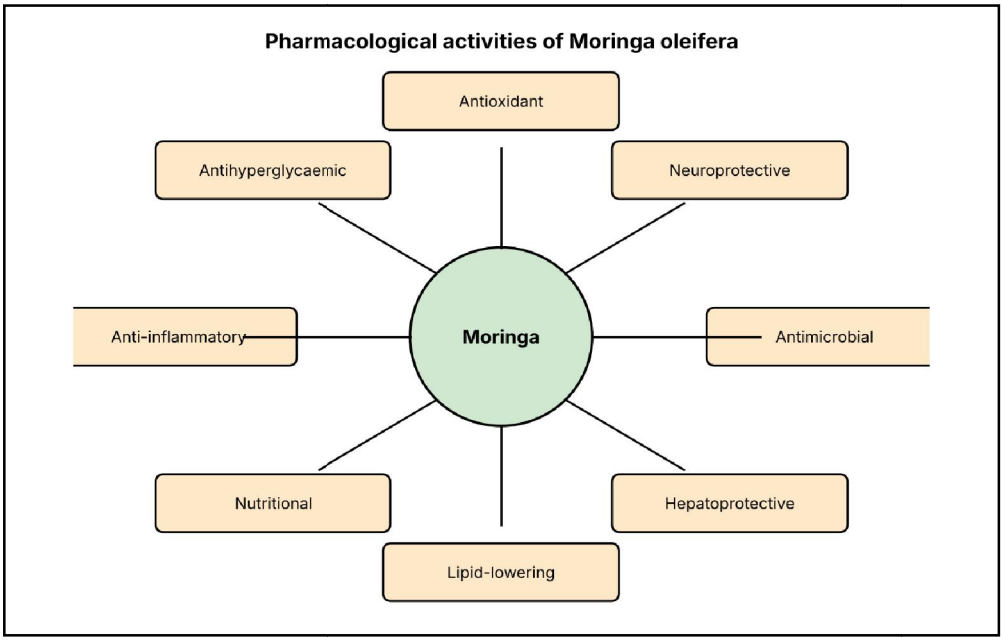


Fig.No.2. Pharmacological Activities of Moringa

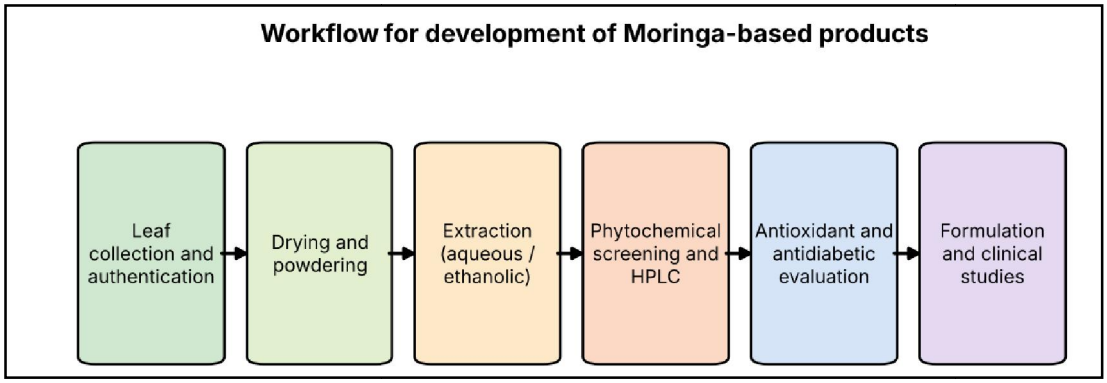


Fig.No.3. From Moringa Leaf to Formulation and Evaluation

6. Hepatoprotective Effects

Extracts protect the liver from chemical injury in animal models [5,16].

7. Antimicrobial Activity

Leaf and seed extracts show activity against bacteria and fungi in vitro [6,17].

8. Neuroprotective Potential

Antioxidant and anti-inflammatory constituents may protect neurons, but evidence is preliminary [9,16].

Reported Findings from Experimental Studies

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1. Phytochemical Analysis

Moringa leaves contain flavonoids (quercetin and kaempferol glycosides), chlorogenic acid, other phenolic acids, glucosinolates and isothiocyanates, carotenoids and vitamins, and composition varies with cultivar, climate and processing [6,8,15].

2. In Vitro Studies

Leaf extracts show antioxidant activity in radical scavenging assays and reduce inflammatory mediator release in macrophages [9,13].

3. In Vivo Antihyperglycaemic Studies

Aqueous leaf extract improved glucose tolerance in normal and diabetic-model rats and reduced blood glucose in hyperglycaemic rats [10,11].

4. Lipid and Antioxidant Studies

Treated animals showed improved lipid profile and higher antioxidant enzyme activity in some studies [9,12].

5. Clinical Studies

Small human studies suggest reduced postprandial glucose and improved lipid profile, but they are limited by size, short duration and variable preparations [12,14].

6. Toxicity Studies

Leaves and seeds appear safe at moderate doses in animals and short-term human studies, while root and bark extracts contain alkaloids and should be avoided in pregnancy [14].

VII. APPLICATIONS OF MORINGA (MORINGA OLEIFERA)

Moringa has nutritional, medicinal, agricultural and industrial applications.

1. Medicinal Applications

Antidiabetic Adjunct: Leaf powder, tea and extracts are used as adjuncts for blood glucose control [12].

Antioxidant Support: Used as a source of dietary antioxidants [9].

Anti-inflammatory: Used traditionally for inflammation and pain [13,17].

2. Nutritional Applications

Leaves, pods and flowers are eaten as vegetables, and leaf powder is used to fortify foods and combat malnutrition [4,6].

3. Industrial and Environmental Applications

Seed press-cake is used for water purification, and seed oil (ben oil) is used in cosmetics, lubricants and as cooking oil [5,6].

4. Agricultural and Veterinary Applications

Leaves are used as animal fodder and as a plant growth enhancer [7].

5. Traditional and Folk Medicine

Leaf juice, root decoction and pod preparations are used for fever, wounds, digestive problems and joint pain [7,17].

Advantage and limitations of Moringa :

VIII. ADVANTAGES OF MORINGA

1. Highly nutritious food plant [6].
2. Rich source of antioxidants [9].
3. Antihyperglycaemic effect in animal models [10,11].
4. Anti-inflammatory isothiocyanates [13].
5. Fast-growing, drought-tolerant and easily cultivated [4].
6. All parts of the plant are useful [5].
7. Leaves and seeds appear safe at moderate doses [14].
8. Inexpensive and widely available.

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9. Potential lipid-lowering effect [12].
10. Multiple uses in food, medicine, water purification and cosmetics [6].

IX. LIMITATIONS OF MORINGA

1. Human clinical trials are few and small [14].
2. Composition varies with cultivar, climate and processing [6].
3. Optimal dose and preparation are not established [12].
4. Root and bark contain alkaloids and should be avoided, especially in pregnancy [14].
5. Possible hypoglycaemia in combination with antidiabetic drugs [12].
6. Possible herb–drug interactions are poorly studied [14].
7. Isothiocyanates are unstable and lost during drying and storage [13].
8. Bioavailability of active constituents is not well known.
9. Long-term safety data are lacking [14].
10. Quality control and adulteration of commercial products [38].

X. FUTURE PROSPECTS OF MORINGA:

1. Pharmaceutical Development
- Standardised leaf extracts with defined phenolic and isothiocyanate content.
- Isolation and development of lead compounds [13].

2. Clinical Trials
- Large randomised trials in type 2 diabetes and prediabetes [12].
- Trials of lipid-lowering and anti-inflammatory effects.

3. Antidiabetic Research
- Identification of active antihyperglycaemic constituents [11].
- Long-term effects on diabetic complications.

4. Nutraceutical Applications
- Functional foods and fortified products.
- Standardised supplements and teas.

5. Drug Delivery Systems
- Nanoformulations to stabilise isothiocyanates.
- Controlled-release products.

6. Combination Therapies
- Combination with conventional antidiabetic drugs.
- Reduction of drug dose and side effects.

7. Nutrition and Public Health
- Use in programmes against malnutrition [4].
- Fortified foods and school meals.

8. Anti-inflammatory Research
- Mechanism studies of isothiocyanates [13].
- Trials in chronic inflammatory conditions.

9. Cosmetic Industry
- Antioxidant skin-care and seed-oil products.
- Natural preservatives.

10. Water Purification
- Low-cost seed-based water treatment [6].
- Community-scale systems.

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11. Agricultural Applications
- Plant growth enhancers and fodder.
- Climate-resilient cultivation.

12. Neuroprotective Research
- Studies in neurodegeneration models [9].
- Brain-targeted delivery.

13. Safety and Toxicology
- Definition of safe dose ranges and herb–drug interactions [14].
- Pharmacovigilance for Moringa products.

14. Quality Control and Certification
- Chemical fingerprints and stability standards.
- Standards for global trade.

15. Integration with Modern Medicine
- Evidence-based integration into nutrition and diabetes care.
- Education on safe use.

XI. SUMMARY

Moringa oleifera is a highly nutritious tree that has been used in food and traditional medicine for thousands of years. Its leaves contain flavonoids, phenolic acids and isothiocyanates with antioxidant, anti-inflammatory, antihyperglycaemic and lipid-lowering activity. In vitro studies show radical scavenging and reduced inflammatory mediator release, and in vivo studies show improved glucose tolerance and reduced blood glucose in rats. Mechanisms include antioxidant defence, reduced carbohydrate absorption, improved insulin action, anti-inflammatory effects and tissue protection. Limitations include a small number of human studies, variable composition, unstable active compounds and incomplete safety data. Future work should focus on standardisation, clinical trials and safety evaluation [12,14].

XII. CONCLUSION

Moringa oleifera is a promising nutritional and medicinal plant with antioxidant and antihyperglycaemic activity supported by preclinical studies and early human data. Standardised preparations, rigorous clinical trials and safety assessment are needed before it can be recommended as an adjunct in diabetes management. Meanwhile, its role as a nutrient-rich food remains well established.

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