REVIEW PAPER

"Therapeutic Potential of Moringa oleifera and Murraya koenigii: A Comprehensive Review of Phytochemistry, Pharmacology and Formulation Strategies"

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ABSTRACT

The growing prevalence of metabolic syndrome and oxidative stress–associated disorders has increased interest in evidence-based polyherbal formulations. *Moringa oleifera* and *Murraya koenigii* are nutritionally rich medicinal plants with complementary phytochemical profiles that justify their combined use in a standardized tablet formulation. *M. oleifera* is abundant in flavonoids, glucosinolates, vitamins, and essential minerals that exhibit antioxidant, anti-inflammatory, hepatoprotective, and glycaemic regulatory activities, whereas *M. koenigii* contains carbazole alkaloids and phenolic compounds associated with antidiabetic, lipid-lowering, antimicrobial, and cytoprotective effects. Comparative experimental evidence suggests that their combination enhances antioxidant defense, improves insulin sensitivity, modulates glucose metabolism, and supports lipid regulation more effectively than single extracts. Dry leaf powders offer higher nutrient density and improved stability for pharmaceutical development compared with fresh leaves. Advances in phytochemical standardization and analytical fingerprinting, along with optimized tablet systems and emerging nano-based delivery approaches, further enhance bioavailability and therapeutic consistency. Although preclinical findings strongly support synergistic benefits, large-scale randomized clinical trials remain limited. Overall, the Moringa–Curry leaf polyherbal tablet represents a scientifically rational nutraceutical strategy for metabolic and oxidative stress management, warranting further dose optimization, pharmacokinetic evaluation, and clinical validation to establish its evidence-based therapeutic potential.

Keywords: *Moringa oleifera*, *Murraya koenigii*, polyherbal tablet, phytochemicals, antioxidant, metabolic health, nutraceutical formulation, functional foods

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INTRODUCTION

The two guiding concepts of Ayurvedic drug formulation are single-drug use and multiple-drug use, the latter of which is referred to as Polyherbal formulation (PHF). Combining multiple medicinal herbs to enhance therapeutic efficacy is known as polypharmacy or polyherbalism, and it is a crucial traditional therapeutic herbal strategy. [1] The need to promote long-term human health and sustainable therapeutic development is what propels the ongoing advancement of phytochemistry research. Scientists discover and describe thousands of novel bioactive substances every year that come from natural sources, especially medicinal plants. Numerous secondary metabolites, which are specialized chemicals with crucial adaptive and protective roles in nature, are produced by these plants. It's interesting to note that humans can benefit greatly from these same compounds. They are utilized as natural pesticides in agriculture, as flavorings and colorants in the food and cosmetics industries, and as antioxidants, nutraceuticals, and therapeutic agents in the medical field. Numerous compounds derived from plants have also demonstrated encouraging promise in the treatment of long-term illnesses like hypertension, underscoring the continued significance of natural products in contemporary drug development. [2]

Phytochemical research continues to expand each year, contributing significantly to sustainable healthcare and natural drug development. To date, nearly 150,000 secondary metabolites have been identified, with thousands of new compounds discovered annually. These phytochemicals—such as alkaloids, flavonoids, tannins, saponins, and phenolic compounds—are natural bioactive substances that interact with nutrients and dietary fiber to promote physiological balance and protect against disease. [3] Many green plants and aromatic culinary herbs are rich sources of these beneficial compounds. One such plant is *Murraya koenigii* (curry leaf), a member of the Rutaceae family, native to India and Sri Lanka and widely cultivated in tropical regions, including Southeast Asia. Traditionally used both as a culinary spice and a medicinal herb, curry leaves have been employed in the management of conditions such as rheumatism, wounds, diarrhoea, and dysentery.[2] Scientifically, the leaves are known to possess various pharmacological activities, including antidiabetic, antioxidant, antimicrobial, larvicidal, and antianxiety effects. Botanically, *Murraya koenigii* is a small tree growing up to 4–6 meters in height, characterized by pinnate compound leaves with a strong aroma, small white flowers, and blackish-brown fruits, with young leaves appearing light green and maturing into a deep green colour.[4]

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Moringa oleifera Lam., commonly known as the "miracle tree," is a fast-growing plant widely cultivated in tropical and subtropical regions worldwide. Although now grown globally, it is believed to be native to South Asia, particularly Afghanistan, Bangladesh, India, and Pakistan.[6] The genus Moringa includes 13 species like *M. arborea, M. rivae, M. ruspoliana, M. drouhardii, M. hildebrandtii, M. concanensis, M. borziana, M. longituba, M. pygmaea, M. ovalifolia, M. peregrina,* and *M. stenopetala* but *M. oleifera* is the most well-known due to its extensive use in nutrition, traditional medicine, agriculture, and even biogas production.[5] It is commercially grown in countries such as India, various parts of Africa, Central and South America, Mexico, Hawaii, and across Asia and Southeast Asia. [6] The plant is commonly known as the "drumstick tree" due to the shape of its immature seed pods, the "horseradish tree" because of the pungent taste of its roots, and the "ben oil tree" for the oil extracted from its seeds. In many regions, the immature pods are consumed as vegetables, while the leaves are extensively used as a nutritious food source owing to their rich content of vitamins, minerals, and other essential nutrients. Although *Moringa oleifera* is widely valued for its nutritional and medicinal properties, there are currently no well-established human clinical trials specifically evaluating its effectiveness in treating undernutrition specially in treating malnutrition in infants and lactating mothers. [7] The present review aims to sum up the updated insight regarding the pharmacological activities, worldwide research analysis, toxicological, phytochemical, and ethnomedicinal properties of *M. oleifera* & *Murraya koenigii.* Traditionally, almost every part of the plant—including the seeds, leaves, oil, sap, bark, roots, and flowers—has been used in various healing practices. Among these, the leaves are particularly recognized for their rich nutritional profile, containing essential vitamins, minerals, amino acids, and fatty acids. They are also a significant source of antioxidant compounds such as ascorbic acid, flavonoids, phenolic compounds, and carotenoids.

Various scientific reviews have highlighted the broad therapeutic potential of *M. oleifera*, reporting activities such as anti-inflammatory, antihypertensive, diuretic, antimicrobial, antioxidant, antidiabetic, antihyperlipidemic, antineoplastic, antipyretic, antiulcer, cardioprotective, and hepatoprotective effects. The potential role of *Moringa* leaves in managing hyperglycemia and dyslipidaemia has also been explored, with emphasis on their strong nutritional value and antioxidant capacity contributing to overall health benefits. [8]

Ethnobotanical Profile: [5,6,9,10]

Table 1: Ethnobotanical Profile of *Murraya koenigii* and *Moringa oleifera*

Language	Vernacular Name	
	Murraya koenigii	***Moringa oleifera***
English	Curry leaf	Drumstick tree / Moringa / Horseradish tree
Hindi	Meetha neem	Sahjan / Munga
Marathi	Kadhilimbu	Shevga
Gujarati	Limdo / Meetholimdo	Saragvo
Punjabi	Kadhi Patta	Soanjna
Bengali	Barsunga	Sajina
Tamil	*Karuveppilai*	Murungai
Telugu	Karivepaku	Munaga
Kannada	Karibevu	Nugge
Malayalam	Kariveppila	Muringa
Sanskrit	Krishnanimbaka	Shigru
Urdu	Kari patta	Sohanjna
French	Feuilles de cari	Moringa / Arbre de raifort
Spanish	Hoja de curry	Árbol de moringa
German	Curryblätter	Meerrettichbaum

Fig: Moringa oleifera

Fig: Murraya koenigii

Ethnobotanical Comparison of *Moringa oleifera* and *Murraya koenigii*:

Table 2: Ethnobotanical Comparison of *Moringa oleifera* and *Murraya koenigii*

Parameter	***Moringa oleifera***	***Murraya koenigii***	**References**
Family	*Moringaceae*	*Rutaceae*	9,5
Common English Name	Drumstick tree / Horseradish tree	Curry leaf tree	9
Origin & Distribution	Native to the Indian subcontinent; widely cultivated in tropical and	Native to India and Sri Lanka; cultivated across South and	9

	subtropical regions worldwide	Southeast Asia	
Parts Used Traditionally	Leaves, seeds, pods, bark, roots	Primarily leaves; also bark and roots in folk medicine	9
Traditional Systems of Use	Ayurveda, Siddha, Unani, folk medicine	Ayurveda, Siddha, folk medicine	9
Traditional Medicinal Uses	Anaemia, malnutrition, diabetes, inflammation, hypertension, digestive disorders, lactation enhancement	Diabetes, dysentery, digestive disorders, antimicrobial uses, hair and skin ailments	9,11
Culinary Importance	Leaves and immature pods consumed as vegetables or powder supplements	Fresh leaves used as flavouring agent in curries and traditional dishes	12
Nutritional Significance	Rich in proteins, vitamins (A, C, E), calcium, iron, potassium	Source of iron, calcium, antioxidants, essential oils	9
Ethnomedicinal Recognition	Often referred to as a "miracle tree" due to broad therapeutic claims	Considered a household medicinal herb with daily dietary integration	9

Comparative Phytochemical Profile of *Moringa Oleifera* and *Murraya Koenigii:*

Table 3: Comparative Phytochemical Profile of *Moringa Oleifera* and *Murraya Koenigii*

Phytochemical Class	*Moringa oleifera*	*Murraya koenigii*	Major Pharmacological Significance	References
Alkaloids	Moringinine, benzylamine	Carbazole alkaloids (mahanine, girinimbine, koenimbine, murrayacine)	Anticancer, antimicrobial, anti-inflammatory, neuroprotective	5,4
Flavonoids	Quercetin, kaempferol, myricetin	Quercetin, rutin, catechin	Antioxidant, antidiabetic, cardioprotective	9,5
Phenolic acids	Chlorogenic acid, gallic acid, ferulic acid	Caffeic acid, gallic acid	Free radical scavenging, hepatoprotective	9,5
Glucosinolates & Isothiocyanates	Glucomoringin, moringin	Not significantly reported	Anti-inflammatory, anticancer, phase II enzyme induction	9
Terpenoids	β-sitosterol	Monoterpenes, sesquiterpenes	Lipid-lowering, anti-inflammatory	14
Saponins	Present (leaf and seed)	Minor quantities	Cholesterol-lowering, immunomodulatory	5
Tannins	Present	Present	Antimicrobial, antioxidant	13
Essential oils	Limited in leaves	Sabinene, β-caryophyllene, α-pinene	Antimicrobial, digestive stimulant	14

Vitamins	Vitamins A, C, E, B-complex	Vitamins A, C	Antioxidant, immune enhancement	9
Minerals	Calcium, potassium, iron, magnesium	Iron, calcium, phosphorus	Nutritional supplementation	9

PHARMACOLOGICAL ACTIVITIES:

1) *Murraya koenigii* (Curry Leaf): [15]

Beyond its culinary importance, *Murraya koenigii* has demonstrated a wide range of pharmacological properties supported by experimental evidence. Numerous studies have reported its antidiabetic, anti-inflammatory, anticancer, antioxidant, antimicrobial, and neuroprotective activities. These effects are primarily attributed to the presence of bioactive carbazole alkaloids, including mahanimbine, koenine, koenimbine, murrayacine, murrayazoline, murrayazolidine, girinimbine, and mukoeic acid.

In vitro and *in vivo* investigations have shown that curry leaf extracts can modulate oxidative stress, regulate glucose metabolism, inhibit inflammatory mediators, and induce apoptosis in certain cancer cell lines. The antioxidant potential further contributes to its protective effects against metabolic and neurodegenerative disorders. Although clinical evidence remains limited, available studies support its traditional use in managing diabetes, gastrointestinal disturbances, and inflammatory conditions.

Collectively, these findings validate the ethnomedicinal applications of *Murraya koenigii* and highlight its potential as a promising source of bioactive compounds for the development of novel therapeutic agents.

2) *Moringa oleifera:*

In recent years, *Moringa oleifera* has gained substantial scientific attention for its broad spectrum of therapeutic properties beyond its nutritional value. Contemporary reviews describe significant antioxidant, anti-inflammatory, antidiabetic, antimicrobial, anticancer, hepatoprotective, and cardioprotective activities associated with this plant [5,16] These effects are mainly attributed to its diverse phytochemical composition, including flavonoids, phenolic acids, glucosinolates, isothiocyanates, alkaloids, vitamins, and carotenoids [5]. Experimental studies demonstrate that *M. oleifera* extracts reduce oxidative stress by enhancing endogenous antioxidant enzymes and modulate glucose metabolism through improved insulin sensitivity [5,17]. Additionally, suppression of pro-inflammatory mediators and inhibition of abnormal cell proliferation have been reported in various in vitro and in vivo models [16, 17]. A recent systematic review further highlighted its hepatoprotective potential, showing improvement in liver histopathology and biochemical markers of hepatic injury [18]. Although robust clinical trials remain limited, emerging evidence supports its application as a functional food and nutraceutical in managing metabolic syndrome, dyslipidaemia, and chronic inflammatory disorders [19]. Collectively, these findings validate its traditional medicinal use and emphasize its potential as a promising source of bioactive compounds for future therapeutic development.

Table 4: From Single to Combined Extracts: Comparative Efficacy of *Moringa oleifera* and *Murraya koenigii*

Parameter	**Moringa**	**Curry Leaves**	**Combined Extracts**
Antioxidant Activity	High	Moderate	Very High
Antidiabetic Effect	Moderate	Moderate	Synergistic
Lipid Regulation	Good	Good	Superior
Anti-inflammatory	Moderate	High	Enhanced

Parameter	**Moringa oleifera**	**Curry Leaves (*Murraya koenigii*)**	**Combined Extracts**	**References**
Antioxidant Activity	High – enhances antioxidant enzymes and reduces oxidative stress	Moderate – due to phenolic and flavonoid compounds	Very High – combination shows synergistic antioxidant activity	20,29
Antidiabetic Effect	Moderate – improves glucose control and insulin sensitivity	Moderate – lowers blood glucose in vivo and in vitro	Synergistic – combined extracts enhance glucose modulation	20,21
Lipid Regulation	Good – improves lipid profile in diabetic models	Good – antihyperlipidemic effects	Superior – combined extract improves lipid metabolism	20,21

Anti-inflammatory	Moderate – reduces pro-inflammatory markers (TNF-α, IL-6)	High – inhibits cytokines and modulates immune response	Enhanced – combination improves anti-inflammatory effect	21,29
Combined Extracts (Synergistic)	–	–	Synergistic benefits in metabolism, oxidative stress, and inflammation	22

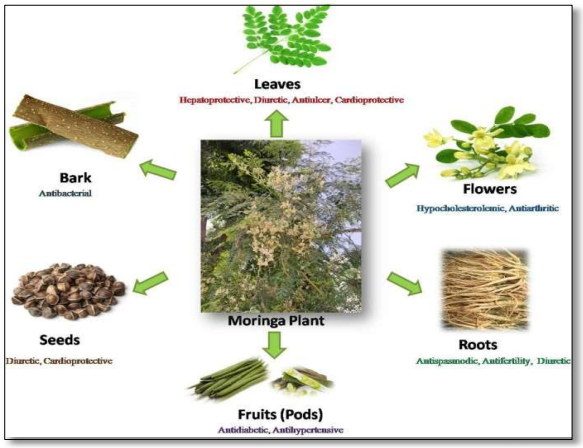

Fig: Pharmacological benefits of *Murraya koenigii* (Curry Leaf) & *Moringa oleifera* [27]

Nutritional Characteristics of Fresh Versus Dried *Moringa oleifera* and *Murraya koenigii:* [23]

Table 5: Nutritional Characteristics of Fresh Versus Dried *Moringa oleifera* and *Murraya koenigii*

Nutrient	Moringa (Fresh)	Moringa (Dry)	Curry Leaves (Fresh)	Curry Leaves (Dry)
Protein (g)	6–7	22–27	6–7	12–18
Calcium (mg)	400–450	1800–2200	800–830	1500–2000
Iron (mg)	6–8	20–28	0.9–1.2	12–20
Vitamin C (mg)	200–220	15–30	4–6	1–3
Fiber (g)	2–3	18–20	6–7	15–20
β-Carotene (µg)	6500–7000	16,000–18,000	7500–8000	13,000 – 15,000

A comparison of fresh and dried leaves of *Moringa oleifera* and *Murraya koenigii* demonstrates that dehydration significantly influences their nutritional density. Fresh *M. oleifera* leaves are well recognized for their high levels of vitamin C, provitamin A carotenoids, calcium, potassium, and quality plant protein, whereas fresh *M. koenigii* leaves provide appreciable amounts of calcium, iron, β-carotene, and essential micronutrients [24,25] Drying removes moisture and consequently concentrates macronutrients, minerals, dietary fiber, and bioactive phytochemicals per unit weight, thereby increasing their functional density. However, heat-sensitive vitamins—particularly vitamin C—may decline during processing [26]. The enhanced mineral and antioxidant concentration in dried leaf powders supports their application in nutraceutical formulations, functional foods, and polyherbal preparations targeting oxidative stress and metabolic disorders. Thus, while fresh leaves are advantageous for vitamin retention and dietary use, dried powders offer superior nutrient density, stability, and suitability for standardized therapeutic product development.

Mechanism of action: [5,19,25]

Both *Moringa oleifera* and *Murraya koenigii* demonstrate broad pharmacological potential, but they act through somewhat different molecular routes. The biological effects of *M. oleifera* are largely linked to its isothiocyanates and polyphenols, which strengthen the body's antioxidant defense system and suppress inflammatory signaling. By

enhancing cellular antioxidant enzymes and limiting pro-inflammatory mediators, it helps reduce oxidative stress and supports programmed cell death in abnormal cells. In comparison, *M. koenigii* derives much of its activity from carbazole alkaloids such as mahanimbine and girinimbine. These compounds are known to interfere with cancer cell survival pathways, promote apoptosis, and regulate glucose metabolism, while also offering neuroprotective benefits. Although both plants share antioxidant and anticancer properties, *M. oleifera* appears more prominent in inflammation and metabolic regulation, whereas *M. koenigii* shows notable alkaloid-driven cytotoxic and neuroprotective effects

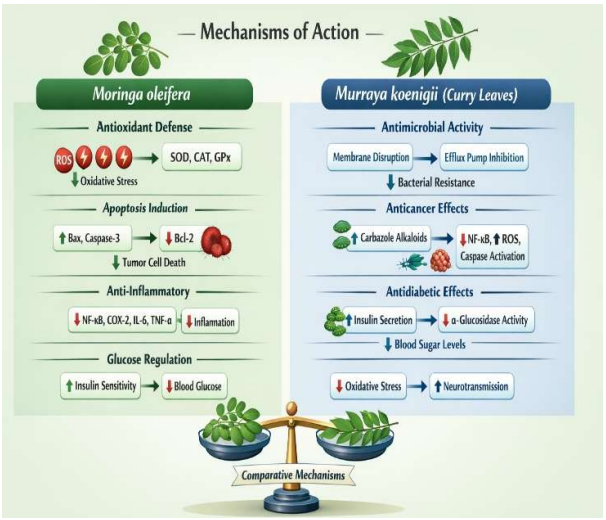

Fig: Comparative mechanism of *Moringa oleifera* vs. *Murraya koenigii*

Comparative Herb–Drug Interactions:
Moringa oleifera* vs. *Murraya koenigii

Herb–drug interactions represent an important consideration in the clinical use of medicinal plants, particularly when combined with conventional pharmacotherapy. Both *Moringa oleifera* and *Murraya koenigii* exhibit pharmacologically active phytoconstituents capable of producing synergistic, additive, or potentially antagonistic interactions with pharmaceutical agents.

1. Pharmacodynamic Interactions

1.1 Synergy with Antidiabetic Agents

Moringa oleifera has demonstrated glucose-lowering activity through improved insulin sensitivity, inhibition of intestinal glucose absorption, and modulation of inflammatory mediators [5,16]. When used alongside standard antidiabetic drugs (e.g., metformin), there is potential for additive or synergistic glycaemic control; however, excessive hypoglycemia may occur if not monitored [5].

Similarly, *Murraya koenigii* exhibits antidiabetic effects attributed to carbazole alkaloids such as mahanimbine and koenimbine, which enhance insulin secretion and reduce oxidative stress [24]. Combined use with oral hypoglycemic agents may potentiate glucose reduction, necessitating careful dose adjustment [11].

1.2 Synergistic Antimicrobial Activity

Moringa oleifera extracts have been shown to enhance antibiotic efficacy through membrane permeabilization and efflux pump inhibition in resistant bacteria [16,17]. Synergistic effects with ampicillin and other β-lactam antibiotics have been reported in experimental models.

Likewise, *Murraya koenigii* stem bark and leaf extracts demonstrate synergistic antibacterial effects when combined with antibiotics, particularly against multidrug-resistant *Staphylococcus aureus* strains [11,32]. The mechanism is thought to involve membrane disruption and interference with bacterial metabolic pathways.

1.3 Anticancer Drug Potentiation

Bioactive compounds in *Moringa oleifera* (e.g., isothiocyanates and flavonoids) modulate apoptotic pathways (Bax/Bcl-2 balance, caspase activation) and oxidative stress, potentially enhancing chemotherapy-induced cytotoxicity [5,17]. Experimental evidence suggests improved efficacy when combined with doxorubicin in vitro.

Murraya koenigii carbazole alkaloids also exhibit antiproliferative activity via NF-κB inhibition, mitochondrial apoptosis induction, and ROS modulation [28,29]. These mechanisms may complement conventional chemotherapeutics and reduce resistance, although clinical validation remains limited.

2. Pharmacokinetic Considerations

Phytochemicals from *Moringa oleifera* have shown the potential to modulate cytochrome P450 enzymes, particularly CYP3A4 and CYP2C9, which may alter the metabolism of co-administered drugs [5]. This raises concerns regarding altered bioavailability of anticoagulants, antiepileptics, and antidiabetic medications. In contrast, limited but emerging evidence suggests that carbazole alkaloids from *Murraya koenigii* may also influence hepatic enzyme activity and drug transporters, though comprehensive pharmacokinetic data are still lacking [28,29]. Further mechanistic studies are needed to clarify these interactions.

3. Safety and Clinical Implications

Both plants exhibit relatively favorable toxicity profiles in preclinical models [5,11]. However:

Concurrent use with antidiabetic drugs may increase risk of hypoglycemia.

Combination with antihypertensives may potentiate blood pressure reduction.

Potential CYP450 modulation warrants monitoring when used with narrow-therapeutic-index drugs.

While pharmacodynamic synergy appears promising - particularly in antimicrobial, antidiabetic, and anticancer

contexts - robust clinical trials are required to confirm efficacy and safety.

Moringa oleifera and *Murraya koenigii* demonstrate overlapping yet distinct herb–drug interaction profiles. *Moringa* interactions are predominantly linked to antioxidant, anti-inflammatory, and metabolic modulation pathways, whereas *Murraya* interactions are largely associated with carbazole alkaloid–mediated antimicrobial and anticancer mechanisms. Despite promising preclinical evidence, standardized clinical evaluations remain essential before routine integration into combination pharmacotherapy.

Integrated Physicochemical and Analytical Methods for Herbal Formulation Standardization: [30]

Table 6: Common Physicochemical Parameters Used for Standardization

Parameter	Purpose	Relevance
Moisture Content	Indicates water content in raw/formulated product	Affects microbial growth and shelf life
Total Ash Value	Measures total mineral content	Indicates presence of inorganic matter
Acid-Insoluble Ash	Detects non-physiological materials (e.g., sand)	Reflects contamination/adulteration
Water-Soluble Extractives	Measures bioactive compounds soluble in water	Reflects hydrophilic phytochemical content
Alcohol-Soluble Extractives	Measures alcohol-soluble compounds	Reflects lipophilic phytochemical content
pH	Indicates acidity/alkalinity	Affects formulation stability and absorption

Table 7: Modern Analytical Techniques for Polyherbal Standardization

Technique	Purpose	Advantage	Disadvantages
HPTLC	Fingerprinting and identification	Quick, cost-effective	Less sensitive for complex markers
HPLC	Quantification of marker compounds	High precision and accuracy	Requires reference standards
GC-MS	Analysis of volatile/semi-volatile compounds	High specificity and sensitivity	Limited to volatile components
LC-MS	Identification of non-volatile compounds	Mass accuracy, structural info	High cost and complex operation
NMR	Structural elucidation	Detailed structure of phytochemicals	Requires pure and large samples

Emerging Formulation Approaches:

Although *Moringa oleifera* and *Murraya koenigii* exhibit considerable pharmacological potential, their practical application can be limited by issues such as low water solubility, inconsistent bioavailability, and instability of active constituents. To address these challenges, recent research has focused on innovative formulation strategies designed to improve stability, absorption, and therapeutic efficiency.

1. Standardized Extracts and Phytochemical Profiling: Ensuring consistency in herbal preparations is essential for reproducible therapeutic outcomes. Standardization based on major bioactive compounds—such as quercetin and chlorogenic acid in *M. oleifera*, and carbazole alkaloids like mahanimbine in *M. koenigii*—helps maintain quality and potency across batches. Advanced analytical tools including HPLC and LC–MS are widely employed for accurate phytochemical characterization and quality control [9].

2. Nanoformulations and Phytosomal Systems: Nanotechnology-based delivery platforms, including nanoparticles, nanoemulsions, and phytosomes, have shown promise in enhancing the solubility and cellular uptake of plant-derived compounds. Encapsulation techniques can improve stability, enable controlled release, and potentially increase antioxidant and antidiabetic activity while allowing lower therapeutic doses [31, 33].

3. Polyherbal Combination Systems:

Formulating *M. oleifera* and *M. koenigii* together in optimized proportions may enhance their complementary biological actions. Modern dosage forms such as bilayer tablets, encapsulated polyherbal blends, and fortified functional products are being explored to improve stability, patient adherence, and therapeutic synergy [32].

4. Functional Foods and Nutraceutical Applications: Incorporating these botanicals into nutraceutical capsules, herbal beverages, fortified foods, and dietary supplements represents a practical strategy for long-term metabolic health management. Such approaches align well with preventive healthcare models aimed at reducing the burden of metabolic disorders.

In summary, integrating phytochemical standardization with advanced delivery technologies is crucial for translating the combined mechanistic benefits of these

plants into reliable clinical applications. Future investigations should focus on pharmacokinetic evaluation, optimized dosing strategies, and well-controlled clinical trials to establish safety and efficacy.

Table 8: Conventional Dosage Forms and Functional Food Applications of *Moringa oleifera* and *Murraya koenigii* [41]

Formulation Type	Examples	Key Benefits
Conventional Dosage Forms	Capsules, Tablets, Powders, Herbal Teas, Fortified Dairy & Bakery Products	Standardized dosing of bioactives- Improved stability and shelf-life- Ease of consumption and compliance- Retention of phytochemicals
Functional Foods & Nutraceuticals	Fortified Yogurt, Energy Bars, Herbal Supplements	Enhanced nutritional profile- Improved antioxidant activity- Acceptable sensory properties- Preventive health benefits and metabolic support

Comparative Clinical Evidence of *Moringa oleifera* and *Murraya koenigii*:

Table 9: Comparative Clinical Evidence

Plant	Study Type	Population / Subjects	Intervention	Outcome Measures	Key Findings	Reference
Moringa oleifera	Randomized clinical trial	T2DM patients (n=32)	8 g *M. oleifera* leaf capsules vs placebo for 4 weeks	FPG, HbA1c, BP	No significant reduction in glycaemia; slight trend to BP reduction	34 (PubMed)
Moringa oleifera	Randomized controlled trial	T2DM subjects (n=40)	20–60 g fresh leaves daily for 14 days	Fasting glucose, BP, lipid profile	No significant glycaemic change; significant SBP drop in one group ($p<0.05$)	35 (PubMed)
Moringa oleifera	Randomized clinical trial *Preprint*	T2DM subjects (n≈107)	Standardized supplementation vs control	RBS, BP	Significant reductions in RBS and modest BP improvements	36 (Preprints)
Moringa oleifera	Systematic review of human and animal studies	Healthy & T2DM adults (multiple studies)	Oral MO leaf powder extracts	Fasting glucose, insulin, antioxidant markers	Some reduction in postprandial glucose and antioxidant increases; mixed glycaemic effects	37 (MDPI)
Murraya koenigii	Clinical supplementation study (older)	NIDDM patients (n=30)	12 g curry leaf powder daily for 30 days	Fasting & post-prandial glucose, lipid profile	Transient reduction in blood glucose at 15 days; no lipid changes	38 (PubMed)
Murraya koenigii	Limited human metabolic trial	*No recent RCTs available*	—	—	Clinical human data is scarce; most evidence is preclinical	—

Limitations and Toxic Effects:

Although *Moringa oleifera* and *Murraya koenigii* are widely regarded as safe medicinal and dietary plants,

certain limitations and potential toxicological concerns must be considered before clinical translation.

1. Dose-Dependent Toxicity

While *M. oleifera* leaves are generally safe at nutritional doses, high concentrations—particularly of root and bark extracts—have demonstrated cytotoxic and genotoxic effects in experimental models. The roots contain alkaloids such as spirochin and benzyl isothiocyanate derivatives that may exhibit neurotoxic or abortifacient properties at elevated doses [39, 40]. Sub-chronic toxicity studies suggest that excessive intake may alter liver enzyme profiles and haematological parameters in animal models. Similarly, *M. koenigii* extracts are considered safe at dietary levels; however, concentrated extracts rich in carbazole alkaloids may exert hepatotoxic or pro-oxidant effects if consumed in large quantities. Toxicological evaluation indicates that safety is dose-dependent and requires standardized preparation.

2. Variability in Phytochemical Composition

One of the major limitations is batch-to-batch variability due to geographic origin, harvesting season, extraction method, and storage conditions. Variability affects bioactive concentration and may lead to inconsistent therapeutic outcomes [26]. Lack of standardized dosing remains a significant barrier for clinical validation.

3. Anti-Nutritional Factors

M. oleifera leaves contain phytates, oxalates, and tannins, which may reduce mineral bioavailability when consumed in excessive quantities. Although levels are generally within safe dietary limits, chronic high intake may interfere with calcium and iron absorption [24]

4. Herb–Drug Interactions

Both plants exhibit hypoglycemic and antihypertensive activities. Concurrent use with antidiabetic or antihypertensive medications may potentiate pharmacological effects, increasing the risk of hypoglycemia or hypotension. Limited clinical studies are available to define interaction profiles, highlighting the need for controlled human trials.

5. Limited Human Clinical Evidence

Despite strong preclinical data, well-designed randomized clinical trials are limited. Most safety data are derived from animal studies, and long-term toxicity data in humans remain insufficient.

Overall, both plants demonstrate favorable safety profiles at dietary and moderate supplemental doses. However, high-dose extract usage, variability in phytochemical composition, anti-nutritional factors, and potential herb–drug interactions warrant careful standardization and clinical monitoring. Future research should prioritize dose–response studies, pharmacokinetic evaluation, and long-term human safety trials.

Polyherbal Synergy: Clinical Translation and Future Directions:

The combined use of *Moringa oleifera* and *Murraya koenigii* brings together two well-known medicinal plants with complementary therapeutic strengths. *Moringa* is widely valued for its powerful antioxidant and anti-inflammatory effects, which help protect tissues from oxidative stress and support metabolic health. *Murraya koenigii* (curry leaves), on the other hand, is recognized for its insulin-enhancing and cytoprotective properties, largely attributed to its bioactive alkaloids and phenolic compounds. When considered together, these plants may offer a broader and more balanced approach to managing metabolic disorders, particularly diabetes.

Although direct clinical studies on their combined use are still limited, existing experimental and mechanistic evidence suggests that their effects could be additive or even synergistic. Advances in standardized extracts and modern formulation strategies further enhance their therapeutic potential. However, carefully designed clinical trials are needed to confirm their combined efficacy and safety in humans.

CONCLUSION

This review highlights the complementary therapeutic potential of *Moringa oleifera* and *Murraya koenigii* as a scientifically rational polyherbal combination. Their distinct yet overlapping phytochemical profiles—including flavonoids, phenolic acids, glucosinolates, essential minerals, and carbazole alkaloids—collectively contribute to enhanced antioxidant, anti-inflammatory, antidiabetic, lipid-regulating, and cytoprotective activities.

Comparative evaluation demonstrates that fresh leaves are nutritionally valuable for dietary use, whereas dried standardized powders offer superior stability, concentration of bioactives, and suitability for tablet and nutraceutical formulation. Emerging pharmaceutical approaches—such as phytochemical standardization, advanced analytical fingerprinting, nano-delivery systems, and optimized tablet design—significantly improve reproducibility, bioavailability, and therapeutic consistency.

Although preclinical evidence strongly supports synergistic metabolic and antioxidant benefits, robust randomized clinical trials are still limited. Therefore, future investigations should focus on:

- Standardized dose–response evaluation
- Long-term human safety assessment
- Herb–drug interaction profiling
- Pharmacokinetic and bioavailability studies
- Multi-center randomized controlled trials

In conclusion, the Moringa–Curry leaf polyherbal tablet represents a promising preventive and adjunct therapeutic formulation targeting metabolic syndrome, diabetes, oxidative stress, and inflammatory disorders. With appropriate scientific validation and quality standardization, this combination has strong potential for successful translation into evidence-based nutraceutical and pharmaceutical applications.

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