Asian J Biol Life Sci., 2025; 14(3):574-585.
https://ajbls.com

Research Article

Identification of Bioactive Compounds in *Meha Mudgara Rasa* Using Gas Chromatography-Mass Spectrometry (GC-MS): Implications in Diabetic Neuropathy

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ABSTRACT

Introduction: Diabetic Neuropathy (DN) is a progressive and debilitating complication of Diabetes Mellitus (DM), primarily caused by chronic hyperglycaemia-induced microvascular damage to peripheral nerves. Despite existing conventional therapies, long-term effective management remains limited. Increasing attention is being directed toward Ayurvedic formulations for their potential role in managing Diabetes Mellitus (DM) and its complications. **Materials and Methods:** The classical Ayurvedic herbo-mineral formulation *Meha Mudgara Rasa*, traditionally used for DM management, was subjected to Gas Chromatography-Mass Spectrometry (GC-MS) analysis. The formulation includes several therapeutic ingredients such as *Dadima* (*Punica granatum*), *Triphala*, *Bilva* (*Aegle marmelos*), and *Gokshura* (*Tribulus terrestris*), known for anti-diabetic and neuroprotective properties. The objective was to identify bioactive compounds potentially beneficial in the treatment of DN. **Results:** GC-MS profiling revealed the presence of multiple phytochemicals with documented pharmacological properties. These include compounds with anti-diabetic, antioxidant, anti-inflammatory, and neuroprotective effects, which may contribute to improved glycaemic control, reduced oxidative stress, and nerve tissue protection. **Discussion:** The identified phytoconstituents support the traditional use of *Meha Mudgara Rasa* in managing DM and DN. These findings suggest its potential as an adjuvant therapy. However, further pharmacological and clinical studies are necessary to confirm its safety and therapeutic efficacy in DN management. **Conclusion:** GC-MS analysis of *Meha Mudgara Rasa* highlights its rich phytochemical composition with potential therapeutic relevance in diabetic neuropathy. This study lays the groundwork for future research to validate its clinical utility and integrate traditional Ayurvedic wisdom with modern scientific approaches.

Keywords: Ayurveda, Diabetic Neuropathy, Neuroprotective, Herbo-mineral medicines.

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Received: 04-08-2025;
Revised: 29-09-2025;
Accepted: 12-11-2025.

INTRODUCTION

GC-MS (Gas Chromatography-Mass Spectrometry) is a Powerful analytical technique combining gas chromatography's separation efficiency with mass spectrometry's precise identification. In Ayurveda, it is crucial for profiling volatile and semi-volatile phytochemicals in complex herbal formulations. GC-MS aids in identifying bioactive compounds linked to classical therapeutic claims, supporting standardisation, quality control, and scientific validation. By offering accurate and reproducible results, GC-MS bridges traditional Ayurvedic knowledge with modern science, contributing to the evidence-based understanding and acceptance of Ayurvedic medicines.[1]

Diabetic Neuropathy (DN) is a progressive nerve disorder closely linked to long-standing Diabetes Mellitus (DM), primarily caused by compromised blood flow through the *vasa nervorum*-the tiny vessels that nourish peripheral nerves. Among its various forms, Diabetic Peripheral Neuropathy (DPN) is the most widespread, yet often goes unnoticed due to its subtle or painless onset. The condition is characterised by damage to both Type A and C nerve fibers, leading to a gradual loss of motor and sensory function. This results in the degeneration of small and large myelinated, as well as demyelinated, nerve fibres. Symptoms usually begin in the lower limbs-especially the feet-and may later involve the hands and arms, with discomfort often intensifying at night. Individuals may experience numbness, burning or tingling sensations, electric shock-like pains, muscle weakness, hypersensitivity to touch, diminished reflexes (particularly in the ankles), and issues

DOI: 10.5530/ajbls.20250008

with balance and coordination.[2] Current medical management emphasises tight blood sugar control to slow progression, complemented by medications such as anticonvulsants (e.g., gabapentin, pregabalin), tricyclic antidepressants (e.g., amitriptyline, imipramine), and, in more severe cases, opioids. Supportive therapies like NSAIDs, corticosteroids, and general analgesics are also useful to alleviate pain and improve quality of life.[3]

Recent research in *Ayurveda* has proved the efficacy of various herbal and herbo-mineral drugs in DM and Diabetic DN. *Ayurvedic* medicines such as *Ashwagandh* (*Withania somnifera* L.),[4] *Amlaki* (*Emblica officinalis* L.,[4] *Guduchi* (*Tinospora cordifolia*),[4] *Shilajatu* (*Asphaltum Punjabianum*)[5] etc., are evaluated through different preclinical or clinical studies.

Meha Mudgara rasa is an herbomineral formulation mentioned in Ayurveda's classical text Bhaishjya Ratanavali, which is under the management of *Prameha (Diabetes)*.[6] It contains 14 herbal ingredients and 01 mineral. *Meha Mudgara Rasa* contains Dadima *(Punica granatum* Linn.),[7] Triphala,[8] Bilva (*Aegle marmelos C.*),[9] Gokshura (*Tribulus terrestris* Linn.)[10] etc., have anti-diabetic, hypolipidemic, neuroprotective activity, etc., which may help reverse the pathophysiology of Diabetic neuropathy. This action may help with Diabetes, peripheral vascular disease, and neuronal disease.

GC-MS Analysis

Preparation of Extracts

The methods that were already published in the literature were used to conduct the GC-MS analysis.[24] The instrument used in the present study was a Gas Chromatography-Mass Spectrometry (GC-MS) system, specifically the Perkin Elmer Autosystem XL model equipped with a Turbo Mass detector. The column employed was Elite-5MS with dimensions of (30 meters * 0.250 mm * 0.250 um). While using an injection volume of two microliters and keeping the temperature of the injector at 260°C, helium was employed as the carrier gas at an ongoing rate of flow of 1 mL/min. The oven was set to increase 10°C/min from 75°C (for 5 min) to 280°C, then descend for 10 min while maintaining the level of temperature. The GC operated for a total of 45 min collecting mass spectra at a scan range of 20 to 610 amu.

Identification of Phytochemical Substances Bioactivity analysis

For GC-MS interpretation of phytochemical components, the resultant component's molecular formula, molar mass, and structure was compared to components listed in the National Institute of Standards and Technology (NIST) online database,[24] the PubChem database of chemical molecules.

MATERIALS AND METHODS

Collection and Authentication of ingredients

All the raw materials of *Meha Mudgara rasa* were purchased from an authorized Ayurved pharmacy. All the herbal drugs were authenticated at the Dravya Guna department, per the standards mentioned in the Ayurveda Pharmacopeia of India (API). The ingredients of *Meha Mudgara Rasa* are outlined in Table 1.

Method of Preparation

Amruteekaran: *Amruteekaran* is a process adopted to remove residual toxins and enhance the drug's therapeutic action. Firstly, *Amruteekaran* of *Kanta Loha Bhas*ma was done as classically mentioned by trituration with a decoction of *Triphala* and subjected to 1 *Puta* (800°C for 3 hr) in an electric muffle furnace.

All herbal ingredients were finely powdered and thoroughly mixed using an end-runner mill to achieve uniformity.

Guggulu was purified following classical procedures and dissolved in Triphala Kashaya, which served as the Bhavana Dravya (levigating agent). This was then mixed thoroughly with the fine herbal powders.

The mixture was combined with *Kanta Loha Bhasma* and processed for 6 hr to ensure uniform distribution. The resulting blend was dried using a tray dryer.

After complete drying, the mass was granulated using a granulator. A starch binder was added in a 1:10 ratio. Finally, the granules were compressed into tablets using a multi-station tablet punching machine.

RESULTS

The phytochemical substances found in *Meha Mudgara Rasa* are outlined in Table 2 [Source: PubMed, Google Scholar, PubChem.].

The phytochemicals found in *Meha Mudgara Rasa*, as listed in Table 2, may play a role in reversing the pathology of diabetic neuropathy, along with additional related effects outlined in Tables 3 and 4.

DISCUSSION

HPTLC and GC-MS are essential analytical techniques in pharmaceutical research. With the help of HPTLC, quick qualitative and quantitative analysis of multicomponent drugs, particularly phytochemicals, is feasible. Due to its very high sensitivity and specificity, GC-MS is of great importance for the identification of metabolized and bioactive compounds in living systems. GC-MS can be used to profile pharmacologically active constituents and monitor metabolic changes following dosing in drug discovery and mechanistic studies. GC-MS facilitates the identification of drug metabolites, aiding in the establishment of pharmacokinetic and pharmacodynamic profiles, which are crucial for validating the drug's mode of action and linking specific metabolites to disease-reversal pathways.

DN, a common and debilitating complication of diabetes mellitus, results from chronic hyperglycaemia-induced peripheral nerve damage. Symptoms such as pain, numbness, tingling, and muscle weakness predominantly affect the extremities and are driven by metabolic dysfunctions, including oxidative stress, inflammation, and microvascular injury. These processes lead to progressive nerve damage, impaired repair mechanisms, and loss of sensory, motor, or autonomic functions. This is outlined in Figure 1.

Conventional therapies, including anticonvulsants, antidepressants, and topical agents, provide symptomatic relief but are often associated with side effects and limited disease-modifying effects. This has prompted interest in alternative therapies targeting the underlying pathology of DN. The present study explores *Meha Mudgara Rasa*, a classical Ayurvedic herbomineral formulation, for its potential therapeutic effects on DN. The goal of the study was to use GC-MS to identify bioactive phytochemicals with antidiabetic, neuroprotective, and anti-inflammatory properties. GC-MS analysis helped identify key chemicals that may influence key pathophysiological mechanisms in DN, including microvascular damage, neuroinflammation, and oxidative stress. Table 3 highlights several phytochemicals that play pivotal roles in reversing the pathology of diabetic neuropathy through a combination of antioxidant, anti-inflammatory, antidiabetic, neuroprotective, and anticonvulsant actions.

The Figure 2 illustrates the antioxidant-mediated mechanisms by which specific compounds counteract diabetic neuropathy. These agents reduce oxidative stress by neutralizing Reactive Oxygen Species (ROS), inhibit lipid peroxidation to preserve neuronal membrane integrity, and stabilize mitochondrial function, thereby preventing oxidative damage-induced apoptosis. Additionally, they downregulate NF-κB signaling, attenuating oxidative inflammation. Through these pathways, antioxidant action promotes neuroprotection and supports functional recovery in diabetic neuropathy (Figure 2).

Figure 3 illustrates the anti-inflammatory mechanisms by which selected compounds mitigate diabetic neuropathy. Compounds such as propanamide derivatives, bromoacetic and dichloroacetic acid esters, and methylenebicyclo ketones modulate inflammatory pathways by inhibiting NF-κB activation, reducing proinflammatory cytokine expression (e.g., TNF-α, IL-1β), and downregulating adhesion molecules involved in leukocyte infiltration. Additionally, they attenuate macrophage activation and suppress oxidative-inflammatory cross-talk. These actions collectively reduce neuroinflammation, prevent neuronal damage, and support peripheral nerve preservation in diabetic neuropathy (Figure 3).

The identified esters modulate diabetic neuropathy by concurrently targeting metabolic and inflammatory pathways.

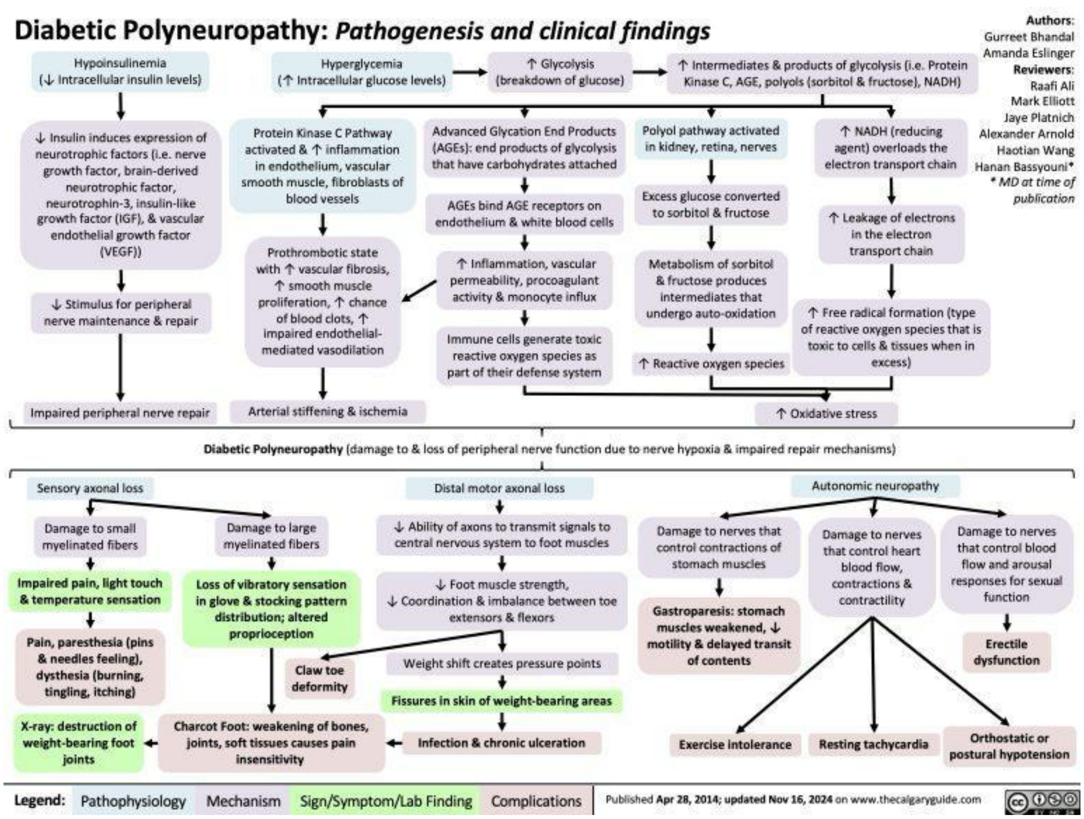

Figure 1: Pathophysiology of Diabetic Neuropathy.[54]

Table 1: Ingredients of *Meha Mudgara rasa*.

Sl. No.	Ingredients	Part used	Quantity	Phytochemical composition	Chemical Composition specific effect
1.	*Amalaki* (*Embilica officinalis* L.)	Fruit	1 part	Galic acid, Ellagic acid, Tannins, Amino acids, Flavanoids.	Antioxidant, Anti diabetic, Anti-microbial, Anti-inflammatory.[11]
2.	*Bibhitaki* (*Terminalia billerica* Roxb.)	Fruit		Chebulagic, Ellagic, and Gallic acid, Gallate ethyl.	Antioxidant, Antidiabetic.[12]
3.	*Haritaki* (*Terminalia chebula* Retz.)	Fruit		Gallic/Ellagic Chebulic/Chebulagic Ascorbic acid.	Antioxidant activity, Antidiabetic retinoprotective, Antinociceptive.[13]
4.	*Rasanjan* (*Berberis aristate* DC.)	Root	1 part	-	-
5.	*Devdaru* (*Cedrus deodara* Roxb.)	Leaves, Bark	1 part	Deodin, Toxifolin, Flavanoids, Glycosides.	Antioxidant, Antimicrobial, Antihyperglycemic, Antispasmodic, Anti-convulsant.[14]
6.	*Bilva* (*Aegle marmelos C.*)	Fruit	1 part	Flavone, Cumin Aldehyde, Eugenol, Rutin, D- limonene.	Antidiabetic, Insecticidal, Antibacterial, Antioxidant, Antiulcer.[15]
7.	*Gokshura* (*Tribulus terrestris* Linn.)	Fruit	1 part	Saponins, Flavanoids, Tannins, Terpenoids, Phenol carboxylic acid, Alkaloids.	Antidiabetic, Anti-inflammatory.[16]
8.	*Dadima* (*Punica granatum* Linn.)	Fruit	1 part	Polyphenol, Alkaloids, Amino acids.	Antioxidant, Antimicrobial, Anti-inflammatory, Anti-cancer.[17]
9.	*Bhunimba* (*Swertia chirayita* Roxb.)	Whole Plant	1 part	Lactones, Diterpenoids, Diterpene glycosides, Flavonoid, Flavonoid glycosides.	Antibacterial, Hepatoprotective, Antitumor, Anticancer, Hypoglycemic, Immunomodulator.[18]
10.	*Pippali* (*Piper longum* L.)	Fruit	1 part	Piperine/Piperlongumine/Piperlonguminine.	Antidiabetic, anti-inflammatory, anti-analgesic, Antioxidant, hypocholesterolaemia.[19]
11.	*Sunthi* (*Zingiber officinale* Roscae.)	Stem		Shogaols/Galanals A and B/zingerone/ gingerol-6/paradol-6	Anticoagulant Effects, Anti-Inflammatory, Antinociceptive, Antioxidant.[20]
12.	*Maricha* (*Piper nigrum* Linn.)	Fruit		Piperine	Antioxidant.[21]
13.	*Trivruta* (*Operculina terpethum* Linn.)	Root bark	1 part	α-andβ-Turpethin, glycosides, coumarins, Scopoletin.	Analgesic, Antioxidant.[22]

Sl. No.	Ingredients	Part used	Quantity	Phytochemical composition	Chemical Composition specific effect
14.	*Guggulu* (*Commiphora wightii* Arnott.)	Extract	4 parts	Guggulsterones, Terpenoids, Flavonoids	Anti-inflammatory, Antioxidant, Cardioprotective, Smooth muscle relaxant.[23]
15.	Loha Bhasma		15 parts	-	-
16.	Bida Lavan		1 part	-	-

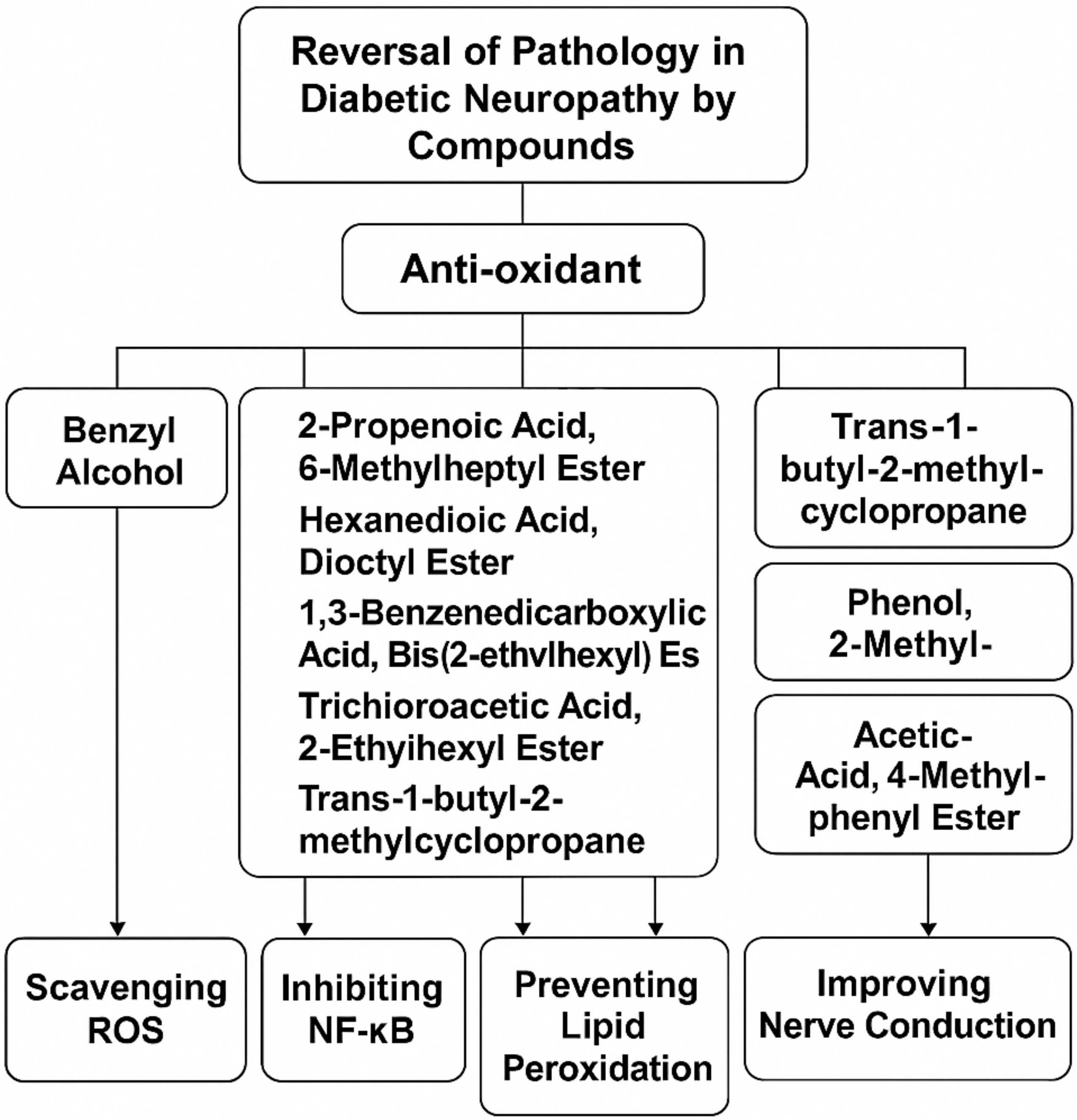

Figure 2: Antioxidant compounds present in *Meha Mudgara Rasa*.

Table 2: Phytochemical Substances found in *Meha Mudgara Rasa*.

Sl. No.	Name of Chemical Substance	Molecular Formula	Molar Mass (g/mol)	Specific Effect of Phytochemical Substance
1.	Carbamic Acid, Methyl-, 3-Methylphenyl Ester	$C_9H_{11}O_2N$	165	Cholinesterase inhibitor
2.	Carbamic Acid, P-Tolyl Ester	$C_8H_9O_2N$	151	Cholinesterase inhibitor
3.	Phenol, 4-(2-Aminoethyl)-	$C_8H_{11}ON$	137	Adrenergic alpha-Agonists; Adrenergic Uptake Inhibitors, Sympathomimetics
4.	Benzyl Alcohol	C_7H_8O	108	Antioxidant, Local Anaesthetic
5.	Benzaldehyde, 4-Methyl-	C_8H_8O	120	Neurodegenerative disease
6.	Benzene, (Ethenyloxy)-	C_8H_8O	120	Diabetic neuropathy
7.	Propanamide, 2-Amino-3-Phenyl	$C_9H_{12}ON_2$	164	Parkinsons, mitochondrial myopathies, Anti-inflammatory.[25]
8.	Cyclopentane, 1,2,3-Trimethyl-	C_8H_{16}	112	Dm, Obesity Antimicrobial, Anticancer, Antiepileptic.[26]
9.	2-Propenoic Acid, 6-Methylheptyl Ester	$C_{11}H_{20}O_2$	184	Hyperplasia, Dermatitis, CNS neoplasia Antioxidant, Anticarcinogenic, and Chemopreventive.[27]
10.	1,2-Cyclohexanedione	C_6H_{16}	112	Hypercholesterolemia, hyperlipoproteinemia
11.	2-Ethylhexyl Methacrylate	$C_{12}H_{22}O_2$	198	Lipid metabolism, Acrylates and methacrylates are detoxified predominantly via conjugation with glutathione via the Michael addition reaction or glutathione-S-transferase. They are also likely to be hydrolyzed via carboxylesterases.
12.	Chloroacetic Acid, Octyl Ester	$C_{10}H_{19}O_2Cl$	206	Parkinsons, catelepsy
13.	Hexanedioic Acid, Mono(2-Ethylhexyl) Ester	$C_{14}H_{26}O_4$	258	Nerve Growth Factor Antioxidant, Antidiabetic.[28]
15.	Hexanedioic Acid, Dioctyl Ester	$C_{22}H_{42}O_4$	370	Gait disorders, neurogenic Pancreatic lipase Antioxidant, Hypoglycaemic, Antibacterial.[29]
16.	Diisooctyl Adipate	$C_{22}H_{42}O_4$	370	Pain
17.	1,3-Benzenedicarboxylic Acid, Bis(2-Ethylhexyl) Ester	$C_{24}H_{38}O_4$	390	Anti-neutrophil cytoplasmic antibody-associated vasculitis Antibacterial, antioxidant, Anti-microbial.[30]
18.	Didodecyl Phthalate	$C_{32}H_{54}O_4$	502	Angiotensin 2 receptor type 1, arginine vasopressin, polyuria, diabetic retinopathy.
19.	Chloroacetic Acid, Octyl Ester	$C_{11}H_{22}O_2$	186	Parkinson's disease, catalepsy.

Sl. No.	Name of Chemical Substance	Molecular Formula	Molar Mass (g/mol)	Specific Effect of Phytochemical Substance
20.	Bromoacetic Acid, 2-Ethylhexyl Ester	$C_{10}H_{19}O_2Br$	250	Anti-inflammatory, antioxidant.[31]
21.	Dichloroacetic Acid, 2-Ethylhexyl Ester	$C_{10}H_{18}O_2C_{12}$	240	Antibacterial, antioxidant, anti fungal.[32]
22.	Trichloroacetic Acid, 2-Ethylhexyl Ester	$C_{10}H_{17}O_2Cl_3$	274	Antioxidant, antidiabetic.[33]
23.	2-Butenedioic Acid (E)-, Bis(2-Ethylhexyl) Ester	$C_{20}H_{36}O_4$	340	Anti Fungal.[34]
24.	4-Nitrobenzoic Acid, Cyclobutyl Ester	$C_{11}H_{11}O_4N$	221	Antioxidant.[35]
25.	Propanoic Acid, Octyl Ester	$C_{11}H_{22}O_2$	186	antioxidant, antibacterial, antifungal and insecticidal.[36]
26.	Oxalic Acid, 2-Ethylhexyl Pentadecyl Ester	$C_{25}H_{48}O_4$	412	Antidiabetic.[37]
27.	Trans-1-Butyl-2-Methylcyclopropane	C_8H_{16}	112	Antioxidant, preventive degeneration.[38]
28.	Phenol, 2-Methyl-	C_7H_8O	108	Antioxidant.[39]
29.	Phenol, 3-Methyl-	C_7H_8O	108	Antioxidant.[40]
30.	Acetic Acid, 4-Methylphenyl Ester	$C_9H_{10}O_2$	150	Antioxidant.[41]
31.	Benzaldehyde, 2-Methyl-	C_8H_8O	120	Antimicrobial, anticancer.[42]
32.	Bicyclo [4.2.0] Octa-1,3,5-Trien-7-Ol	C_8H_8O	120	Antimicrobial.[43]
33.	6-Methylenebicyclo [3.2.0] Hept-3-En-2-One	C_8H_8O	120	antibacterial, antifungal, and insecticidal.[44]
34.	Cyclobutanecarboxylic Acid, 2-Ethylhexyl Ester	$C_{13}H_{24}O_2$	212	antibacterial, antifungal, antioxidant.[45]
35.	1,2-Benzenedicarboxylic Acid, Butyl Methyl Ester	$C_{13}H_{16}O_4$	236	Antioxidant.[46]
36.	Hexanedioic Acid, Bis(2-Ethylhexyl) Ester	$C_{22}H_{42}O_4$	370	Antioxidant, Antidiabetic.[47]
37.	Cyclohexanecarboxylic Acid, Cyclobutyl Ester	$C_{11}H_{18}O_2$	182	Antioxidant.[48]
38.	Aziridine, 2-Methyl-2-(2,2,4,4-Tetramethylpentyl)-	$C_{12}H_{25}N$	183	Antioxidant, antimicrobial.[49]
39.	Oxalic Acid, 2-Ethylhexyl Tetradecyl Ester	$C_{24}H_{46}O_4$	398	Antidiabetic.[50]
40.	1,2-Benzenedicarboxylic Acid, Mono(2-Ethylhexyl) Ester	$C_{16}H_{22}O_4$	278	Antioxidant, Antidiabetic.[51]
41.	3-Chloropropionic Acid, 2-Ethylhexyl Ester	$C_{11}H_{22}O_2Cl$	220	Anti-fungal.[52]
42.	1,2-Benzenedicarboxylic Acid, Diisooctyl Ester	$C_{24}H_{38}O_4$	390	Antioxidant.[53]

Through AMPK activation, they enhance insulin sensitivity and glucose uptake while suppressing hepatic gluconeogenesis. Simultaneously, NF-κB inhibition reduces proinflammatory cytokine release, decreasing neuroinflammation. This dual modulation restores metabolic balance, alleviates oxidative stress, and preserves neuronal function, presenting a synergistic therapeutic strategy (Figure 4).

Through hypolipidemic and neuroprotective mechanisms, the compounds 1,2-cyclohexanedione, 2-ethylhexyl methacrylate, benzene (ethenyloxy)-, hexanedioic acid mono(2-ethylhexyl) ester, hexanedioic acid dioctyl ester, and benzaldehyde, 4-methyl-, have two opposing effects in diabetic neuropathy. 1,2-cyclohexanedione and 2-ethylhexyl methacrylate reduce lipid-induced oxidative stress and hyperlipidemia and decrease neurodegeneration. Hexanedioic acid dioctyl ester and mono(2-ethylhexyl) ester strengthen cell membranes, enhance mitochondrial activity, and decrease oxidative damage to maintain neural integrity. By decreasing neuroinflammation and enhancing the expression of neurotrophic factor, which supports nerve regeneration, benzoene (ethenyloxy)- and benzaldehyde, 4-methyl-act exert their effects through antioxidant and anti-inflammatory pathways. In combination, these compounds reduce oxidative stress, enhance neuronal survival and repair, and re-establish metabolic balance.

By inhibiting acetylcholinesterase and protecting the central nervous system, the drugs cyclopentane, 1,2,3-trimethyl-, trans-1-butyl-2-methylcyclopropane, chloroacetic acid, octyl ester, and carbamic acid derivatives (methyl-, 3-methylphenyl ester, and p-tolyl ester) provide therapeutic actions for diabetic neuropathy. The carbamic acid esters, through the inhibition of acetylcholinesterase, enhance synaptic transmission and cholinergic neurotransmission. Cyclopentane, 1,2,3-trimethyl- and trans-1-butyl-2-methylcyclopropane provide anticonvulsant and neuroprotective effects by stabilising the neuronal membrane and preventing excitotoxicity. Chloroacetic acid, octyl ester decreases oxidative stress, further enhancing neuronal integrity. In combination, the compounds restore cholinergic function, decrease neuroinflammation, and enhance neuronal survival, facilitating reversal of diabetic neuropathy.

In DN, the compounds phenol, 4-(2-aminoethyl)-, 1,3-benzenedicarboxylic acid bis(2-ethylhexyl) ester, didodecyl phthalate, benzyl alcohol, and diisooctyl adipate perform multiple actions. By suppressing pain transmission, benzyl alcohol and diisooctyl adipate modulate nociceptive pathways, most likely by antagonistic interactions with TRPV1 receptors. 1,3-Benzenedicarboxylic acid bis(2-ethylhexyl) ester and didodecyl phthalate cause peripheral vasodilation, increasing microcirculation and enhancing neural perfusion, thus preventing ischemic damage. Phenol, 4-(2-aminoethyl)- induces vasodilation by activating the Nitric Oxide (NO) pathway, enhancing vascular tone and diminishing endothelial dysfunction. These drugs in

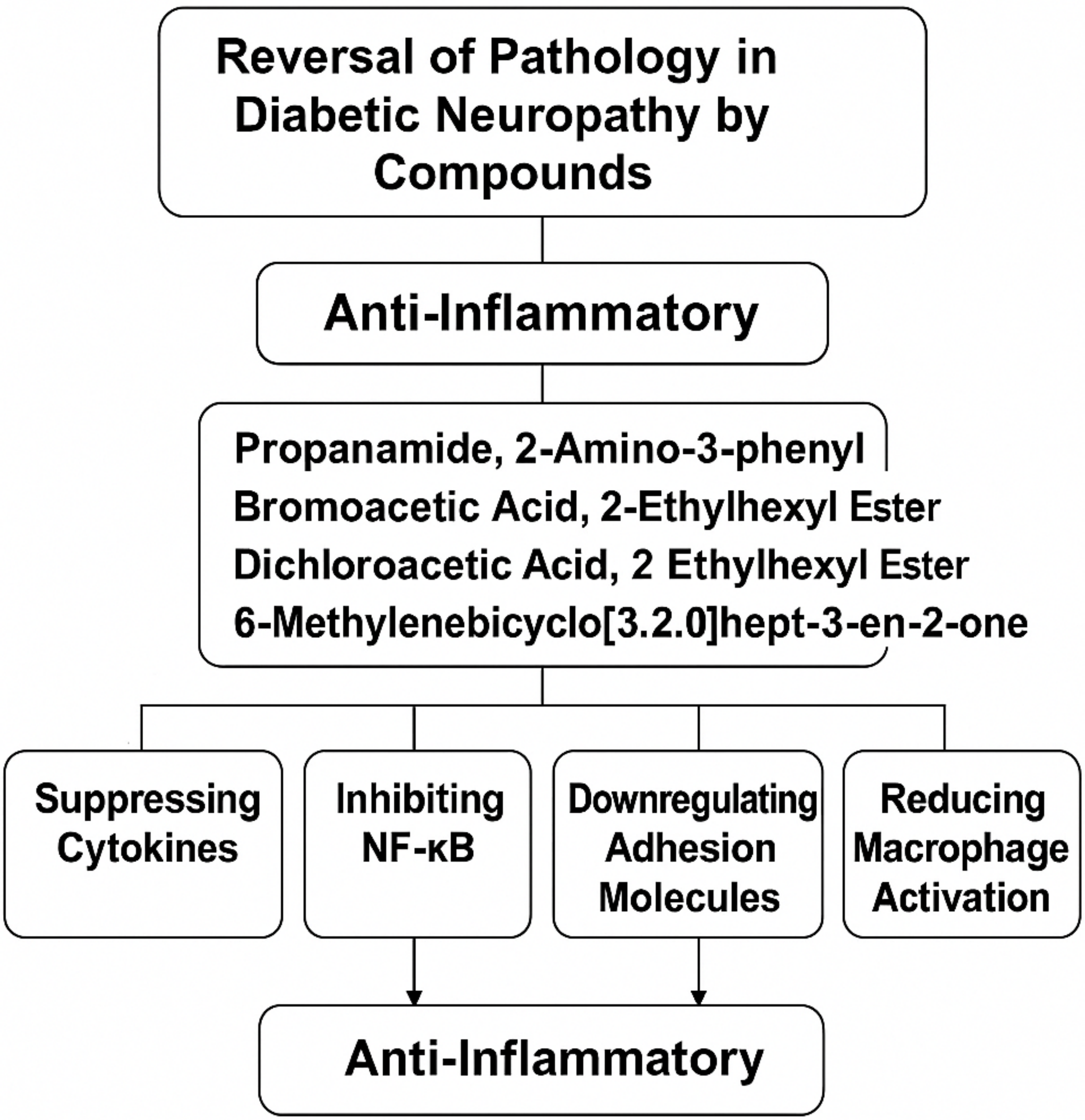

Figure 3: Anti-inflammatory compounds present in *Meha Mudgara Rasa*.

Table 3: Chemical substances with therapeutic effects on the pathophysiology of diabetic neuropathy.

Sl. No.	Action	Phytochemicals
1.	Antioxidant	Benzyl Alcohol, 2-Propenoic Acid, 6-Methylheptyl Ester, Hexanedioic Acid, Dioctyl Ester, 1,3-Benzenedicarboxylic Acid, Bis(2-ethylhexyl) Ester, Trichloroacetic Acid, 2-Ethylhexyl Ester, Trans-1-butyl-2-methylcyclopropane, Phenol, 2-Methyl-,|| Phenol,3-Methyl || Acetic acid, 4-MethylPhenyl Ester|| 1,2-Benzediccarboxylic acid, Butyl Methyl Ester || Hexanedioic acid, Bis (2-Ethylhexyl) Ester|| 1,2-Benzenedicarboxylic Acid, Mono (2-Ethylhexyl) Ester || 1,2-Benzenedicarboxylic Acid, Diisooctyl Ester.
2.	Anti-Inflammatory	Propanamide, 2-Amino-3-phenyl ||Bromoacetic Acid, 2-Ethylhexyl Ester||Dichloroacetic Acid, 2-Ethylhexyl Ester||6-Methylenebicyclo[3.2.0]hept-3-en-2-one.
3.	Anti- Diabetic	Hexanedioic Acid, Mono(2-ethylhexyl) Ester|| Trichloroacetic acid, 2-ETthylhexyl Ester || Oxalic acid, 2-Ethylhexyl Pentadecyl Ester|| Hexanedioic acid, Bis (2-Ethylhexyl) Ester|| Oxalic acid, 2- Ethylhexyl Tetradecyl Ester || 1,2-Benzenedicarboxylic Acid, Mono(2-ethylhexyl) Ester
4.	Hypolipidemic	1,2-Cyclohexanedione||, 2-Ethylhexyl Methacrylate
5.	Nerve Protection / Regeneration	Benzene, (Ethenyloxy)-|| Hexanedioic Acid, Mono(2-ethylhexyl) Ester || Hexanedioic Acid, Dioctyl Ester || Benzaldehyde,4- Methyl-
6.	Anticonvulsant / CNS Protection	Cyclopentane, 1,2,3-Trimethyl- || Trans-1-butyl-2-methylcyclopropane || Chloroacetic Acid, Octyl Ester
7.	Acetylcholinesterase Inhibitors	Carbamic acid, Methyl-, 3-Methylphenyl Ester|| Carbamic acid, P-Tolyl Ester
8.	Analgesic	Benzyl alcohol, Diisooctyl adipate
9.	Vasodilator Effects	1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester || Didodecyl phthalate||Phenol, 4-(2-aminoethyl)-
10.	Sympathomimetics	Phenol, 4-(2-aminoethyl)-
11.	Diabetic Retinopathy	Didodecyl phthalate

combination decrease pain, increase tissue oxygenation, and facilitate neuronal repair, providing potential for reversing DN pathophysiology.

As a sympathomimetic, phenol, 4-(2-aminoethyl)-, stimulates the sympathetic nervous system through activation of β-adrenergic receptors. By promoting vasoconstriction and augmenting the perfusion of peripheral neurons, the modulation elevates norepinephrine release, decreasing diabetic neuropathy ischemic damage. Also, by enhancing adrenergic signalling, it amplifies neurotransmission, which could potentially correct autonomic dysfunction and minimise neuroinflammation. These activities lead to recovery of vascular integrity, neuronal rescue, and regeneration, presenting with therapeutic potential in reversing diabetic neuropathy.

Table 4 illustrates some of the bioactive compounds contained in *Meha Mudgara Rasa* that, through a range of pharmacological mechanisms, including antifungal, anticancer, antibacterial, and immunomodulatory activities, all contribute to the therapy modulation of diabetic neuropathy. These are recognized for their potent antifungal activities and include compounds such as bromoacetic acid, 2-ethylhexyl ester and dichloroacetic acid, 2-ethylhexyl ester that decrease microbial infections that lead to inflammation, subsequently decreasing the aggravated neuropathic pain that is commonly observed among diabetic patients.

Moreover, through the inhibition of oxidative stress and cellular apoptosis, chemicals like cyclopentane, 1,2,3-trimethyl-, and hexanedioic acid derivatives and other anticancer/anti-neoplastic drugs ensure cellular integrity and encourage regenerative processes, thus preventing neuronal degeneration. Through its antibacterial action, cyclopentane 1,2,3-trimethyl- and benzoaldehyde, 2-methyl- not only repress microbial growth but also reduce oxidative damage, improving neural function and cell resistance.

Moreover, immunomodulatory compounds such as 6-methylheptyl ester, 2-amino-3-phenyl, 2-propanamide, and 2-propenoic acid regulate immune homeostasis and reduce chronic inflammation, which accelerates neurodegeneration processes in diabetic neuropathy. By promoting nerve regeneration and providing analgesic relief, these compounds act in synergy to modulate infection, inflammation, oxidative stress, and cellular repair pathways, providing a holistic strategy to the treatment of diabetic neuropathy.

Meha Mudgara Rasa offers holistic therapeutic potential in managing diabetic and other peripheral neuropathies. Its antioxidant, anti-inflammatory, immunomodulatory, and neuroprotective actions help combat oxidative stress, chronic inflammation, and impaired glucose metabolism. These effects support nerve protection, regeneration, pain relief, and improved blood circulation. Additionally, it strengthens immune responses and prevents infections, promoting overall nerve health. Beyond diabetic neuropathy, it may benefit conditions like chemotherapy-induced and idiopathic neuropathies by restoring nerve function and providing multi-targeted symptomatic relief.

Limitations and Future Scope of the Study

GC-MS has revealed several compounds, many remain pharmacologically uncharacterized, which may currently limit the full exploitation of its clinical potential. To establish its efficacy comprehensively, *Meha Mudgara Rasa* should be subjected to systematic evaluation across all four phases of clinical trials. This would enable a robust assessment of its safety, efficacy, and therapeutic value in the treatment of diabetic neuropathy, peripheral neuropathy, and peripheral vascular disorders, paving the way for its integration into evidence-based medical practice.

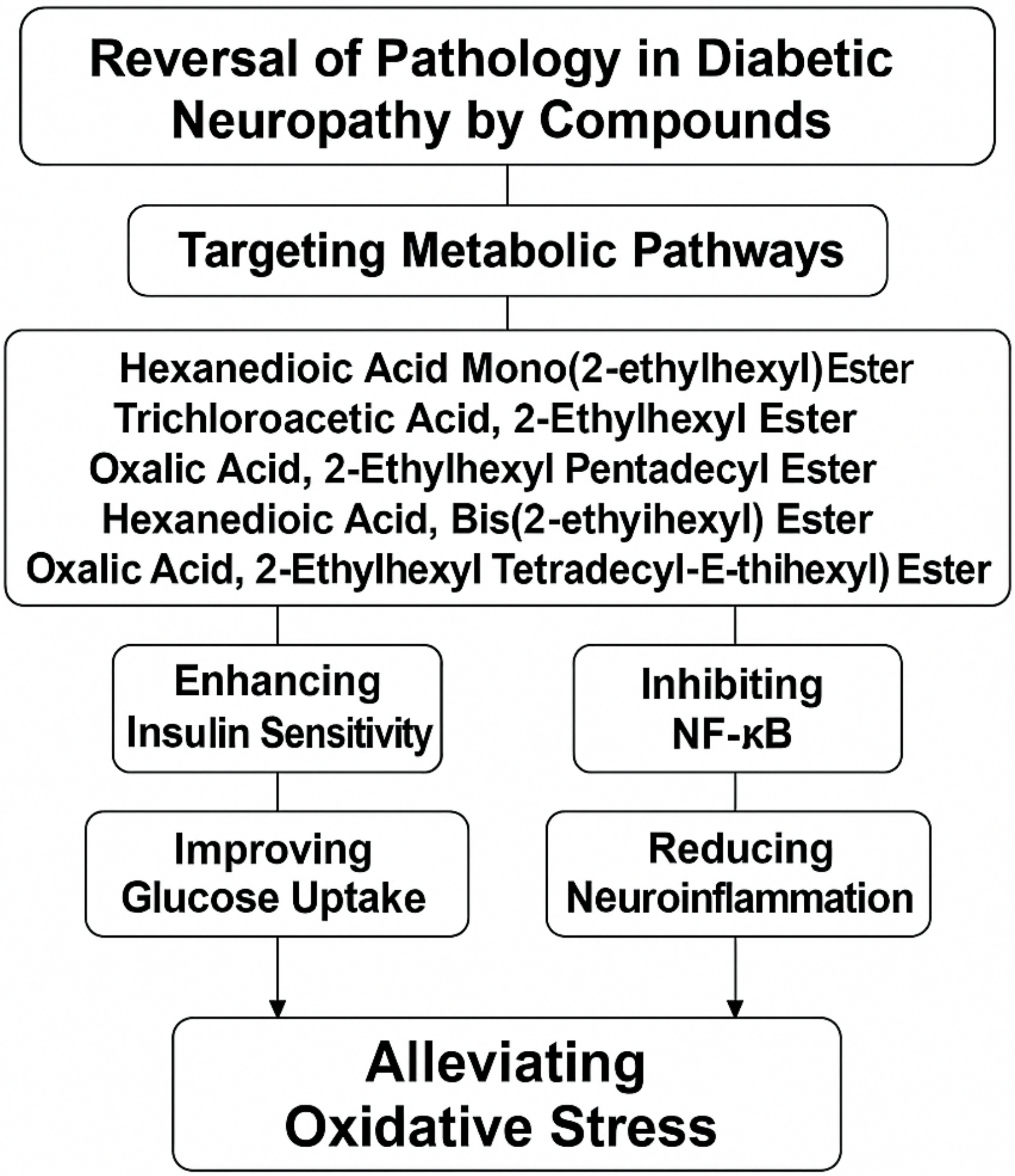

Figure 4: Anti-Diabetic activity.

Table 4: Chemical compounds with other associated actions.

Sl. No.	Action	Phytochemicals
1.	Antifungal Agent	Bromoacetic acid, 2-ethylhexyl ester|| Dichloroacetic acid, 2-ethylhexyl ester|| 2-Butenedioic acid (E)-, bis(2-ethylhexyl) ester|| Propanoic acid, octyl ester|| 6-Methylenebicyclo[3.2.0]hept-3-en- 2-one|| Cyclobutanecarboxylic acid, 2-ethylhexyl ester|| 3-Chloropropionic acid, 2-ethylhexyl ester
2.	Anticancer / Anti-neoplastic activity	Cyclopentane, 1,2,3-trimethyl-|| 2-Propenoic acid, 6-methylheptyl ester|| Hexanedioic acid, mono(2-ethylhexyl) ester|| Hexanedioic acid, dioctyl ester|| 1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester|| 4-Nitrobenzoic acid, cyclobutyl ester|| Benzaldehyde, 2-methyl-
3.	Antibacterial / Antimicrobial	Cyclopentane, 1,2,3-trimethyl-|| Hexanedioic acid, dioctyl ester|| 1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester|| Bromoacetic acid, 2-ethylhexyl ester|| Dichloroacetic acid, 2-ethylhexyl ester|| 2-Butenedioic acid (E)-, bis(2-ethylhexyl) ester|| Propanoic acid, octyl ester|| Benzaldehyde, 2-methyl-|| Bicyclo[4.2.0]octa-1,3,5-trien-7-ol|| 6-Methylenebicyclo[3.2.0]hept-3-en-2-one|| Cyclobutanecarboxylic acid, 2-ethylhexyl ester|| 1,2-Benzenedicarboxylic acid, butyl methyl ester|| Aziridine, 2-methyl-2-(2,2,4,4-tetramethylpentyl)-|| 3-Chloropropionic acid, 2-ethylhexyl ester|| 1,2-Benzenedicarboxylic acid, diisooctyl ester
4.	Immunomodulators	Propanamide, 2-amino-3-phenyl|| 2-Propenoic acid, 6-methylheptyl ester|| Hexanedioic acid, mono(2-ethylhexyl) ester|| 1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester

CONCLUSION

The current study identifies phytochemical components and assesses the effect of an Ayurvedic formulation, *Meha Mudgara Rasa*, on diabetic neuropathy. *Meha Mudgara Rasa* has demonstrated the ability to manage and prevent the progression of diabetic neuropathy at various stages, i.e., prior to and following the development of ischemia in peripheral microvasculature and neuronal hypoxia, which eventually results in neuronal dysfunction and peripheral nerve loss. Furthermore, the therapeutic potential of *Meha Mudgara Rasa* in different peripheral neurological and vascular disorders could be further evaluated.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

DN: Diabetic Neuropathy; **DM:** Diabetes Mellitus; **GC-MS**: Gas Chromatography–Mass Spectrometry; **MMR:** Meha Mudgara Rasa; **PG:** Postgraduate.

SUMMARY

Meha Mudgara Rasa, a classical Ayurvedic herbo-mineral formulation traditionally used in diabetes management, was analyzed using Gas Chromatography-Mass Spectrometry (GC-MS) to identify bioactive compounds. The study revealed several phytochemicals with known anti-diabetic, antioxidant, anti-inflammatory, and neuroprotective properties. These findings support its traditional use and suggest potential benefits in diabetic neuropathy. Further pharmacological and clinical investigations are recommended to confirm its therapeutic efficacy and safety.

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Cite this article: Deshpande S, Gandhi M. Identification of Bioactive Compounds in *Meha Mudgara Rasa* Using Gas Chromatography-Mass Spectrometry (GC-MS): Implications in Diabetic Neuropathy. Asian J Biol Life Sci. 2025;14(3):574-85.