

MADHUMEHARI CHURNA IN DIABETES MELLITUS: EXPLORING ITS PHYTOCHEMICAL LANDSCAPE, PHARMACOLOGICAL MECHANISMS AND TRANSLATIONAL POTENTIAL

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ABSTRACT

Diabetes mellitus is a complex metabolic disorder characterized by persistent hyperglycemia and progressive alterations in multiple physiological pathways, which may ultimately contribute to microvascular and macrovascular complications. The multifactorial nature of diabetes has increased interest in therapeutic approaches capable of influencing multiple biological targets simultaneously. Among traditional Ayurvedic preparations, Madhumehari Churna, a polyherbal formulation comprising twelve medicinal botanicals, has traditionally been used in the management of *Prameha* and diabetes-related disorders. This review critically examines the available evidence concerning its phytochemical composition, proposed pharmacological mechanisms, therapeutic potential, and safety considerations. The constituent botanicals of Madhumehari Churna contain diverse classes of bioactive compounds, including flavonoids, phenolic acids, tannins, alkaloids, terpenoids, triterpenoids, saponins, glycosides, polysaccharides, and dietary fibres. Experimental studies of its individual constituents suggest potential effects on carbohydrate digestion and absorption, insulin secretion and sensitivity, glucose utilization, lipid metabolism, oxidative stress, and inflammatory signaling. These findings provide a pharmacological rationale for the traditional use of the formulation; however, an important proportion of the available mechanistic evidence is derived from individual herbs or their phytoconstituents rather than from the complete Madhumehari Churna formulation. Therefore, the reported activities should be interpreted as potentially complementary pharmacological effects rather than established synergistic actions. Available clinical evidence remains limited and is characterized by variation in study design, formulation, dosage, treatment duration, and outcome assessment. Similarly, formulation-specific toxicological, pharmacokinetic, and standardization data are comparatively scarce. Further well-designed preclinical investigations and adequately powered clinical studies, together with systematic quality-control and phytochemical standardization, are required to establish the efficacy, safety, reproducibility, and clinical relevance of Madhumehari Churna in diabetes management. Such evidence will help determine its potential role as a multi-component therapeutic approach within contemporary diabetes care.

KEYWORDS: Diabetes mellitus; Madhumehari Churna; Ayurvedic medicine; polyherbal formulation; phytochemicals; antidiabetic activity; pharmacological mechanisms; standardization; therapeutic potential.

INTRODUCTION

Polyherbal formulations are the combinations of multiple herbal ingredients that are the cornerstones of traditional medicine in Asia and Africa.^[1] The rationale behind these polyherbal formulations is the combination of different bioactive compounds, which may increase therapeutic outcomes in a holistic approach to health and wellness.^[2] These formulations use a number of plant ingredients because, in traditional belief, the combination of various herbs complements and enhances their individual therapeutic effects, reduces side effects, and increases treatment efficacy. The scope of the polyherbal formulations comprises a wide range from simple folk medicine to modern-day pharmacological research and clinical use.^[3]

Polyherbal formulations (PHFs) are gaining popularity among modern and traditional medicine due to their advantage in combining the therapeutic properties of many plant species, which may often present increased

efficacy, diminished toxicity, and reduced adverse effects. These formulations incorporate two or more herbs, where each is chosen for the pharmacological action, it represents that is complementary to those presented by the other formulation constituents.^[4,5]

The bioactive compounds in PHFs can interact synergistically and cause increased therapeutic effects than single-herb formulations. This review conceptually, compositionally, and mechanistically discusses the concept of synergy in PHFs with comparison to single-herb formulations in terms of broader therapeutic applications, efficacy, safety, and cost-effectiveness. PHFs have been promising in wound healing, microbial infection management, and chronic diseases such as diabetes and cancer. This outcome reiterates the importance of polyherbal formulations, being valuable holistic therapy especially in diseases complex and multifactorial in origin.^[6,7]

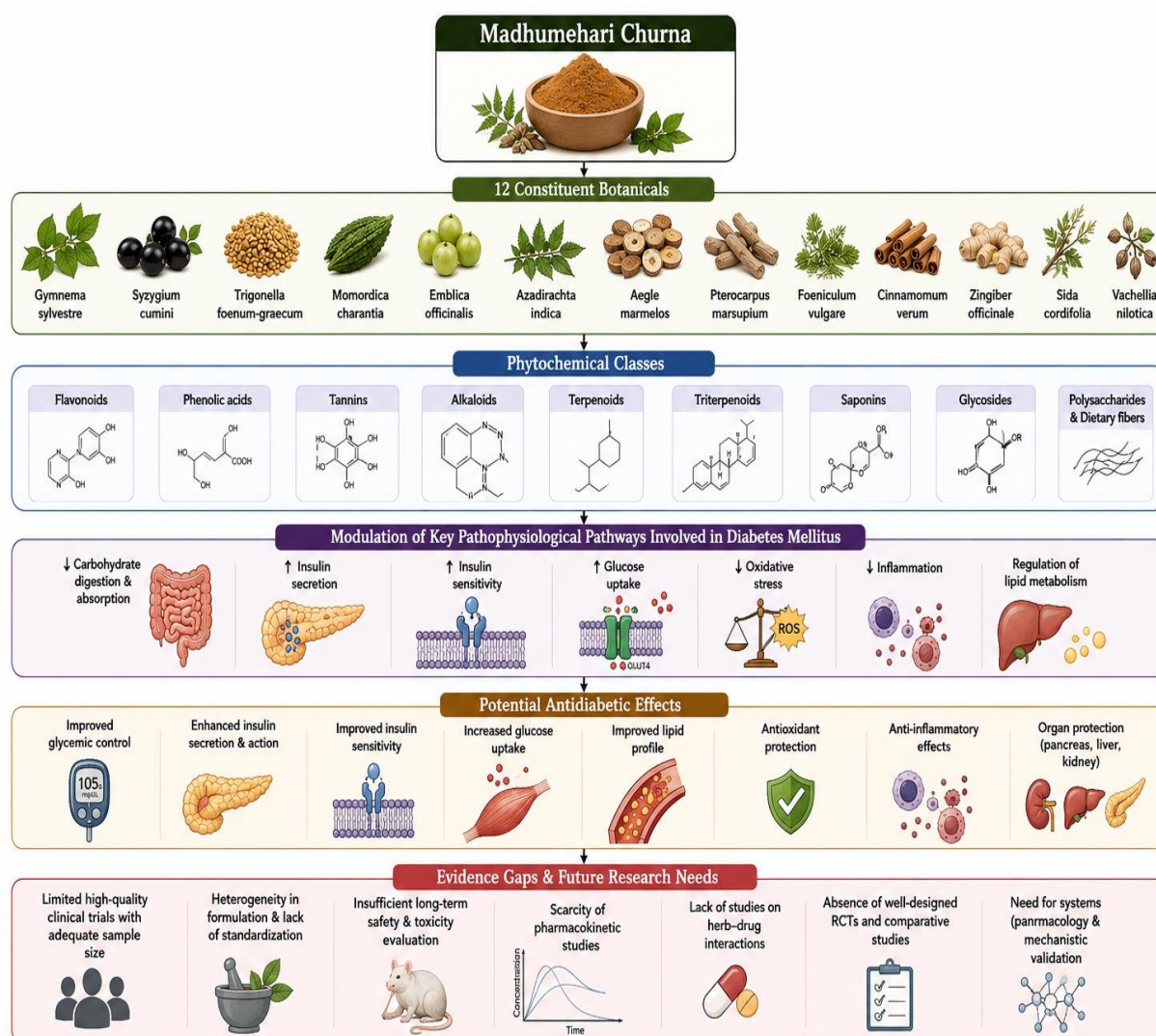


Figure 1: Overview of Madhumehari Churna from constituent botanicals and phytochemicals to pharmacological actions, therapeutic implications and existing evidence gaps.

In "The Ayurvedic Formulary of India," Part-III, published in 2011 by the Ministry of Health and the Department of Ayurveda, Yoga & Naturopathy, Unani, Siddha, and Homeopathy, Madhumehari Churna is a polyherbal formulation listed in group no. 6 (Churna) on page no. 14.^[8] This medication is an anubhoota yoga (clinically experienced) made by the National Institute of Ayurveda, Jaipur's GMP-certified pharmacy. Its twelve herbs include prameha (increased frequency and turbidity of urine), madhumeha (diabetes mellitus), ikshumeh (glycosuria), and laalaameha (albuminuria) in doses of three to six grams with water. It is noteworthy that Madhumehari Churna is widely used to treat diabetes, especially in Rajasthan.^[9]

Each medication stated in the yoga is properly cleaned, dried, powdered, and sieved to produce the powder. This review article explores the thorough scientific analysis of each Madhumehari Churna component, explaining each

one's unique characteristics in great detail. Bhatnagar et al. reported on the 12-herb proprietary formulation of Madhumehari Churna, which contains Jambu, Aamra, Kaaravellaka, Meshasrngi, Methika, Bilva, Nimba, Sunthi, Misreya (Shatapushpa), Swarnapatri (Sonamukhi), Balaa, and Babula (Aryavaidyan, 2024).^[10] This formulation has also been employed in later analytical and clinical studies. Madhumehari Churna's antidiabetic properties are a result of a range of bioactive phytochemicals. The primary groups of phytochemicals include flavonoids, phenolic acids, tannins, alkaloids, terpenoids, triterpenoids, saponins, glycosides, steroids, polysaccharides, and dietary fibers. These compounds have anti-inflammatory, insulin-sensitizing, antihyperglycemic, and antioxidant properties.^[11] The general information of the formulation is given in Table No.1. The properties and actions are mentioned in Table No. 2 and 3 respectively.

Table 1: General information of the ingredients of Madhumehari churna.^[9]

Sl.No.	NAME OF THE HERB	BOTANICAL NAME	FAMILY	PART USED
1	Jambu	<i>Syzygium cumini</i>	Myrtaceae	Beeja (Seed)
2	Aamra	<i>Mangifera indica</i>	Anacardiaceae	Phala-asthi majjaa/ Beeja-majja (seed kernel)
3	Kaaravellaka	<i>Momordica charantia</i>	Cucurbitaceae	Phala (Fruit)
4	Meshasrngi	<i>Gymnema sylvestre</i>	Asclepiadaceae	Patra (Leaf)
5	Methika	<i>Trigonella foenum-graecum</i>	Leguminosae	Beeja (Seed)
6	Bilva	<i>Aegle marmelos</i>	Rutaceae	Patra (Leaf)
7	Nimba	<i>Azadirachta indica</i>	Meliaceae	Beeja (Seed)
8	Sunthi	<i>Zingiber officinale</i>	Zingiberaceae	Kanda (Rhizome)
9	Misreya	<i>Foeniculum vulgare</i>	Apiaceae	Phala (Fruit)
10	Swarnapatri	<i>Senna alexandrina</i> <i>Cassia angustifolia</i>	Leguminaeae	Patra (Leaf)
11	Balaa	<i>Sida cordifolia</i>	Malvaceae	Beeja (Seed)
12	Babula	<i>Vachellia nilotica</i> <i>Acacia arabica</i>	Leguminaeae	Phala (Fruit)

Table 2: Properties of the ingredients in Madhumehari Churna.^[9]

Sl.No.	Drug Name	Rasa	Guna	Veerya	Vipaaka	Effect on Dosha		
						Vata	Pitta	Kapha
1	Jambu	Kashaaya (astringent) Madhura (sweet) Amla(sour)	Laghu (light) Rooksha (dry)	Seeta (cold)	Katu (pungent)	-	↓	↓
2	Aamra	Kashaaya,	Laghu, Rooksha	Seeta	Katu	↓	↓	-
3	Kaaravellaka	Katu, Tikta (bitter)	Laghu	Ushna (hot)	Katu	-	↓	↓
4	Meshasrngi	Kashaaya, Tikta	Laghu, Rooksha;	Ushna	Katu	↓	-	↓
5	Methika	Katu	Snigdha, Laghu	Ushna	Katu	↓	-	↓
6	Bilva	Kashaaya, Tikta	Laghu, Rooksha	Ushna	Katu	↓	-	↓
7	Nimba	Tikta, Kashaaya	Laghu	Seeta	Katu	-	↓	↓
8	Sunthi	Katu	Laghu Snigdha	Ushna	Madhura	↓	-	↓
9	Misreya	Madhura, Katu, Tikta	Laghu Snigdha	Seeta	Madhura	↓	↓	-
10	Swarnapatri	Katu Tikta, Madhura, Kashaaya	Laghu, Rooksha, Teekshna(sharp)	Ushna	Katu	↓	↓	↓
11	Balaa	Madhura	Laghu, Snigdha, Picchila(slimy)	Seeta	Madhura	↓	↓	-
12	Babula	Kashaaya	Guru (heavy) Rooksha	Seeta	Katu	-	↓	↓

Table 3: Actions of the ingredients of Madhumehari Churna.^[9]

SL NO.	DRUGS	THERAPEUTIC ACTIONS
1	Jambu	Pramehaghna (useful in urinary disorders), Krimidoshaghna (useful in worm infestation), Mootra-sangraahi (antidiuretic)
2	Aamra	Pramehaghna, Kaphaghna (pacifies Kapha), Balya (strengthening), Sukhakara (contenting), Hrdya (relishing), Agnivardhaka (improves digestive power)
3	Kaaravellaka	Pramehaghna, Bhedaka (facilitates defecation by breaking feces into pieces), Kaphaghna, Pittaghna (pacifies Pitta), Anulomaka (facilitates the downward movement of vaata dosha and mala), Deepana (improves digestive power)
4	Meshasrngi	Pramehaghna, Deepana, Sramsana (forceful evacuation of the feces), Sleshmaghna, Deepana
5	Methika	Agnideepana, Kaphaghna, Balya, Daaha-prasmana (pacifies hotness), useful in ajeerna (indigestion) and Agnimaandhya (weak digestive capacity)
6	Bilva	Vaata- kaphanasaka (pacifies Vaata and Kapha), Anulomaka, Deepana-Paacana, Balya
7	Nimba	Pramehaghna, Kaphapitta-saamaka, Rocana (appetite enhancer), Daaha-prasmana, Vednaasthaapana (normalises sensation), Kandughna (relieves itching), Cakshushya (beneficial for eyes)
8	Sunthi	Bhedana, Ruci-kaaraka
9	Misreya	Agnimaandya-hara, Vedanaasthaapana
10	Swarnapatri	Kaphavatasaaamaka, Mrdu-recani, Kaayasodhini (removes feces and Dosha from body)
11	Balaa-beeja	Balya, Rasaayana (rejuvenator), Vrshya (aphrodisiac), Brmhana (nourishing), Hrdya
12	Babula	Kaphapitta-hara, vranaropana (healing of wound)

Hypoglycemic Actions of the Ingredients of Madhumehari Churna

1. Jambu-beeja (*S. cumini*)^[12,13,14]



The seeds of jambu contain an alkaloid named jambosine, and glycoside named jambolin, which curb the conversion of starch into sugar. Review studies report that its different parts have anti-inflammatory, antioxidant, anti-microbial, anti-bacterial and antifungal activities. It also has antidiarrheal, gastroprotective and anti-ulcerogenic activities. The antioxidant effect is because of flavonoids in the seeds. The extracts of the seeds, leaves and bark reveal a moderate sugar lowering action. Its powder also decreases symptoms like polyuria, polydipsia and polyphagia.

2. Aamrasthi-majja (*Mangifera indica*)^[15,16]



The seed kernel is a rich source of protein and gallic acid. Barks or leaves extracts of *Mangifera indica* shows hypoglycemic effect in an experimental study. It inhibits glucose absorption in the gut. An experimental study in diabetic rats indicates that it exerts a potent hypoglycemic activity by suppressing oxidative and inflammatory processes and thus checking apoptosis of pancreatic β cell, enhancing their function and improving metabolism of hepatic glucose.

3. Kaaravellaka (*Momordica charantia*)^[17-20]



Momordica Charantia is a well-known dietary substance and traditional medicine as well used in the treatment of diabetes. It has bioactive compounds which lower high blood sugar levels, improve secretion of insulin and amplify function of β -cell. Its use has markedly improved glucose tolerance and insulin sensitivity in some experimental studies in rats.

4. Meshasrngi (*Gymnema sylvestre*)^[21,22]



It constitutes phytochemicals like glycosides, saponins, flavonol, gymnemanol and gurmardin. Various activities like hypoglycemic, anti-inflammatory, anti-oxidative and lipid-lowering have been reported. It is also useful in treatment of drug-induced liver injury. It pacifies kapha and is very useful in prameha. The powder of its leaves is used as medicine or as dietary ingredient in diabetes insipidus also. The extract of its leaves has been reported to interfere with the perception of sweet taste by blocking taste buds on the tongue. It may limit the intake of sweet foods by making it less appealing and thus helping in controlling diet and hence diabetes. It also helps in insulin secretion and cholesterol reduction.

5. Methika (*Trigonella foenum-graecum*)^[23]



The hypoglycaemic mechanism of fenugreek seed includes slow absorption of carbohydrates from the intestines, reduction in glucose transport and modulation in peripheral glucose utilization. Result of a clinical study shows that the fenugreek seed has an influence on lipid metabolism.

6. Bilva-patra (*Aegle marmelos*)^[24]



The extract of *Aegle marmelos* has antioxidant activities. Leaf and callus extracts produced significant decreases in blood sugar level in a study on streptozotocin induced diabetic rats and reduced hyperglycemia by attenuating

oxidative stress and improving endogenous antioxidant defense.

7. Nimba (*Azadirachta indica*)^[25,26]



The aqueous extract of leaves of *Azadirachta indica* has shown significant hypoglycemic effect in Type 1 and type 2 diabetes mellitus. It also enhanced glucose tolerance. Neem leaf extract promotes wound healing in diabetic foot. Alcoholic extract has also shown hypoglycemic activity in *Wistar* albino rats.

8. Sunthi (*Zingiber officinale*)^[27]



Ethanol extract of *Z. officinale* reduced body weights, levels of glucose and total cholesterol and revealed protective effect in the development of metabolic syndrome in rats fed with high fat diet. It also has insulinotropic property and glucose-lowering potential. Misreya.

9. Saunf/Fennel (*Foeniculum vulgare*)^[28,29]



Its extract has shown hypoglycemic and antioxidant activity in streptozotocin induced diabetes in experimental animals and restoration of cardiovascular, renal and hepatic complications of diabetes. Essential oil of *Foeniculum vulgare* in diabetic rats showed hypoglycemic action and effect on other abnormalities brought about through its anti-oxidative effect.

10. Swarnapatri / Senna (*Cassia angustifolia* Vahl)^[30,31]



Senna leaves work in multiple ways in long-term management of diabetes by correcting skin pathology, liver disorders and neurological complications. A study suggests that senna and pomegranate leaves extracts are helpful in the treatment of obesity and type-2 Diabetes mellitus. Leaf extract of *C. angustifolia* was found effective in ameliorating metabolic abnormalities associated with diabetes and retardation of risk of complications due to chronic hyperglycemia.

11. Balaa-beeja (*Sida cordifolia*)^[32-34]



It possesses anti-inflammatory, hypoglycemic and hepatoprotective activity as well. It also has analgesic action. The phytochemical analysis of the extracts of *Sida cordifolia* reports the presence of different phytochemical components like sterols, terpenoids, alkaloids and flavonoids. The ethanolic and aqueous extracts showed dose dependent anti-diabetic activity when compared to standard drug Glibenclamide. The extracts significantly controlled the blood glucose level, body weight loss and alteration in different lipid metabolic enzymes. All parts of *Sidacordifolia* have shown hypoglycemic activity.

12. Babula-phala (*Acacia arabica* Wild)^[35,36]



Extracts of *Acacia arabica* in STZ-induced diabetes rats shows improved glucose and lipid metabolism and oxidative stress by increasing insulin levels. In alloxan induced diabetic rats methanolic and aqueous extracts of *Acacia arabica* exhibited significant antidiabetic actions.

Table No. 4: Pharmacological activity of Madhumehari Churna, with emphasis on the principal constituent herbs, bioactive phytoconstituents, molecular processes, and evidence for their role in the treatment of diabetes mellitus and its complications.^[37-40]

Pharmacological activity	Major ingredients of Madhumehari Churna	Major phytoconstituents	Mechanisms	Evidences
Antidiabetic	<i>Gymnema sylvestre</i> , <i>Syzygium cumini</i> , <i>Momordica charantia</i> , <i>Trigonella foenum-graecum</i>	Gymnemic acids, jamboline, ellagic acid, charantin, polypeptide-P, 4-hydroxyisoleucine, diosgenin	α -Amylase and α -glucosidase inhibition, AMPK activation, GLUT4 translocation, enhanced insulin secretion, reduced intestinal glucose absorption	<i>In vitro</i> enzyme inhibition, STZ/HFD diabetic animal models, clinical studies on constituent herbs
Antioxidant	<i>Azadirachta indica</i> , <i>Aegle marmelos</i> , <i>Zingiber officinale</i> , <i>Syzygium cumini</i>	Quercetin, rutin, gallic acid, ellagic acid, gingerols, shogaols	Nrf2 activation, ROS scavenging, increased SOD, CAT, GPx and GSH, reduced lipid peroxidation	DPPH, ABTS, FRAP assays and diabetic animal models
Anti-inflammatory	<i>Azadirachta indica</i> , <i>Momordica charantia</i> , <i>Zingiber officinale</i> , <i>Gymnema sylvestre</i>	Nimbolide, quercetin, charantin, gingerols, gymnemic acids	NF- κ B inhibition, COX-2 suppression, reduced TNF- α , IL-6 and IL-1 β , inhibition of MAPK signaling	Cell culture and animal inflammation models
Hypolipidemic	<i>Trigonella foenum-graecum</i> , <i>Momordica charantia</i> , <i>Gymnema sylvestre</i>	Diosgenin, steroidal saponins, charantin, gymnemic acids	PPAR- α activation, reduced HMG-CoA reductase activity,	High-fat diet animal studies and metabolic syndrome models

			decreased lipogenesis, enhanced fatty acid oxidation	
Insulin-sensitizing	<i>Gymnema sylvestre</i> , <i>Trigonella foenum-graecum</i> , <i>Momordica charantia</i>	Gymnemic acids, 4-hydroxyisoleucine, diosgenin, charantin	PI3K/Akt activation, IRS-1 phosphorylation, GLUT4 translocation, improved adiponectin signaling	Insulin-resistant cell lines and diabetic animal models
β-cell protective	<i>Gymnema sylvestre</i> , <i>Syzygium cumini</i> , <i>Momordica charantia</i>	Gymnemic acids, ellagic acid, charantin, flavonoids	Reduced oxidative stress, anti-apoptotic activity, enhanced β-cell regeneration and insulin secretion	STZ-induced diabetic models and pancreatic histopathology studies
Hepatoprotective	<i>Aegle marmelos</i> , <i>Azadirachta indica</i> , <i>Zingiber officinale</i> , <i>Momordica charantia</i>	Marmelosin, aegeline, nimbolide, gingerols, flavonoids	Reduced oxidative stress and inflammation, improved hepatic antioxidant defense, inhibition of steatosis	Hepatotoxicity and NAFLD animal models
Nephroprotective	<i>Syzygium cumini</i> , <i>Azadirachta indica</i> , <i>Gymnema sylvestre</i>	Ellagic acid, quercetin, limonoids, gymnemic acids	Reduced oxidative stress, inhibition of renal fibrosis, decreased AGE formation, anti-inflammatory activity	Diabetic nephropathy models and renal function studies

Mechanism of action

Madhumehari Churna is an ayurvedic polyherbal formulation used in the treatment of Madhumeha (Type 2 Diabetes Mellitus). Madhumehari Churna exhibit the anti-diabetic effect through synergistic effects of the herbs through various molecular pathways rather than a single target.^[41] The phytoconstituents present in Madhumehari Churna, which include flavonoids, phenolic acids, tannins, alkaloids, terpenoids, triterpenoids, saponins, glycosides, phytosterols, polysaccharides, and dietary fibers, are responsible for its antidiabetic efficacy.^[42] It reduces postprandial glucose absorption by inhibiting intestinal α -amylase and α -glucosidase, suppresses hepatic gluconeogenesis through AMPK activation, increases insulin sensitivity by boosting PI3K/Akt-mediated GLUT-4 translocation, and stimulates pancreatic β -cell function and insulin secretion. Its polyphenols and flavonoids also have strong anti-inflammatory and antioxidant qualities that reduce oxidative stress, block NF- κ B-mediated inflammatory pathways, enhance lipid metabolism, and shield pancreatic β -cells from damage caused by hyperglycemia. Its herbal components work in concert to improve glucose management and maybe slow the development of diabetes complications.^[43]

Case reports, case-series reports and clinical trials on Madhumehari Churna

The effect of Madhumehari Churna as a single drug or as a part of therapy in the dose of 5g with Luke warm water before meal has shown hypoglycemic action and relief in symptoms of madhumeha in single case reports, as well as case-series reports. Successful treatment of diabetic

foot ulcer with osteomyelitis was done. Some clinical studies have also shown good effect in the management of madhumeha.^[44,45]

Acute Toxicity of Madhumehari Churna

The entire Madhumehari Churna formulation has not been the subject of any documented acute oral toxicity investigations. However, in OECD-guideline acute toxicity studies, a number of its constituent herbs, such as *Gymnema sylvestre*, *Momordica charantia*, *Syzygium cumini*, *Trigonella foenum-graecum*, *Azadirachta indica*, and *Aegle marmelos*, have shown a broad margin of safety with no significant mortality or severe behavioral abnormalities at experimentally tested doses. Although formulation-specific toxicity studies are still required, these results imply that the formulation is unlikely to cause acute toxicity when given at therapeutic levels.^[46,47]

Adverse Effects of Madhumehari Churna

In general, Madhumehari Churna is well tolerated. Its constituent herbs are mostly responsible for reported or theoretically anticipated negative effects, which include:

- Mild gastrointestinal distress (constipation, diarrhea, nausea, or fullness in the abdomen)
- Flatulence, especially when *Trigonella foenum-graecum* is present
- Reduced appetite or bitter taste
- Allergic responses in vulnerable people
- Hypoglycemia, particularly in conjunction with long-term fasting or antidiabetic medications

Although severe adverse responses to the formulation itself have not been routinely observed, patients with numerous comorbidities and the elderly should be closely monitored.^[48]

Limitations of Current Research^[49,50,51]

Despite growing scientific interest in polyherbal formulations for diabetes mellitus, data for Madhumehari Churna is unexplored. The majority of existing research focus on the pharmacological properties of the individual constituent herbs rather than the entire formulation, making it difficult to determine formulation-specific efficacy and processes.

1. **Limited experimental research specific to formulations:** Madhumehari Churna has only been the subject of a small number of investigations. Research on certain herbs, such as *Gymnema sylvestre*, *Momordica charantia*, *Syzygium cumini*, and *Trigonella foenum-graecum*, provides the majority of the evidence. As a result, nothing is known about the synergistic interactions between the substances.
2. **Lack of high-quality clinical trials:** There are few well-designed randomized, double-blind, placebo-controlled clinical trials assessing Madhumehari Churna, despite the fact that polyherbal formulations have demonstrated encouraging antihyperglycemic effects in a number of clinical investigations. Small sample sizes, brief treatment durations, poor randomization, and insufficient long-term follow-up are common features of current research.
3. **Insufficient mechanistic evidence:** Without fully clarifying the underlying molecular pathways, the majority of studies find improvements in lipid profiles and decreases in blood glucose. There are still not enough thorough research looking at pathways including AMPK, PI3K/Akt, GLUT4, PPAR γ , NF- κ B, Nrf2, and gut microbiome regulation.
4. Lack of marker-based standardization
5. Limited pharmacokinetic information
6. Limited herb–drug interaction data
7. Inadequate toxicological characterization

Future perspectives

To determine effectiveness of Madhumehari Churna and long-term safety, future studies should concentrate on carrying out carefully planned multi-center randomized clinical trials. To guarantee batch-to-batch uniformity, the formulation must be standardized using sophisticated phytochemical profiling and quality control. The multi-target activities and synergistic interactions of Madhumehari Churna should be clarified by more mechanistic research using molecular biology, network pharmacology, metabolomics, and artificial intelligence. To enable its incorporation into evidence-based diabetes management, thorough pharmacokinetic, toxicological, and herb-drug interaction studies are also required, as are studies on its effects on diabetic complications like

nephropathy, neuropathy, retinopathy, and cardiovascular diseases.^[52]

- **Formulation standardization:** Establish consistent standards for raw-material authentication, botanical identity, plant-part selection, processing methods, phytochemical markers, and batch-to-batch quality to ensure reproducibility and therapeutic consistency.
- **Whole-formulation pharmacology:** Investigate the pharmacological activity of the complete Madhumehari Churna using validated *in vitro* and *in vivo* models rather than extrapolating its effects solely from studies of individual ingredients.
- **Mechanistic validation:** Experimentally validate the proposed molecular pathways involved in glucose regulation, insulin sensitivity, oxidative stress, inflammation, and lipid metabolism using appropriate biochemical, molecular and cellular approaches.
- **Toxicological evaluation:** Conduct systematic acute and repeated-dose toxicity studies, together with appropriate long-term safety assessments, to establish the safety profile of the complete formulation.
- **Pharmacokinetic characterization:** Investigate the absorption, distribution, metabolism and elimination of major bioactive constituents and determine whether interactions among formulation components influence their systemic exposure and biological activity.
- **Herb–drug interactions:** Evaluate potential pharmacodynamic and pharmacokinetic interactions between Madhumehari Churna and commonly prescribed antidiabetic medicines, particularly where combined use may enhance glucose-lowering effects or alter drug disposition.

Collectively, these investigations will help bridge the gap between traditional use and evidence-based application of Madhumehari Churna and provide a stronger scientific foundation for assessing its reproducibility, safety and potential clinical relevance in diabetes mellitus.

CONCLUSION

Diabetes mellitus is a complicated metabolic disease that calls for treatment approaches that can simultaneously target several pathological pathways. The complimentary pharmacological qualities of the medicinal herbs that make up Madhumehari Churna, a traditional Ayurvedic polyherbal preparation, make it a promising multi-target intervention in this regard. As per the data collected of each herb it can be concluded that the formulation inhibits starch to-glucose conversion, improves glucose tolerance, enhances lipid metabolism, impacts insulin metabolism and scavenges free radicals. In essence, the formulation is hypoglycemic, antioxidant and lipid-modulating, presenting a multifactored approach to the management of diabetes mellitus. According to the evidence that is currently available, its bioactive

phytoconstituents—which include flavonoids, phenolic acids, alkaloids, saponins, terpenoids, tannins, and glycosides—exert antihyperglycemic effects through a variety of mechanisms, including inhibition of α -amylase and α -glucosidase, enhancement of insulin secretion and sensitivity, activation of AMPK and PI3K/Akt signaling, promotion of GLUT4 translocation, reduction of oxidative stress and inflammation, and protection against diabetic complications that affect the liver, kidneys, and pancreas. Madhumehari Churna is one of such formulations which show promising results in the management of diabetes and related health issue. Overall, Madhumehari Churna shows significant therapeutic potential as a multi-component, safe phytomedicine for diabetes mellitus; however, more interdisciplinary research is needed to confirm its clinical effectiveness, standardize its quality, and completely understand its molecular mechanisms of action.

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