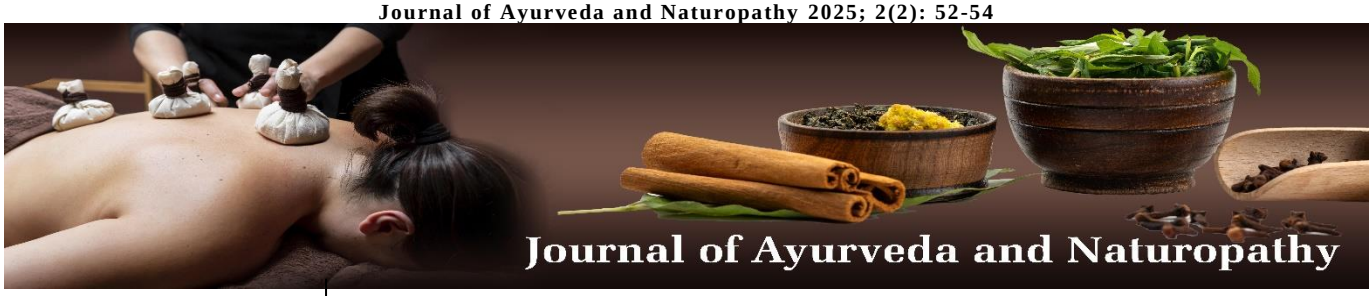

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Role of *Momordica charantia* L. in traditional ayurvedic formulations for metabolic disorders

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Abstract
Metabolic disorders, particularly diabetes mellitus, dyslipidaemia, and obesity, have become major public health challenges in both developed and developing countries. In India, where traditional systems of medicine continue to play a significant role, *Momordica charantia* L. (commonly known as bitter gourd or karela) is widely recognized as a medicinal plant of choice in the management of metabolic conditions. In Ayurveda, the fruit is described as Karavellaka and recommended for conditions related to *Prameha* and *Medoroga*, which broadly correspond to diabetes and obesity in modern terminology. Its qualities such as *tikta* (bitter) taste, *laghu* (light) and *ruksha* (dry) properties, and *ushna virya* (hot potency) explain its therapeutic actions within the Ayurvedic framework. At the same time, phytochemical research has identified compounds such as charantin, polypeptide-p, and momordicosides that exert hypoglycaemic, hypolipidaemic, and antioxidant actions. This paper explores the traditional use, phytochemical composition, modern biomedical evidence, and clinical applications of *M. charantia* in managing metabolic disorders, emphasizing its integration into traditional Ayurvedic formulations. By bridging classical Ayurvedic insights with contemporary findings, the paper highlights the potential of bitter gourd as a culturally appropriate, scientifically relevant, and therapeutically valuable plant in metabolic health management.

Keywords: *Momordica charantia*, Ayurveda, metabolic disorders, diabetes mellitus

Introduction
Metabolic disorders are among the most pressing health issues of the twenty-first century. Diabetes mellitus, metabolic syndrome, and obesity are rising at alarming rates, leading to cardiovascular complications, kidney disease, and reduced quality of life. In India alone, estimates suggest that over seventy million individuals live with diabetes, with projections continuing to rise. Lifestyle factors such as sedentary behaviour, poor dietary practices, and chronic stress play an important role, but genetic predisposition and urbanization also contribute significantly.

Ayurveda, the classical medical tradition of India, recognized disorders similar to diabetes under the term *Prameha*. Ancient physicians described excessive urination, debility, and deranged metabolism as key symptoms of this condition, which often overlapped with obesity and lipid disorders classified as *Medoroga*. In this context, herbal remedies, dietary corrections, and lifestyle adjustments were emphasized as the first line of intervention. Among the numerous plants recommended for *Prameha*, *Momordica charantia* occupies a special place due to its bitter taste and ability to regulate digestion, metabolism, and glucose homeostasis.

Bitter gourd has long been consumed as both food and medicine. Villagers in many parts of India still drink fresh bitter gourd juice at dawn as a preventive measure against diabetes. While this may seem like a folk tradition, scientific investigations have increasingly supported its role in improving glycaemic control. This convergence of tradition and modern science offers a valuable opportunity to re-examine the role of *M. charantia* within Ayurvedic formulations for metabolic disorders.

Ayurvedic Understanding of Karavellaka
In Ayurvedic texts, *Momordica charantia* is referred to as Karavellaka. Its *rasa* (taste) is described as predominantly bitter (*tikta*) with a pungent undertone (*katu*). Its *guna* (qualities)

are *laghu* (light) and *ruksha* (dry), which make it suitable for conditions where heaviness, excess moisture, and sluggish metabolism prevail. Its *virya* (potency) is classified as hot (*ushna*), and its *vipaka* (post-digestive effect) is pungent. These attributes together indicate that Karavellaka pacifies *kapha* and *pitta* doshas while stimulating the digestive and metabolic fire (*agni*).

In disorders like *Prameha*, which Ayurveda attributes to excessive *kapha* and impaired *agni*, bitter gourd works by clearing blockages in the micro-channels (*srotas*), reducing accumulated fat and phlegm, and enhancing metabolic transformations. Classical texts highlight its usefulness not only in *Prameha* but also in skin disorders, intestinal worms, and sluggish digestion, which are often seen as associated conditions in individuals with metabolic imbalance.

Importantly, Ayurveda does not recommend single-drug therapy in most cases. Herbs are usually combined in formulations that balance each other's properties. For instance, bitter gourd may be combined with *Gudmar* (Gymnema sylvestre), *Haridra* (turmeric), and *Methika* (fenugreek) to create a synergistic effect against hyperglycaemia and obesity. In this way, Karavellaka functions as both a standalone agent and as part of complex formulations tailored to the patient's constitution and disease state.

Phytochemistry of *M. charantia*

Modern phytochemical investigations have revealed a wide range of bioactive compounds in bitter gourd. Cucurbitane-type triterpenoids such as charantin, momordicosides, and karavilagenin derivatives are considered central to its hypoglycaemic activity. Charantin, in particular, has been used as a marker for standardization in pharmacological research.

Another compound of interest is polypeptide-p, often referred to as "plant insulin." It is a protein fraction that demonstrates insulin-mimetic activity, although its oral bioavailability remains under debate. Additional components include saponins, alkaloids, phenolic acids, and flavonoids. Together, these compounds exert antioxidant, anti-inflammatory, hypolipidaemic, and anti-obesity effects.

The seeds of bitter gourd contain vicine, which has been linked to haemolytic reactions in individuals with G6PD deficiency, underscoring the importance of safe preparation and patient screening. Nonetheless, the diversity of compounds within bitter gourd reflects a multi-targeted mode of action that aligns well with the complex nature of metabolic disorders.

Mechanisms of Action in Metabolic Disorders

The therapeutic benefits of *M. charantia* can be explained through several complementary mechanisms. Firstly, its bitter principles delay glucose absorption by inhibiting intestinal enzymes such as α-glucosidase and α-amylase, thereby moderating post-prandial glucose spikes. Secondly, bitter gourd enhances peripheral glucose utilization by increasing the translocation of glucose transporter proteins, particularly GLUT4, in skeletal muscle and adipose tissues. Thirdly, it stimulates AMPK (adenosine monophosphate-activated protein kinase) activity, a central regulator of energy metabolism that promotes fatty acid oxidation and suppresses hepatic gluconeogenesis.

Beyond glycaemic regulation, bitter gourd exerts lipid-lowering effects. Studies suggest that it reduces serum triglycerides and VLDL while improving HDL levels, possibly by down-regulating SREBP-1c, a transcription factor that governs lipid synthesis. Its antioxidant and anti-inflammatory properties further protect against the oxidative stress and chronic inflammation that underlie metabolic syndrome.

Interestingly, the bitter taste itself has physiological effects. Recent research has shown that bitter taste receptors in the gut influence hormone secretion, including GLP-1, which enhances insulin secretion and satiety. This validates the Ayurvedic emphasis on *tikta rasa* in managing kapha-related disorders.

Traditional Formulations and Preparations

In Ayurvedic practice, *M. charantia* is employed in several forms. Fresh juice (*swarasa*) is perhaps the most popular, consumed in doses of 10-30 mL on an empty stomach. Powders (*churna*) made from dried fruit pulp are also common, administered with warm water or buttermilk. Decoctions (*kvatha*) are used for patients with sluggish digestion, while electuaries (*avaleha*) are prepared for those who cannot tolerate bitterness directly.

Formulations often combine Karavellaka with other herbs. For instance, pairing with *Gudmar* enhances its anti-diabetic potency, while turmeric provides anti-inflammatory support. The seeds of *Jambu* (Syzygium cumini) and fenugreek are frequently included in compound powders for glycaemic control. Such combinations reflect Ayurvedic logic, where herbs are blended to balance tastes, energies, and organ affinities.

Dietary use of bitter gourd as a vegetable is equally important. Recipes such as stir-fried karela with fenugreek and cumin illustrate how culinary traditions preserved its therapeutic use in daily life, blurring the boundary between food and medicine.

Clinical Evidence and Trials

While traditional knowledge is compelling, the relevance of *M. charantia* in modern times depends on scientific validation. Numerous preclinical studies in animal models have shown its ability to reduce blood glucose and lipids. Clinical trials, though fewer and often small in sample size, provide supportive evidence.

Several randomized controlled trials have reported significant reductions in fasting plasma glucose and post-prandial glucose levels in patients receiving bitter gourd extracts. HbA1c reduction has also been observed, although the magnitude is usually modest compared to standard antidiabetic drugs. Lipid profiles tend to improve, particularly in terms of triglyceride reduction.

Importantly, outcomes vary depending on preparation method, plant part used, and dose. Fresh juice, dried powder, and standardized extracts may not be directly comparable. Some studies fail to show significant results, highlighting the need for improved standardization and larger clinical trials. Nevertheless, the overall body of evidence supports the traditional claim that bitter gourd contributes to metabolic health, particularly as an adjunct to lifestyle measures and standard therapies.

Safety and Contraindications

Bitter gourd is generally safe when consumed as food or in moderate medicinal doses. However, caution is warranted in

certain populations. Individuals taking insulin or hypoglycaemic drugs should monitor blood glucose closely to avoid additive effects. Pregnant and lactating women are advised against medicinal doses due to limited safety data.

The seeds may pose risks in patients with G6PD deficiency, as they contain vicine, which can trigger haemolytic anaemia. Gastrointestinal discomfort such as nausea or abdominal pain may occur in sensitive individuals. To minimize adverse effects, practitioners often recommend starting with small doses and adjusting according to tolerance and glycaemic response.

Integration into Ayurvedic and Naturopathic Care

For effective management of metabolic disorders, Ayurveda emphasizes a holistic plan involving diet (*ahara*), lifestyle (*vihara*), and herbal formulations (*aushadha*). Bitter gourd aligns perfectly with this approach. Consuming its juice in the morning, including it in meals several times a week, and supplementing with powders or decoctions in structured doses ensures consistent therapeutic exposure.

Lifestyle guidance includes regular physical activity, yogic postures such as Surya Namaskar and Pawanmuktasana, and breathing practices like Anulom-Vilom to regulate stress and metabolism. When combined with such practices, bitter gourd serves not as an isolated cure but as part of a synergistic strategy that addresses the root causes of metabolic imbalance.

Naturopathic principles also emphasize plant-based diets, mindful eating, and moderate fasting, all of which resonate with Ayurvedic guidelines. Thus, *M. charantia* functions as a bridge between traditional Indian medicine and global naturopathic practice.

Limitations and Research Gaps

Despite promising findings, several challenges remain. The variability in phytochemical content between cultivars and preparation methods complicates dosage recommendations. Many clinical trials are limited by small sample sizes, short durations, and lack of blinding. More robust studies are needed to confirm long-term benefits and safety, especially when used alongside modern drugs.

Standardization of extracts using reliable markers like charantin, development of novel delivery systems to enhance bioavailability, and exploration of synergistic formulations represent important research directions. Integrating patient-centred outcomes such as quality of life, fatigue reduction, and weight maintenance would also strengthen the clinical case for bitter gourd.

Conclusion

Momordica charantia L., celebrated in Ayurveda as Karavellaka, embodies the meeting point of tradition and modern science in the management of metabolic disorders. Its classical attributes—bitter taste, lightness, dryness, and hot potency—explain its ability to pacify kapha and correct metabolic sluggishness. Phytochemistry reveals compounds that act on multiple pathways, from enzyme inhibition to insulin sensitization and lipid regulation. Clinical studies, while modest in scale, substantiate its role as an adjunct in diabetes and metabolic syndrome management.

The greatest value of bitter gourd lies in its integration into a comprehensive Ayurvedic plan that includes dietary reform, lifestyle modification, and synergistic herbal combinations. By respecting both traditional insights and modern scientific rigor, *M. charantia* can continue to play an important role in addressing the global epidemic of metabolic disorders.

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