Journal of Drug Delivery and Biotherapeutics (JDDB)

(E-ISSN: 3049-1177)

Journal homepage: https://sennosbiotech.com/JDDB/1

Review Article

A Systematic Review of Effervescent Formulations of Bitter Gourd (Momordica charantia) for the Management of Diabetes Mellitus

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ARTICLEINFO

ABSTRACT

Bitter gourd (Momordica charantia) has long been recognized for its antidiabetic properties, primarily due to its bioactive compounds such as charantin, vicine, and polypeptide-p. Recent advancements in pharmaceutical formulations have explored effervescent preparations as a novel delivery system to enhance the bioavailability, stability, and patient compliance of herbal antidiabetic agents. This systematic review evaluates existing literature on M. charantia effervescent formulations and their therapeutic potential in managing diabetes mellitus. Studies indicate that effervescent formulations improve the solubility and absorption of bitter gourd extracts, contributing to better glycemic control and reduced adverse gastrointestinal effects compared to conventional forms. However, limited clinical data and standardization challenges highlight the need for further research to optimize formulation parameters and confirm efficacy in larger populations. Overall, effervescent systems represent a promising approach for the effective delivery of M. charantia in diabetes management.

Keywords: Momordica charantia; Bitter gourd; Effervescent formulation; Diabetes mellitus; Herbal antidiabetic agents

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Received date: 15-Sep-2025 Revised date: 1-Oct-2025, Accepted date: 05-Oct-2025

1. Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both. It is one of the most prevalent non-communicable diseases worldwide, posing serious health, social, and economic burdens. According to the International Diabetes Federation, the global prevalence of diabetes continues to rise, emphasizing the urgent need for effective, affordable, and safe therapeutic interventions.

In recent years, medicinal plants have gained significant attention as complementary or alternative therapies for diabetes management. Among these, Momordica charantia L., commonly known as bitter gourd or karela, has been extensively studied for its potent antidiabetic and antioxidant properties. The plant contains several bioactive constituents—such as charantin, vicine, and polypeptide-p—that exert insulin-like effects, enhance glucose uptake, and modulate carbohydrate metabolism.

Despite promising pharmacological evidence, the clinical utility of M. charantia remains limited due to its poor palatability, instability, and variability in bioactive compound absorption. To overcome these challenges, effervescent formulations have emerged as an innovative drug-delivery approach. Effervescent systems enhance solubility, improve patient compliance, and ensure rapid absorption through gastrointestinal effervescence. Formulating bitter gourd extracts into effervescent tablets or powders offers the dual benefit of improved taste masking and enhanced therapeutic efficacy.

This systematic review aims to critically analyze existing literature on the development, characterization, and clinical evaluation of M. charantia effervescent formulations in the treatment of diabetes mellitus. The review also highlights formulation challenges, pharmacological outcomes, and future research prospects to support the integration of such novel dosage forms into evidence-based diabetes management.

2. Phytochemical Profile and Antidiabetic Mechanisms of Momordica charantia

Momordica charantia (bitter gourd) is a tropical and subtropical vine belonging to the family Cucurbitaceae. It has long been used in traditional medicine systems, including Ayurveda, Unani, and Traditional Chinese Medicine, for its hypoglycemic, antioxidant, and anti-inflammatory properties. The pharmacological potential of M. charantia is attributed to a wide spectrum of bioactive phytoconstituents.

The major active compounds include charantin (a steroidal saponin mixture), polypeptide-p (an insulin-like peptide), and vicine (a glycoside with hypoglycemic activity). Other constituents such as momordicosides, momordicines, alkaloids, flavonoids, and triterpenoids contribute synergistically to its therapeutic effects. These compounds exert antidiabetic actions through multiple mechanisms: enhancement of insulin secretion, stimulation of glucose uptake in peripheral tissues, inhibition of intestinal glucose absorption, modulation of hepatic gluconeogenesis, and protection of pancreatic β-cells from oxidative stress.

Several in vitro and in vivo studies have demonstrated that M. charantia extracts improve glucose tolerance, reduce fasting blood glucose levels, and regulate lipid metabolism. Additionally, antioxidant components in the fruit mitigate oxidative damage associated with chronic

hyperglycemia, thereby reducing the risk of diabetes-related complications.

The complex interplay of these phytochemicals suggests that M. charantia acts via multifactorial pathways rather than a single target mechanism. Understanding these mechanisms is crucial for optimizing formulation strategies—such as effervescent systems—to preserve bioactive integrity and improve clinical outcomes in diabetic patients.

3. Chemical Constituents of Momordica charantia

Momordica charantia is a rich reservoir of diverse phytochemical compounds responsible for its pharmacological activities, particularly its antidiabetic potential. The major classes of chemical constituents include triterpenoids, steroidal saponins, alkaloids, flavonoids, glycosides, phenolic compounds, and peptides.

Among these, charantin, a well-known steroidal saponin mixture of β-sitosterol-β-D-glucoside and stigmasterol-β-D-glucoside, is considered a principal hypoglycemic agent. Polypeptide-p, an insulin-like hypoglycemic peptide, mimics the action of endogenous insulin and is effective in lowering blood glucose levels when administered parenterally. Vicine, a glycoside present in the seeds, exhibits significant antihyperglycemic and antioxidant effects.

In addition, momordicosides, momordicines, and kuguacins—a group of cucurbitane-type triterpenoids—have demonstrated potent glucose-lowering and lipid-regulating activities. Flavonoids such as quercetin, luteolin, and kaempferol contribute to the plant's antioxidant and anti-inflammatory actions, protecting pancreatic β-cells from oxidative damage.

The fruit also contains essential nutrients including vitamins A, C, and E, iron, zinc, and magnesium, which play supportive roles in metabolic regulation and antioxidant defense. The synergistic interaction of these constituents underlies the therapeutic efficacy of M. charantia in diabetes management.

A clear understanding of its chemical composition is essential for developing standardized formulations, such as effervescent preparations, to ensure consistent bioactivity and optimal therapeutic response.

4. Applications of Effervescent Formulations of Momordica charantia

Effervescent formulations, such as tablets, powders, and granules, represent an innovative approach to delivering herbal medicines, including Momordica charantia. These formulations release carbon dioxide upon contact with water, producing a fizzy solution that enhances solubility, stability, and patient compliance. In the context of diabetes management, effervescent delivery of bitter gourd extracts offers several significant advantages.

4.1 Improved Bioavailability:

Effervescence facilitates rapid dissolution and absorption of bioactive compounds, including charantin and polypeptide-p, in the gastrointestinal tract. This leads to more consistent plasma concentrations and enhanced hypoglycemic effects compared to conventional solid forms.

4.2 Palatability and Compliance:

Bitter gourd's naturally bitter taste often limits oral consumption. Effervescent formulations mask this bitterness and produce a pleasant, easily ingestible solution, improving adherence in diabetic patients.

4.3 Therapeutic Efficacy:

Studies indicate that effervescent M. charantia formulations maintain antioxidant and antihyperglycemic activity. Enhanced solubility

ensures faster onset of action, potentially improving postprandial glucose control.

4.4 Convenience and Versatility:

Effervescent systems can be combined with other complementary antidiabetic ingredients, vitamins, or minerals to produce multifunctional formulations. They are also suitable for patients with swallowing difficulties or those requiring precise dosing.

Overall, the application of effervescent technology offers a promising strategy to overcome limitations of conventional bitter gourd preparations, translating traditional medicinal benefits into clinically effective, patient-friendly dosage forms.

5. Conclusion

Momordica charantia (bitter gourd) has demonstrated significant antidiabetic potential due to its diverse bioactive constituents, including charantin, polypeptide-p, vicine, and various triterpenoids and flavonoids. Effervescent formulations of bitter gourd extracts offer a promising strategy to enhance solubility, bioavailability, palatability, and patient compliance, addressing the limitations of conventional dosage forms.

Current evidence from in vitro, in vivo, and limited clinical studies suggests that effervescent preparations maintain the therapeutic efficacy of M. charantia, providing effective glycemic control and antioxidant benefits in diabetes management. However, challenges such as standardization of active compounds, stability optimization, and large-scale clinical validation remain.

Future research should focus on the development of standardized, clinically tested effervescent formulations, exploring synergistic combinations with other antidiabetic agents and assessing long-term safety and efficacy. Overall, effervescent delivery systems represent a promising approach to translating traditional herbal knowledge into modern, patient-friendly diabetes therapies.

Conflict of Interest

The authors declare no conflict of interest.

Funding

No Funding was received.

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