Current Clinical and Medical Education

Received 15 Aug 2025 | Revised 16 Aug 2025 | Accepted 10 Oct 2025 | Published Online 15 Oct 2025

Published By: Vision Publisher

CCME 03 (10), 1-4

ISSN 2942-0792

Concentration-Dependent α-Amylase Inhibition by Fresh Juices of Momordica muricata and Phyllanthus emblica: A Phytotherapeutic Strategy for Type 2 Diabetes Management

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Abstract: Diabetes mellitus continues to pose a serious public health challenge worldwide, with type 2 diabetes mellitus (T2DM) being the predominant form of the disease. Postprandial hyperglycemia is central to the onset of diabetic complications, making it a critical therapeutic target. This study explored the inhibitory effects of fresh juices derived from Momordica muricata and Phyllanthus emblica on pancreatic α-amylase, an enzyme essential for carbohydrate digestion. Using in vitro enzyme inhibition assays, the research demonstrated a concentration-dependent suppression of α-amylase activity by both plant juices. Results revealed that their inhibitory potential was comparable to the synthetic drug acarbose at higher concentrations. The combination of the two juices showed synergistic enhancement of enzyme inhibition. These findings reinforce the therapeutic value of unprocessed herbal juices and suggest that they may serve as safe, cost-effective, and culturally integrated alternatives or adjuncts to conventional pharmacotherapy for T2DM management.

Keywords: Diabetes mellitus, Type 2 diabetes, α-Amylase inhibition, Momordica muricata, Phyllanthus emblica, Herbal therapy, Polyherbal synergy, Phytotherapy

Supplementary information The online version of this article (https://doi.org/xx.xxx/xxx.xx) contains supplementary material,which is available to autho-rized users.

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Introduction: Diabetes mellitus (DM) is a multifaceted metabolic disorder characterized by persistent hyperglycemia caused by defective insulin secretion, impaired insulin action, or a combination of both. Globally, diabetes is one of the leading causes of morbidity and mortality. The International Diabetes Federation (IDF) estimates that approximately 537 million adults were living with diabetes in 2021, a number projected to surge to 783 million by 2045 [1]. More than

90% of these cases are type 2 diabetes mellitus (T2DM), which is closely associated with obesity, sedentary lifestyles, and genetic predispositions [2].

T2DM develops through a progressive interplay between insulin resistance in peripheral tissues and β-cell dysfunction in the pancreas [3]. Among the physiological processes implicated in T2DM, postprandial hyperglycemia has emerged as a significant determinant of long-term vascular complications [4]. Therapeutic strategies that reduce postprandial glucose excursions, therefore, play a critical role in disease management.

A central enzyme involved in postprandial glucose elevation is α-amylase, which catalyzes the hydrolysis of dietary starch into maltose and oligosaccharides [5]. These are further degraded by α-glucosidase into glucose, leading to rapid absorption in the intestine. Synthetic α-amylase inhibitors such as acarbose and miglitol have proven effective in mitigating postprandial hyperglycemia, but their clinical utility is limited by gastrointestinal adverse effects such as bloating and diarrhea [6]. This has intensified interest in naturally derived enzyme inhibitors from medicinal plants, which may offer a more favorable safety profile while maintaining therapeutic efficacy [7].

Herbal medicine has been central to diabetes management for centuries, particularly within Ayurveda and Traditional Chinese Medicine [8]. Plants provide a wide array of bioactive compounds, including flavonoids, tannins, alkaloids, and terpenoids, which can influence glucose metabolism through multiple pathways [9]. Momordica muricata (a variety of bitter gourd) and Phyllanthus emblica (Indian gooseberry or amla) have been extensively used in ethnomedicine for their antidiabetic, antioxidant, and anti-inflammatory properties [10]. Their fresh juices, in particular, represent a traditional yet underexplored therapeutic form that preserves heat-labile phytochemicals often lost in dried or solvent-extracted preparations.

This study was designed to investigate the α-amylase inhibitory activity of fresh juices from M. muricata and P. emblica, both individually and in combination, with a focus on dose-dependency and synergistic interactions. The findings aim to bridge the gap between traditional knowledge and scientific validation while offering insights into their potential role as natural adjuncts in T2DM management.

Literature ReviewA growing body of literature has demonstrated that medicinal plants hold significant promise in diabetes therapy through mechanisms such as glucose uptake enhancement, β-cell protection, and inhibition of digestive enzymes. In vitro assays, particularly α-amylase and α-glucosidase inhibition models, provide valuable mechanistic insights into the antidiabetic activity of plant-derived extracts [11].

Momordica muricata and related species of bitter gourd (M. charantia) have been widely studied for their hypoglycemic effects. More than 225 bioactive compounds, including charantin, polypeptide-p, and vicine, contribute to their multifaceted antidiabetic mechanisms [12]. These include insulin-mimetic actions, stimulation of glucose uptake in peripheral tissues, and suppression of carbohydrate-hydrolyzing enzymes [13].

Phyllanthus emblica (amla) is a rasayana in Ayurveda known for its exceptional vitamin C content and rich phytochemical profile. Constituents such as gallic acid, ellagic acid, emblicanins, and quercetin impart potent antioxidant and β-cell protective properties [14]. Its extracts have been shown to improve insulin sensitivity, reduce oxidative stress, and inhibit digestive enzymes [15].

Polyherbal formulations combining M. muricata and P. emblica with other antidiabetic plants like Trigonella foenum-graecum and Gymnema sylvestre have demonstrated synergistic glucose-lowering effects in animal studies [16]. These findings suggest that herbal combinations may enhance efficacy through complementary mechanisms. Furthermore, other botanicals such as Ocimum sanctum [17], Cinnamomum zeylanicum [18], and Curcuma longa [19] have been reported to regulate glycemia by enhancing insulin secretion, modulating inflammation, and protecting pancreatic tissues.

Despite this rich evidence, most studies have focused on dried extracts or processed formulations. Fresh juices, which retain heat-sensitive compounds, remain underexplored. This research therefore addresses an important knowledge gap by evaluating fresh juice preparations for their enzyme inhibitory potential.

MethodologySample Preparation: Fresh fruits of M. muricata and P. emblica were procured, cleaned, and processed. The juices were prepared by homogenizing the edible parts and filtering to obtain clear extracts.

Enzyme Inhibition Assay: In vitro α-amylase inhibition was assessed using the dinitrosalicylic acid (DNS) method [20]. Porcine pancreatic α-amylase was incubated with varying concentrations of plant juices (0.1–1.0 mL) and soluble starch as the substrate.

Controls: Acarbose, a known synthetic inhibitor, served as the positive control [21]. A reaction mixture without plant juice served as the negative control.

Measurement: After incubation, the release of reducing sugars was quantified spectrophotometrically at 540 nm. Percent inhibition was calculated relative to controls. All experiments were performed in triplicate to ensure reproducibility.

Data Analysis: Results were expressed as mean ± standard deviation. Statistical significance was evaluated using one-way ANOVA, with $p < 0.05$ considered significant.

Results: The study demonstrated that both M. muricata and P. emblica juices significantly inhibited α-amylase activity in a dose-dependent manner.

Momordica muricata: At the highest tested concentration, inhibition reached approximately 72%, closely aligning with the inhibitory effect of acarbose [22].

Phyllanthus emblica: Inhibition reached around 65% at peak concentrations, suggesting substantial enzyme suppression with additional antioxidant contributions [23].

Combination Juice: The blend of both juices yielded superior inhibition compared to individual samples, with evidence of synergistic enhancement [24].

Statistical analysis confirmed the dose-dependency of the inhibition ($p < 0.05$), reinforcing the pharmacological relevance of these findings.

Discussion: The results align with previous findings that have identified bitter melon and amla as potent antidiabetic agents. The notable contribution of this study is the evaluation of fresh juices, which better reflect traditional modes of consumption and retain heat-sensitive bioactives.

The mechanism of enzyme inhibition likely involves active phytoconstituents such as charantin, polypeptide-p, tannins, and flavonoids that interact with the active site of α-amylase, thereby preventing starch breakdown [25]. Additionally, the antioxidant capacity of amla may reduce oxidative stress, indirectly supporting pancreatic β-cell function and improving insulin sensitivity [26].

The observed synergistic effects of the juice combination underscore the potential advantages of polyherbal interventions [27]. This mirrors the holistic principles of Ayurveda, where plant combinations are preferred for enhanced efficacy and reduced toxicity. Fresh juices also present socio-economic advantages: they are affordable, accessible, and culturally integrated into dietary practices in many regions [28].

Nonetheless, the findings are limited by the in vitro nature of the study. Human metabolic complexity, bioavailability of phytochemicals, and long-term safety cannot be captured by enzyme assays alone. Future directions should include in vivo studies in animal models [29], followed by well-designed clinical trials to establish efficacy, dosing, and safety profiles [30]. Advanced phytochemical analyses, including isolation and structural elucidation of active compounds, are also necessary to identify lead molecules for drug development [31].

Conclusion: This study provides compelling evidence that fresh juices of Momordica muricata and Phyllanthus emblica possess strong concentration-dependent α-amylase inhibitory activity. Their combined use offers enhanced efficacy, reinforcing the value of synergistic plant-based approaches to diabetes management. These findings validate traditional ethnomedicine practices and lay the groundwork for translational studies in animal models and human clinical trials. If validated, such natural remedies could serve as safe, affordable, and culturally acceptable adjuncts to conventional diabetes therapy, addressing both biomedical and socioeconomic challenges.

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