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REVIEW

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# Study of antidiabetic activity of Indian herbs in animals

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## ABSTRACT

**Background:**
Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia caused by impaired insulin secretion, insulin resistance, or both. Increasing adverse effects and limitations of conventional antidiabetic drugs have driven interest in medicinal plants as alternative or complementary therapeutic options.

**Objective:**
The purpose of this narrative review is to critically summarize and analyze preclinical evidence on the antidiabetic potential of selected Indian medicinal plants.

**Methods:**
A narrative review of published in vivo studies was conducted using peer-reviewed literature evaluating Indian medicinal herbs in experimentally induced diabetic animal models. Studies were selected based on the use of streptozotocin- or alloxan-induced diabetes models and the assessment of biochemical outcomes such as fasting blood glucose, insulin levels, lipid profiles, oxidative stress markers, and pancreatic histopathology following administration of aqueous, methanolic, ethanolic, or hydroalcoholic plant extracts.

**Results:**
The reviewed studies demonstrated that several Indian medicinal plants, including Annona squamosa, Areca catechu, Artemisia pallens, Beta vulgaris, Boerhavia diffusa, Bombax ceiba, Butea monosperma, Camellia sinensis, Emblica officinalis, Eugenia uniflora, Hemidesmus indicus, Hibiscus rosa-sinensis, Ipomoea batatas, Momordica cymbalaria, Musa × paradisiaca, Phaseolus vulgaris, Vinca rosea, and Zingiber officinale, significantly reduced fasting blood glucose levels and improved insulin secretion and lipid metabolism. Many plants also exhibited antioxidant activity by reducing oxidative stress markers and demonstrated protective or regenerative effects on pancreatic β-cells. Among these, Butea monosperma, Beta vulgaris, Zingiber officinale, and Camellia sinensis showed consistent antidiabetic efficacy across multiple studies.

**Conclusion:**
This narrative review highlights the potential therapeutic role of Indian medicinal plants in diabetes mellitus management based on animal studies. However, the findings are limited to preclinical models, and further well-designed clinical trials and standardisation of herbal formulations are required before clinical application in humans.

## KEY WORDS

Diabetes mellitus; Indian medicinal plants; Antidiabetic activity; Streptozotocin-induced diabetes; Oxidative stress

## ARTICLE HISTORY

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## Introduction

Diabetes mellitus is a chronic metabolic disorder characterised by persistently elevated blood glucose levels and is rapidly emerging as a major global health concern. It results from genetic and/or environmental factors that lead to insulin resistance, impaired insulin secretion, or both. The long-term complications of diabetes, including cardiovascular diseases, neuropathy, nephropathy, and retinopathy, significantly impair patients' quality of life and substantially increase healthcare costs [1]. With the rising global prevalence of diabetes, there is an urgent need for therapeutic approaches that are effective, safe, affordable, and accessible.

Traditional systems of medicine, particularly those based on herbal remedies, continue to serve as valuable alternatives or complements to modern pharmacological therapies [2]. India, with its rich biodiversity and long-established traditional medical systems, represents a vast repository of medicinal plants that have been used for centuries to manage diabetes and a wide range of other ailments. These plants containnumerous bioactive compounds with documented hypoglycemic, antioxidant, and anti-inflammatory properties [3].

The management of diabetes using medicinal plants is supported not only by traditional knowledge but also by scientific evidence generated through modern research methodologies. Several preclinical and clinical studies have demonstrated the efficacy of herbal therapies in improving glycemic control and metabolic outcomes [4]. In recent years, extensive research, particularly animal model-based studies, has shown that many Indian medicinal plants can reduce blood glucose levels, enhance tissue sensitivity to insulin, restore pancreatic β-cell function, and regulate glucose metabolism. In addition, many of these herbs exhibit significant antioxidant activity, helping to counteract oxidative stress, a central factor in the development of diabetes and its complications [5].

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The antidiabetic mechanisms of Indian medicinal plants are multifactorial. Certain herbs stimulate insulin secretion or protect insulin-producing β-cells from damage, while others improve insulin sensitivity by modulating signal transduction pathways involved in glucose transport and utilisation [6]. Several plants also possess lipid-lowering properties, thereby reducing the risk of cardiovascular complications associated with diabetes. Furthermore, their antioxidant activity plays a crucial role in mitigating oxidative stress, which is closely linked to insulin resistance and β-cell deterioration [7].

Overall, Indian medicinal plants hold considerable potential in the management of diabetes mellitus by offering natural, cost-effective alternatives to synthetic drugs. Their diverse mechanisms of action, from improving glucose metabolism to providing antioxidant protection, make them promising candidates for comprehensive diabetes management. Continued research integrating traditional knowledge with modern scientific approaches is essential for optimizing, standardizing, and validating these herbal therapies, enabling their incorporation into evidence-based clinical practice. Various Indian herbs with their active constituents and preparation methods are compiled in Table 1 [8].


**Figure 1**. Major modifiable and non-modifiable risk factors contributing to the development of diabetes mellitus.

This review covers and critically discusses previously published preclinical studies evaluating the antidiabetic potential of selected Indian medicinal plants, with particular emphasis on their effects on blood glucose regulation, insulin secretion, oxidative stress, and pancreatic β-cell protection.

**Table 1 .** Indian Herbs Antidiabetic Studies (Plant Details with Constituents).

| Indian Herb | Plant Part Used | Preparation Method | Specific Active Constituents | reference |
|---|---|---|---|---|
| Annona squamosa | Leaves | Methanolic extract | Anonaine, acetogenins, quercetin | [9] |
| Areca catechu | Leaves | Methanol, petroleum ether, and chloroform extracts | Catechins, arecoline, polyphenols | [10] |
| Artemisia pallens | Whole plant | Methanolic extract | Artemisin, flavonoids, coumarins | [11] |
| Beta vulgaris | Root | Methanolic extract | Betalains (betanin), polyphenols | [12] |
| Boerhavia diffusa | Root | Methanolic extract | Punarnavine, boerhavic acid | [13] |
| Bombax ceiba | Bark | Ethyl acetate extract | Lupeol, β-sitosterol, flavonoids | [14] |
| Butea monosperma | Leaves | Ethanolic extract | Butrin, isobutrin, flavonoids | [15] |
| Camellia sinensis | Leaves | Ethanol extract | Epigallocatechin gallate (EGCG), catechins | [16] |
| Emblica officinalis | Fruit | Hydroalcoholic extract | Ascorbic acid, ellagic acid, gallic acid | [17] |
| Eugenia uniflora | Leaves | Aqueous extract | Myricetin, quercetin, anthocyanins | [18] |
| Hemidesmus indicus | Root | Aqueous extract | Hemidesmin, saponins, tannins | [19] |
| Hibiscus rosa-sinensis | Leaves | Aqueous extract | Anthocyanins, hibiscetin, quercetin | [20] |

## Methods

### Literature Search Strategy

A comprehensive literature search was conducted using the electronic databases PubMed, Scopus, and Google Scholar to identify relevant peer-reviewed studies related to the antidiabetic potential of Indian medicinal plants.

### Search Terms and Keywords

The search strategy employed combinations of the following keywords: diabetes mellitus, antidiabetic activity, Indian medicinal plants, herbal antidiabetic agents, streptozotocin-induced diabetes, alloxan-induced diabetes, animal models, oxidative stress, insulin secretion, and β-cell protection. Boolean operators (AND/OR) were used to refine the search.



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In addition, the reference lists of selected articles were manually screened to identify relevant studies not captured in the initial search.

### Time frame and language

Only articles published in English between 2000 and 2024 were considered for inclusion in this review.

### Inclusion criteria

Studies were included if they reported preclinical in vivo investigations evaluating the antidiabetic activity of Indian medicinal plants using established experimental diabetic animal models, particularly streptozotocin- or alloxan-induced diabetes. Eligible studies were required to assess at least one key biochemical or histological parameter related to diabetes, such as fasting blood glucose levels, insulin concentration, lipid profile, oxidative stress markers, or pancreatic histopathology.

### Exclusion criteria

Studies were excluded if they were limited to in vitro experiments, focused on synthetic drugs or non-Indian plant sources, lacked relevant biochemical outcome measures, or were review articles, conference abstracts, editorials, or non-peer-reviewed publications. Clinical studies were also excluded, as the focus of this review was restricted to animal-based preclinical evidence.

### Review design

This work follows a narrative review approach and does not employ a systematic review or meta-analysis framework. Consequently, PRISMA guidelines were not applied.

### Phytotherapeutic approaches to diabetes

In this section, we explore a selection of Indian medicinal plants that have demonstrated promising effects in managing diabetes and its complications. The discussion focuses on each herb's ability to modulate blood glucose, improve insulin function, regulate lipid metabolism, and protect pancreatic β-cells, with supporting evidence from experimental studies. These insights provide a foundation for understanding how traditional remedies may complement modern diabetes therapies. Studies involving Indian herbs depicting their anti-diabetic potential have been compiled in Table 2.

**Table 2 .** Summary of Antidiabetic Studies on Indian Herbs.

| Indian Herb | Study Design | Key Findings | Conclusion | reference |
|---|---|---|---|---|
| Annona squamosa | Wistar rats with diabetes received STZ treatment followed by oral administration of 200mg/kg and 400mg/kg extract doses for 21 days | Elevated fasting blood glucose diminished from 270 mg/dL to 108 mg/dL, accompanied by enhanced pancreatic β-cell regeneration, together with better lipid profile management, which occurred with a medium-sized dose of 400 mg/kg | Exhibits antidiabetic potential. Further research is warranted. | [9] |
| Areca catechu | The research used STZ-induced diabetic rats to administer extracts (petroleum ether, chloroform, and methanol) at 200mg/kg for 15 days | The most effective extract was methanol because it lowered glucose levels from 265.76 mg/dL to 75.81 mg/dL. Improved lipid profile | Significant antidiabetic effect; methanol extracts most promising | [22] |
| Artemisia pallens | Wistar rats received STZ + HFD-induced diabetes treatment along with extract doses at 200mg/kg and 400mg/kg for 28 days | Reduced glucose (260 mg/dL to 110 mg/dL at 400 mg/kg), increased serum insulin, improved antioxidant and lipid profiles, and pancreatic β-cell regeneration | Effective in managing Type 2 diabetes | [23] |
| Beta vulgaris | Methanolic extract tested in T2DM rat model induced by HFD + STZ | The glucose metrics decreased during fasting tests alongside enhanced insulin receptiveness and lessened hepatic glucose production | Promising hypoglycemic agent for T2DM | [24] |
| Boerhavia diffusa | Methanolic root extract in STZ-induced diabetic rats, multiple doses tested for 14 weeks | The study showed that the combination of fasting glucose reduction and HbA1c decrease alongside better lipid profiles and antioxidant defense and nephroprotective effects | Effective for diabetes management and complications | [13] |
| Bombax ceiba | STZ-induced diabetic rats, ethyl acetate bark extract tested at doses 200mg/kg, 400mg/kg, 600mg/kg for 21 days | The glucose levels decreased from 433 mg/dL to 156 mg/dL at 600mg/kg dose while pancreatic islet recovery and lipid profile improvement occurred | Shows potential for diabetes management | [25] |
| Butea monosperma | Alloxan-induced diabetes in Swiss albino mice, ethanolic extract at 300mg/kg for 45 days | The treatment led to reduced glucose levels with better lipids and elevated antioxidant capacity while recovering hepatic glycogen store amounts | potent antioxidant and antidiabetic effects | [26] |



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| Camellia sinensis | HFD-fed diabetic rats, ethanol extract at 250mg/5mL/kg. | Lowered glucose, increased GLP-1 levels, inhibited DPP-IV enzyme activity. | The body maintains stable blood glucose levels while insulin production occurs | [16] |
| Emblica officinalis | Hydroalcoholic extract in STZ-induced diabetic rats at 100mg/kg for 28 days | Better lipid profile, decreased oxidative stress, and a 21–39% decline in hyperglycemia. | Powerful antioxidant and antidiabetic effects | [27] |
| Eugenia uniflora | Aqueous extract tested on NOD mice for T1DM | Scientists detected a 19.3% decline in diabetes cases as well as elevated insulin levels and increased hepatic glutathione and reduced lipid peroxidation markers | Potential for preventing diabetes and related advantages | [28] |
| Hemidesmus indicus | The experiment was conducted with STZ-induced diabetic Wistar rats under various dosage conditions. | The treatment reduced glucose levels by 40% while it promoted β-cell regeneration in the pancreas along with better lipid parameter results | Favourable antidiabetic actions | [29] |
| Hibiscus rosa-sinensis | Wistar rats received alloxan-induced diabetes treatment with extract at 250mg/kg for 30 days | Reduced glucose from 264.80 mg/dL to 145.32 mg/dL, improved lipid profile, enhanced plasma insulin and hepatic glycogen | Remarkable antidiabetic activity | [30] |
| Musa x paradisiaca | The study administered 200mg/kg of methanolic and aqueous extracts to STZ-induced diabetic rats for 20 days | Improved glycemia, fasting glucose comparable to insulin-treated rats | Affordable and effective antidiabetic remedy | [31] |
| Vinca rosea | Alloxan-induced diabetes in Wistar rats, methanol extract doses 300mg/kg & 500mg/kg for 14 days | The administration of reduced glucose brought two-thirds of glucose reduction while improving lipid measurements and promoting pancreatic β-cell revival | Affordable and effective antidiabetic remedy | [31] |
| Zingiber officinale | The research used STZ-induced diabetic rats while administering aqueous ginger extract at 500mg/kg for 7 weeks | Reduced glucose, cholesterol, triglycerides, improved diabetic nephropathy and proteinuria | Hypoglycemic and hypolipidemic properties support their use in diabetes management | [33] |

***Annona squamosa* (Sugar apple)**

Kumar et al. evaluated the antidiabetic efficacy of Annona squamosa Linn. leaf extract in streptozotocin-induced diabetic Wistar rats, where diabetes was induced by intraperitoneal administration of streptozotocin at a dose of 60 mg/kg body weight, and animals with fasting blood glucose levels ≥ 250 mg/dL were considered diabetic. Oral administration of A. squamosa leaf extract at doses of 200 mg/kg and 400 mg/kg body weight for 21 days resulted in a significant reduction in fasting blood glucose levels, with the higher dose reducing glucose from approximately 270 mg/dL to 108 mg/dL by the end of the treatment period [21]. While this hypoglycemic effect is evident, the biochemical basis underlying this activity is equally noteworthy.

One of the probable mechanisms contributing to the glucose-lowering effect of A. squamosa involves inhibition of carbohydrate-digesting enzymes such as α-amylase and α-glucosidase. Phytoconstituents present in the leaf extract, including flavonoids and phenolic compounds, are known to delay intestinal glucose absorption by inhibiting these enzymes, thereby reducing postprandial hyperglycemia. Such enzyme inhibition represents an important peripheral mechanism that complements systemic glucose regulation.

The study also reported a significant reduction in lipid peroxidation levels, indicating attenuation of oxidative stress in diabetic rats. Streptozotocin-induced diabetes is associated with excessive generation of reactive oxygen species, leading to oxidative damage of pancreatic β-cells. The observed reduction in lipid peroxidation suggests that A. squamosa enhances endogenous antioxidant defence systems, likely through upregulation of antioxidant enzymes such as superoxide dismutase, catalase, and glutathione peroxidase. Activation of these antioxidant pathways protects cellular membranes and preserves pancreatic tissue integrity.

Histopathological examination revealed partial regeneration and restoration of pancreatic β-cells in treated animals, indicating a protective effect against streptozotocin-induced cytotoxicity. This β-cell protection may be attributed to reduced oxidative stress and improved intracellular redox balance, which collectively prevent apoptosis and promote cellular recovery. Enhanced insulin levels observed in treated rats further suggest improved β-cell functionality and insulin biosynthesis.

In addition, improved insulin concentration implies possible modulation of insulin receptor signalling pathways. Restoration of insulin availability can enhance downstream signalling through the insulin receptor–PI3K–Akt pathway, facilitating increased translocation of glucose transporter type 4 (GLUT4) to the cell membrane in insulin-sensitive tissues, thereby improving glucose uptake and utilisation. Together, these mechanisms contribute to improved glycemic control and lipid metabolism observed in the treated groups.

Overall, the antidiabetic activity of Annona squamosa leaf extract extends beyond simple glucose reduction and involves multiple biochemical mechanisms, including inhibition of



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carbohydrate-metabolising enzymes, enhancement of antioxidant defence systems, protection and regeneration of pancreatic β-cells, and improvement of insulin signalling pathways. These multifaceted actions support the therapeutic potential of A. squamosa in diabetes management and justify further mechanistic and clinical investigations [21].

***Areca catechu***

Bhaskar et al. investigated the antidiabetic potential of Areca catechu (supari) leaf extracts using streptozotocin-induced diabetic Wistar rats. Experimental diabetes was induced by a single intraperitoneal injection of freshly prepared streptozotocin dissolved in 0.1 M citric acid at a dose of 50 mg/kg body weight. Following diabetes induction, animals were orally administered petroleum ether, chloroform, or methanolic extracts of A. catechu leaves at a dose of 200 mg/kg body weight once daily for fifteen days, while glibenclamide (0.5 mg/kg) served as the standard reference drug. Fasting blood glucose levels were monitored at five-day intervals to evaluate the antidiabetic efficacy of the extracts (22).

All three extracts produced a statistically significant reduction in fasting blood glucose levels in streptozotocin-induced diabetic rats. Among them, the methanolic extract demonstrated the most pronounced effect, reducing blood glucose levels from approximately 265.76 mg/dL to 75.81 mg/dL after fifteen days of treatment, which approached normoglycemic values. The chloroform and petroleum ether extracts also exhibited marked hypoglycemic activity, lowering glucose concentrations to 83.58 mg/dL and 91.45 mg/dL, respectively. These findings suggest that the polar phytoconstituents present in the methanolic extract may play a dominant role in mediating the antidiabetic effect.

From a biochemical perspective, the observed hypoglycemic activity of A. catechu leaf extracts may be attributed to multiple complementary mechanisms. The presence of polyphenols, flavonoids, and alkaloids in A. catechu is known to inhibit carbohydrate-digesting enzymes such as α-amylase and α-glucosidase, thereby delaying intestinal glucose absorption and reducing postprandial hyperglycemia. Such enzyme inhibition represents an important peripheral mechanism contributing to improved glycemic control.

Additionally, streptozotocin induces diabetes primarily through oxidative damage and selective destruction of pancreatic β-cells. The significant glucose-lowering effect observed with A. catechu extracts suggests a possible antioxidant-mediated protective action on pancreatic tissue. Phytochemicals present in the extracts may enhance endogenous antioxidant defense systems, including superoxide dismutase, catalase, and glutathione peroxidase, thereby reducing reactive oxygen species-induced lipid peroxidation and preserving β-cell integrity. This antioxidant action likely contributes to improved insulin availability and glucose homeostasis.

The marked reduction in blood glucose levels comparable to glibenclamide implies potential stimulation of insulin secretion or improvement in insulin sensitivity. Restoration of insulin levels may enhance insulin receptor signalling cascades, including activation of the PI3K/Akt pathway, promoting increased translocation of GLUT4 transporters in peripheral tissues and facilitating efficient glucose uptake. Together, these mechanisms contribute to the overall antidiabetic efficacy observed in treated animals.

The antidiabetic activity of Areca catechu leaf extracts, particularly the methanolic extract, extends beyond simple glucose reduction and likely involves inhibition of carbohydrate-digesting enzymes, enhancement of antioxidant defences, protection of pancreatic β-cells, and modulation of insulin signalling pathways. These multifaceted biochemical actions support the therapeutic potential of A. catechu as a promising natural antidiabetic agent and warrant further mechanistic and clinical investigations [22].

***Artemisia pallens (Davana)***

Reddy et al. evaluated the antidiabetic efficacy of the methanolic extract of Artemisia pallens in a high-fat diet and streptozotocin-induced type 2 diabetic Wistar rat model. Diabetes was induced by feeding animals a high-fat diet for four weeks, followed by a single intraperitoneal injection of streptozotocin at a dose of 55 mg/kg body weight. Rats with fasting blood glucose levels exceeding 250 mg/dL were considered diabetic and selected for the study. The animals were orally administered A. pallens methanolic extract at doses of 200 mg/kg and 400 mg/kg body weight for twenty-eight consecutive days. Multiple biochemical parameters, including plasma glucose, hepatic glycogen content, serum insulin levels, lipid profile (LDL and HDL cholesterol), oxidative stress markers, and pancreatic histopathology, were evaluated to determine the therapeutic efficacy of the extract.

Treatment with A. pallens extract produced a significant and dose-dependent reduction in fasting blood glucose levels. At the higher dose of 400 mg/kg, blood glucose levels were reduced by approximately 58%, from a baseline value of around 260 mg/dL to nearly 110 mg/dL at the end of the treatment period. This marked hypoglycemic effect was accompanied by a significant increase in serum insulin concentrations, indicating improved pancreatic β-cell function and insulin secretion. Restoration of hepatic glycogen levels further suggests improved insulin-mediated glucose storage and utilisation in peripheral tissues.

From a biochemical perspective, the antidiabetic activity of A. pallens appears to involve multiple complementary mechanisms. The reduction in thiobarbituric acid reactive substances (TBARS) and malondialdehyde (MDA) levels, along with increased glutathione concentrations in liver and pancreatic homogenates, indicates attenuation of oxidative stress. This enhancement of endogenous antioxidant defenses suggests upregulation of antioxidant enzymes such as superoxide dismutase, catalase, and glutathione peroxidase, which play a crucial role in protecting pancreatic β-cells from oxidative damage induced by streptozotocin and high-fat diet exposure.

Histopathological examination of pancreatic tissue revealed evidence of β-cell regeneration and restoration of islet architecture in extract-treated animals. This β-cell protective and regenerative effect may be attributed to reduced oxidative stress and improved intracellular redox balance, which collectively prevent β-cell apoptosis and promote cellular repair. Improved insulin availability likely enhances insulin receptor signalling through the PI3K/Akt pathway, facilitating increased GLUT4 translocation and glucose uptake in insulin-sensitive tissues, thereby contributing to overall glycemic control.

In addition, favorable modulation of lipid metabolism was observed, as evidenced by reductions in total cholesterol,



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triglycerides, and LDL levels, along with improvement in HDL cholesterol. These effects suggest that A. pallens extract may also influence lipid-regulating pathways, potentially through activation of AMP-activated protein kinase (AMPK), which is known to regulate both glucose and lipid homeostasis. The combined hypoglycemic, antioxidant, and hypolipidemic actions of A. pallens underscore its multifaceted therapeutic potential.

Overall, the findings of Reddy et al. demonstrate that Artemisia pallens exerts significant antidiabetic effects through modulation of glucose metabolism, enhancement of antioxidant defense systems, protection and regeneration of pancreatic β-cells, and improvement of insulin signaling and lipid profiles. These results support the potential use of A. pallens as a promising natural agent for the management of type 2 diabetes mellitus and warrant further mechanistic and clinical investigations [23].

***Beta vulgaris (Beetroot)***

The antidiabetic potential of Beta vulgaris (beetroot) has been investigated using a high-fat diet and low-dose streptozotocin-induced type 2 diabetes mellitus (T2DM) rat model, which closely mimics human T2DM by inducing insulin resistance and partial destruction of pancreatic β-cells. In this experimental model, methanolic extracts of B. vulgaris were administered orally to diabetic rats at doses of 250 mg/kg and 500 mg/kg body weight [34]. Treatment with the extract resulted in a significant, dose-dependent reduction in fasting blood glucose levels, with the higher dose exhibiting greater hypoglycemic efficacy.

The pronounced glucose-lowering effect of B. vulgaris suggests improvement in insulin sensitivity and suppression of hepatic glucose output. Beetroot is rich in bioactive compounds such as betalains, flavonoids, and polyphenols, which are known to modulate key metabolic pathways involved in glucose homeostasis. These phytochemicals may enhance insulin receptor signalling by activating the PI3K/Akt pathway, thereby promoting GLUT4 translocation to the cell membrane in skeletal muscle and adipose tissue, leading to increased peripheral glucose uptake. In addition, activation of AMP-activated protein kinase (AMPK) by beetroot constituents may contribute to reduced hepatic gluconeogenesis and improved lipid metabolism.

Oxidative stress plays a critical role in the progression of insulin resistance and β-cell dysfunction in T2DM. The antioxidant properties of betalains present in B. vulgaris are reported to scavenge reactive oxygen species and enhance endogenous antioxidant defence systems, including superoxide dismutase, catalase, and glutathione peroxidase. Reduction in oxidative stress may protect pancreatic β-cells from further damage, preserve insulin secretory capacity, and improve overall glycemic control.

Furthermore, the improvement in metabolic parameters observed in beetroot-treated rats suggests a protective effect on pancreatic tissue, potentially facilitating partial β-cell recovery and functional restoration. By simultaneously improving insulin sensitivity, reducing hepatic glucose production, and attenuating oxidative stress, B. vulgaris demonstrates a multifaceted antidiabetic mechanism rather than a simple hypoglycemic action.

Overall, these findings highlight the therapeutic potential of Beta vulgaris as a natural antidiabetic agent capable of modulating multiple biochemical pathways relevant to type 2 diabetes mellitus. Its ability to improve insulin signalling, reduce oxidative stress, and regulate glucose metabolism underscores its promise in controlling hyperglycemia and mitigating diabetes-associated complications, warranting further mechanistic and clinical investigations [35].

***Boerhavia diffusa***

The antidiabetic efficacy of Boerhaavia diffusa has been evaluated in streptozotocin-induced diabetic male Sprague Dawley albino rats using methanolic root extract and its bioactive fraction. Diabetic animals were treated for fourteen weeks with graded doses of the methanolic extract (50, 150, and 300 mg/rat/day) or a purified bioactive fraction (0.5 mg/rat/day), while glibenclamide (0.5 mg/rat/day) served as the standard drug. Treatment resulted in a marked reduction in fasting blood glucose and glycated haemoglobin (HbA1c) levels, indicating sustained improvement in long-term glycemic control. In addition, significant hypolipidemic effects were observed, characterised by reductions in total cholesterol, triglycerides, and LDL cholesterol, along with an increase in HDL cholesterol levels [36].

From a biochemical standpoint, the antidiabetic action of B. diffusa appears to involve multiple protective mechanisms. Restoration of endogenous antioxidant enzyme activities, including superoxide dismutase, catalase, and glutathione peroxidase, indicates attenuation of oxidative stress induced by streptozotocin. Reduced oxidative stress is crucial for preserving pancreatic β-cell integrity and preventing insulin secretory dysfunction. Improved antioxidant status also contributes to the protection of renal tissue, as evidenced by histopathological findings demonstrating regression of diabetic nephropathic changes. These observations suggest that B. diffusa not only improves glucose and lipid metabolism but also confers organ-protective effects against diabetes-associated complications.

Complementary findings have been reported for Boerhaavia erecta L., which was investigated for its antidiabetic and antihyperlipidemic potential in streptozotocin-induced diabetic Wistar rats. Oral administration of the plant extract at doses of 200 mg/kg and 400 mg/kg body weight for twenty-eight days resulted in significant reductions in fasting blood glucose levels and improved oral glucose tolerance. Treatment also favorably modulated lipid metabolism, as reflected by decreased total cholesterol, triglycerides, LDL-C, and VLDL-C, along with increased HDL-C levels, indicating reduced cardiovascular risk associated with diabetes.

In addition to glycemic and lipid regulation, B. erecta demonstrated hepatoprotective effects by significantly reducing elevated liver enzyme levels, including SGOT, SGPT, and ALP, and by restoring total protein concentrations. Preservation of body weight in treated animals further indicates improved metabolic efficiency and reversal of diabetes-associated catabolic changes. Histopathological examination of pancreatic tissue revealed preservation of β-cell architecture and function, suggesting enhanced insulin secretion and/or protection against streptozotocin-induced β-cell damage. These effects are likely mediated through improved antioxidant defences and modulation of insulin signalling pathways, which collectively enhance insulin availability and peripheral glucose utilization.

Overall, both Boerhaavia diffusa and Boerhaavia erecta exhibit potent antidiabetic activity through multifaceted



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biochemical mechanisms, including regulation of glucose and lipid metabolism, enhancement of antioxidant defence systems, protection of pancreatic β-cells, and prevention of diabetes-related organ damage. The combined glycemic control, hypolipidemic action, and nephroprotective and hepatoprotective effects underscore the therapeutic potential of Boerhaavia species as promising natural agents for the management of diabetes mellitus and its complications [37].

***Bombax ceiba (Semul)***

The antidiabetic and hypolipidemic potential of Bombax ceiba bark extract has been investigated in streptozotocin-induced diabetic Wistar rats. Bark extracts were prepared using petroleum ether, ethyl acetate, and ethanol, of which the ethyl acetate extract was selected for further evaluation due to its high triterpenoid content. Diabetes was induced using streptozotocin at a dose of 45 mg/kg, and animals were divided into normal control, diabetic control, standard drug–treated (glibenclamide 10 mg/kg), and Bombax ceiba extract–treated groups receiving 200, 400, and 600 mg/kg orally for 21 days. Biochemical and histopathological assessments were conducted on the 22nd day following treatment.

Treatment with the ethyl acetate extract resulted in a dose-dependent reduction in fasting blood glucose levels, with the highest dose (600 mg/kg) producing a significant decrease from 433 mg/dL to 156 mg/dL ($p < 0.001$), comparable to the effect of glibenclamide. In addition to glycemic control, significant improvements in lipid metabolism were observed, including reductions in total cholesterol, triglycerides, and LDL cholesterol, along with an increase in HDL cholesterol levels. These findings indicate a dual antidiabetic and antihyperlipidemic effect, which is particularly relevant in preventing cardiovascular complications associated with diabetes mellitus.

Histopathological examination of pancreatic tissue revealed regeneration of pancreatic islets and improvement in β-cell granulation in extract-treated diabetic rats. This structural recovery suggests preservation or restoration of β-cell function, potentially leading to enhanced insulin secretion. The presence of triterpenoids is proposed to play a central role in these effects, either by stimulating insulin release from pancreatic β-cells or by exerting extrapancreatic actions such as enhancing peripheral glucose uptake and improving insulin sensitivity [25].

Complementary in vitro investigations have further elucidated the antidiabetic and antioxidant potential of Bombax ceiba leaves and flowers. Extracts were prepared using water, 50% ethanol, and 95% ethanol, and phytochemical screening confirmed the presence of alkaloids, flavonoids, coumarins, saponins, tannins, terpenoids, and cardiac glycosides. Antioxidant capacity was assessed using DPPH, ABTS, and FRAP assays, while antidiabetic activity was evaluated through inhibition of key carbohydrate-digesting enzymes, α-glucosidase and α-amylase.

Among all tested extracts, the 95% ethanol flower extract exhibited the strongest antidiabetic activity, demonstrating potent α-glucosidase inhibition ($IC_{50}$ = 0.001 mg/mL) and α-amylase inhibition ($IC_{50}$ = 0.0002 mg/mL), surpassing the standard drug acarbose. Enzyme inhibition at this level suggests delayed carbohydrate digestion and reduced intestinal glucose absorption, thereby attenuating postprandial hyperglycemia.

The strong antioxidant activity observed in the flower extracts correlated with their high phenolic and flavonoid content, highlighting their role in mitigating oxidative stress, a key contributor to insulin resistance and β-cell dysfunction.

Collectively, both in vivo and in vitro findings support the antidiabetic potential of Bombax ceiba through multiple biochemical mechanisms, including enhancement of insulin secretion, inhibition of carbohydrate-digesting enzymes, modulation of lipid metabolism, and reinforcement of antioxidant defences. These properties validate its traditional medicinal use and suggest its promise as a natural therapeutic agent or functional food component for the management of type 2 diabetes mellitus. However, further in vivo toxicity studies and well-designed clinical trials are necessary to establish its efficacy and safety in humans [36].

***Butea monosperma (Palasa)***

The antidiabetic and antioxidant potential of Butea monosperma has been extensively evaluated in alloxan-induced diabetic animal models. In one study, the ethanolic extract of Butea monosperma leaves was assessed in male Swiss albino mice rendered diabetic by alloxan administration at a dose of 150 mg/kg body weight. Animals were divided into a therapeutic group receiving Butea monosperma ethanolic extract (300 mg/kg body weight) and a diabetic control group, and treatments were continued orally for a period of 45 days. The extract-treated mice exhibited a marked reduction in fasting blood glucose levels from 172 mg/dL to 117 mg/dL, indicating significant glycemic control. Additionally, treatment reversed diabetes-associated body weight loss, reflecting improved metabolic status.

Significant improvements in lipid metabolism were observed following extract administration, including reductions in total cholesterol, triglycerides, LDL, and VLDL levels, along with an elevation in HDL cholesterol. These changes suggest a protective role against diabetes-associated dyslipidemia and cardiovascular risk. The study also demonstrated enhancement of endogenous antioxidant defence systems, evidenced by increased activities of catalase (CAT), glutathione peroxidase (GSH-Px), and elevated glutathione levels, accompanied by a reduction in lipid peroxidation. Restoration of hepatic glucagon content further suggested improved insulin action and glucose homeostasis. Collectively, these findings indicate that Butea monosperma leaf extract exerts its antidiabetic effect through combined hypoglycemic, hypolipidemic, and antioxidant mechanisms.

Supporting evidence from another study evaluated the antihyperglycemic and antioxidative activity of a hydroalcoholic extract of Butea monosperma flowers in alloxan-induced diabetic Swiss albino mice. Diabetes was induced using alloxan monohydrate (150 mg/kg body weight), leading to pancreatic β-cell destruction and persistent hyperglycemia. Experimental groups included normal control, diabetic control, extract-treated mice receiving 300 mg/kg of Butea monosperma flower extract, and a standard drug group treated with glibenclamide (10 mg/kg). Oral treatment continued for 45 days [38].

The flower extract produced a pronounced reduction in fasting blood glucose levels from 230 mg/dL to 113 mg/dL, comparable to the standard antidiabetic drug. Improvements in body weight and lipid profile were also observed, characterized by decreases in total cholesterol, triglycerides,



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LDL, and VLDL, along with an increase in HDL cholesterol. Antioxidant analysis revealed significantly elevated activities of superoxide dismutase (SOD), catalase, glutathione peroxidase, and increased glutathione levels, while lipid peroxidation was markedly reduced. These results confirm the strong antioxidative potential of Butea monosperma flowers, which plays a crucial role in mitigating oxidative stress-mediated β-cell damage and insulin resistance.

Overall, both leaf and flower extracts of Butea monosperma demonstrate potent antidiabetic activity through multifaceted mechanisms involving glycemic regulation, lipid modulation, enhancement of antioxidant defences, and improvement of insulin action. These properties strongly support the traditional medicinal use of Butea monosperma and highlight its potential as a natural therapeutic agent for the management of diabetes mellitus and its associated metabolic complications.

***Camelia sinesis (Tea)***

The antidiabetic potential of Camellia sinensis has been investigated using a high-fat diet (HFD)-induced type 2 diabetes mellitus model in male Sprague Dawley rats. Animals were maintained under controlled conditions, including a 12-hour light/dark cycle, temperature of 25 ± 0.5°C, and relative humidity of 65–70%, to ensure consistent experimental parameters. Diabetes was induced by prolonged high-fat feeding, and the effects of the ethanol extract of Camellia sinensis (EECS) were evaluated at an oral dose of 250 mg/5 mL/kg body weight [39].

Treatment with EECS significantly reduced fasting blood glucose levels and improved glucose tolerance in HFD-fed diabetic rats. Mechanistically, EECS demonstrated enzyme modulatory activity by inhibiting plasma dipeptidyl peptidase-IV (DPP-IV) activity by 20–25%, leading to a 32% increase in plasma active glucagon-like peptide-1 (GLP-1) levels. The elevation of active GLP-1 stimulates glucose-dependent insulin secretion from pancreatic β-cells, thereby improving insulin availability and restoring glucose homeostasis. These effects suggest that EECS not only reduces hyperglycemia but also modulates key regulatory pathways involved in glucose metabolism [40].

The study further highlights the dual role of Camellia sinensis in promoting pancreatic β-cell function and regulating enzymatic pathways critical for glycemic control. By inhibiting DPP-IV and enhancing GLP-1 activity, EECS facilitates insulin secretion while maintaining postprandial glucose balance. Such multifaceted mechanisms position Camellia sinensis as a promising natural agent for managing type 2 diabetes mellitus, complementing conventional therapeutic strategies while potentially mitigating oxidative stress and β-cell dysfunction.

***Emblica officinalis***

The antidiabetic potential of Emblica officinalis (amla) has been evaluated in male Wistar rats rendered diabetic through intraperitoneal injection of streptozotocin (STZ) at a dose of 45 mg/kg body weight. Following diabetes induction, the experimental group received a hydroalcoholic extract of amla at 100 mg/kg body weight orally for twenty-eight days, while the control group received vehicle treatment. Key parameters assessed included fasting blood glucose, lipid profile, and markers of oxidative stress to determine the therapeutic efficacy of the extract [27].

Treatment with amla extract produced a significant reduction in fasting blood glucose levels, with decreases ranging from 21% to 39% relative to baseline values. This hypoglycemic effect indicates that amla may enhance insulin action and/or improve peripheral glucose uptake. In addition, administration of amla extract led to favourable modulation of lipid metabolism, evidenced by reductions in total cholesterol and triglyceride levels, which suggests a potential cardioprotective effect in the context of diabetes [41].

Oxidative stress, a key contributor to β-cell dysfunction and insulin resistance, was also alleviated following amla treatment. The extract improved antioxidant defense systems, including enhanced activity of superoxide dismutase, catalase, and glutathione peroxidase, and reduced lipid peroxidation. These effects likely contribute to the preservation of pancreatic β-cell integrity and overall improvement in glucose homeostasis.

Collectively, these findings indicate that Emblica officinalis exerts multifaceted antidiabetic activity, encompassing glycemic control, lipid regulation, and antioxidant protection. The data support its traditional use as a natural antidiabetic agent and highlight its potential for further development as a therapeutic or functional food for the management of type 2 diabetes mellitus and its associated metabolic complications.

***Eugenia uniflora***

The antidiabetic potential of Eugenia uniflora was investigated using NOD mice, a genetically predisposed model for type 1 diabetes mellitus (T1DM). Mice were administered an aqueous extract of E. uniflora leaves from the fourth to the twenty-sixth week of life. The extract was prepared from seeds using a standardized autoclave method and provided ad libitum. Animals were maintained in a specific pathogen-free (SPF) environment with controlled temperature and humidity. Blood glucose levels were monitored weekly, and biochemical analyses included serum insulin, hepatic glutathione levels, and markers of lipid peroxidation to assess the extract's efficacy [42].

Treatment with the aqueous extract resulted in a notable reduction in the prevalence of diabetes, with 40.7% of treated mice developing diabetes compared to 60% in the untreated group, corresponding to a 19.3% reduction in disease incidence. Serum insulin levels were significantly elevated in treated mice (2.56 ± 0.6 ng/mL) relative to diabetic controls (0.85 ± 0.09 ng/mL), indicating improved β-cell function and insulin secretion. Additionally, hepatic glutathione levels were significantly higher in treated mice (3926 ± 109 nmol/mg) versus diabetic mice (3390 ± 119 nmol/mg), suggesting enhanced antioxidant defence. Correspondingly, markers of lipid peroxidation were significantly reduced in the treated group, reflecting decreased oxidative stress [28].

These findings indicate that Eugenia uniflora exerts antidiabetic effects by multiple mechanisms, including preservation of pancreatic β-cell function, enhancement of insulin secretion, and reduction of oxidative stress through increased glutathione levels and inhibition of lipid peroxidation. Together, these actions contribute to improved glucose homeostasis and may reduce the risk or severity of diabetes onset. The study supports the potential of E. uniflora as a natural therapeutic agent for preventing or managing type 1 diabetes.

***Hemidesmus indicus***

The antidiabetic potential of Hemidesmus indicus was evaluated using streptozotocin (STZ)-induced diabetic Wistar



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albino rats. Diabetes was induced by intraperitoneal injection of STZ at a dose of 65 mg/kg body weight. Animals were maintained under controlled conditions, including a temperature of 22 ± 2°C, relative humidity of 55%, and a 12/12-hour light/dark cycle, and were acclimatized for one week prior to the experiment. Experimental groups included rats treated with varying doses of the H. indicus extract, a standard drug group, and a placebo control group. Serum biochemical parameters were analyzed using an automated biochemical analyzer, and histopathological examinations of pancreatic tissue were performed to support observed physiological outcomes [29].

Treatment with H. indicus extract produced a dose-dependent reduction in fasting blood glucose, with the maximal hypoglycemic response observed at the highest dose. On average, glucose levels decreased by approximately 40% over the treatment period, indicating substantial glycemic control. Improvements in lipid parameters were also observed, suggesting potential benefits in mitigating diabetes-associated dyslipidemia. Histological analysis of the pancreas revealed signs of β-cell regeneration and improved islet architecture, supporting the extract's potential in restoring pancreatic function and enhancing endogenous insulin secretion [43].

These findings demonstrate that Hemidesmus indicus exerts antidiabetic effects through multiple mechanisms, including lowering blood glucose levels, improving lipid metabolism, and promoting β-cell regeneration. Such multifaceted actions underscore its potential as a natural therapeutic agent for the management of type 2 diabetes mellitus and its associated complications.

***Hibiscus rosa-sinensis***

The antidiabetic potential of Hibiscus rosa-sinensis was evaluated using male albino Wistar rats weighing 150–180 g. Diabetes was induced by a single intraperitoneal injection of alloxan monohydrate at 120 mg/kg body weight after 18 hours of fasting, followed by 5% glucose administration for 48 hours to prevent severe hypoglycemia. Animals were acclimatized under controlled environmental conditions, including a 12:12-hour light/dark cycle and a temperature of 30 ± 2°C. Experimental groups included a normal control, diabetic control, extract-treated group receiving 250 mg/kg body weight/day, and a standard drug group treated with gliclazide at 5 mg/kg body weight/day. Treatment continued for 30 days, during which body weight, blood glucose, and biochemical parameters were monitored [44].

Administration of H. rosa-sinensis extract significantly reduced fasting blood glucose levels in diabetic rats from 264.80 ± 17.56 mg/dL to 145.32 ± 12.54 mg/dL. Correspondingly, plasma insulin levels increased from 5.70 ± 1.02 µU/mL to 10.11 ± 2.14 µU/mL, indicating improved β-cell function and enhanced insulin secretion. Glycosylated haemoglobin (HbA1c) levels decreased from 12.28 ± 2.69% to 8.02 ± 1.90%, reflecting long-term glycemic control. Additionally, hepatic glycogen content was restored from 18.60 ± 2.17 mg/g tissue weight to 32.78 ± 3.96 mg/g, suggesting improved glucose storage and utilization [30].

These findings demonstrate that Hibiscus rosa-sinensis exhibits potent antidiabetic activity through multiple mechanisms, including lowering fasting blood glucose, enhancing insulin secretion, improving long-term glycemic indices, and restoring hepatic glycogen levels. The extract's efficacy was comparable to the standard antidiabetic drug gliclazide, highlighting its potential as a natural therapeutic agent for the management of type 2 diabetes mellitus and its associated metabolic disturbances.

***Ipomoea batatas (sweet potato)***

The antidiabetic potential of Ipomoea batatas (sweet potato) has been investigated primarily in rodent models of chemically induced diabetes. Diabetes was induced using streptozotocin (STZ) or alloxan at doses ranging from 50 to 120 mg/kg body weight, administered intraperitoneally or intravenously, to selectively damage pancreatic β-cells and simulate type 2 diabetes mellitus. Animals were maintained under controlled conditions, including a 12:12-hour light/dark cycle and a temperature of 22 ± 2°C, with free access to food and water. Experimental groups included normal controls, diabetic controls, and treatment groups receiving various doses of I. batatas extracts or fractions over 2–6 weeks. Key outcome measures included fasting and postprandial blood glucose, serum insulin, glycogen content in liver and muscle, and tissue-specific biochemical indices to assess β-cell function and metabolic status [45].

Administration of I. batatas extract significantly reduced fasting blood glucose levels from diabetic ranges of approximately 250–300 mg/dL to near-normal levels of 110–140 mg/dL. Insulin levels were increased by 1.5–2-fold compared to diabetic controls, indicating improved pancreatic β-cell function. Glycogen content in the liver and skeletal muscles was also enhanced, reflecting better glucose storage and utilization. Furthermore, fasting and postprandial blood glucose levels decreased by 30–40%, and glycosylated haemoglobin (HbA1c) levels were improved, demonstrating both short-term and long-term glycemic control [46].

***Momordica cymbalaria (Kadavanchi)***

The antidiabetic potential of Momordica cymbalaria was evaluated using female Wistar rats (140–170 g). Diabetes was induced by a single intraperitoneal injection of streptozotocin (STZ) at 65 mg/kg body weight, dissolved in 0.01 M citrate buffer (pH 4.5). Three days after induction, rats with fasting blood glucose levels exceeding 200 mg/dL were selected for the study. Animals were housed under standard laboratory conditions, including a 12:12-hour light/dark cycle and a temperature of 25 ± 2°C, with free access to food and water. Treatment groups received oral gavage of aqueous root extract at doses of 250 and 500 mg/kg body weight for 30 days, while glibenclamide (500 µg/kg) served as the reference standard. Key outcome measures included fasting blood glucose, lipid profiles, hepatic glycogen content, and body weight [47].

Treatment with the M. cymbalaria root extract produced dose-dependent improvements in glycemic control, with fasting blood glucose levels reduced by 23.50% and 45.95% in the 250 mg/kg and 500 mg/kg groups, respectively. Lipid profile improvements were also observed: total cholesterol decreased by 15.93% and 45.15%, triglycerides decreased by 43.35% and 63.68%, and HDL cholesterol increased by 57.67%, indicating potential cardioprotective effects. Hepatic glycogen concentration increased by 41.26% at the higher dose, suggesting enhanced glycogenesis and improved glucose utilization. The extract's efficacy in reducing hyperglycemia and modulating lipid metabolism was comparable to that of glibenclamide, supporting its potential as a natural antidiabetic agent [48].



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These results indicate that Momordica cymbalaria exerts antidiabetic effects through multiple mechanisms, including lowering fasting blood glucose, improving lipid metabolism, and enhancing glycogen storage. Collectively, these actions highlight its potential for managing type 2 diabetes mellitus and associated metabolic complications using a natural therapeutic approach.

***Musa x paradisiaca***

The antidiabetic potential of Musa × paradisiaca was investigated using male Wistar rats (140–160 g, 6 weeks old). Diabetes was induced by a single intravenous injection of streptozotocin (STZ, 40 mg/kg body weight) dissolved in citrate buffer (pH 4.5). Rats with post-induction glycemia above 350 mg/dL were selected for further experimentation. Animals were maintained under standard environmental conditions and divided into experimental groups receiving aqueous or methanolic extracts of M. × paradisiaca bracts and flowers at 200 mg/kg orally for 20 days. Glucose tolerance tests (GTT) were performed on day 15, following a 12-hour fast and oral glucose load of 2 g/kg body weight. Insulin-treated diabetic rats (4 IU/day) were included as a reference for comparison [49].

Administration of M. × paradisiaca extracts significantly improved fasting blood glucose levels and enhanced glucose tolerance, as observed in the GTT, with glycemia levels approaching those of insulin-treated rats by 120 minutes. Methanolic flower fractions were particularly effective, demonstrating a pronounced reduction in fasting glycemia compared to untreated diabetic controls. These results indicate that the extracts can restore glucose homeostasis, potentially by enhancing insulin secretion or improving peripheral glucose utilization. The study highlights M. × paradisiaca as a cost-effective and efficient natural antidiabetic agent, comparable in effect to standard insulin therapy in experimental conditions [31].

These findings suggest that Musa × paradisiaca exerts antidiabetic effects through mechanisms including lowering fasting glucose, improving glucose tolerance, and potentially stimulating insulin activity, reinforcing its therapeutic potential for type 2 diabetes management.

***Phaseolus vulgaris (White kidney bean)***

The antidiabetic potential of Phaseolus vulgaris was evaluated using C57BL/6J male mice rendered obese and insulin-resistant through a high-fat diet, simulating a type 2 diabetes mellitus model. The experimental group received a diet supplemented with 0.5% white kidney bean extract for eight weeks, while the control group continued the high-fat diet without supplementation. Key parameters assessed included body weight, fasting blood glucose (FBG), insulin sensitivity, and hepatic steatosis [50].

Supplementation with P. vulgaris extract resulted in a significant reduction in FBG by approximately 24% compared to the control group. Additionally, the homeostasis model assessment of insulin resistance (HOMA-IR) improved by around 30%, indicating enhanced insulin sensitivity. These outcomes suggest that the extract effectively ameliorates hyperglycemia, improves insulin receptor signalling, and contributes to the normalization of glucose homeostasis. The study supports the potential of white kidney bean extract as a natural antidiabetic agent capable of addressing both glycemic and metabolic disturbances in type 2 diabetes [51].

Mechanistically, P. vulgaris may act by enhancing insulin sensitivity, modulating glucose uptake in peripheral tissues, and reducing hepatic glucose production, making it a promising candidate for dietary or therapeutic interventions in diabetes management.

***Vinca rosea (Periwinkle)***

The antidiabetic potential of Vinca rosea was investigated using Wistar albino rats. Diabetes was induced by a single intraperitoneal injection of alloxan monohydrate (150 mg/kg body weight), which selectively destroys pancreatic β-cells, creating a diabetic-like condition. Methanolic extracts of V. rosea were administered orally at doses of 300 mg/kg and 500 mg/kg for 14 days. The experimental groups included a normal control, a diabetic control, and an extract-treated group, all of which were maintained under standard environmental conditions of temperature, humidity, and light/dark cycles. Acute toxicity tests revealed no mortality at doses up to 2000 mg/kg, indicating a wide safety margin. Key outcome measures included fasting blood glucose, lipid profiles, and histological assessment of pancreatic β-cells relative to acinar cells [32].

Treatment with V. rosea extract demonstrated dose-dependent antihyperglycemic effects. The higher dose (500 mg/kg) significantly reduced fasting blood glucose by nearly two-thirds over 14 days, approaching the efficacy of the standard drug glibenclamide (5 mg/kg). Improvements were also observed in lipid parameters, body weight, and pancreatic β-cell regeneration, indicating both glycemic control and protective effects on pancreatic tissue. The extract's ability to restore β-cell mass suggests mechanisms involving enhanced insulin secretion and preservation of pancreatic function [52].

Overall, Vinca rosea exhibits potent antidiabetic activity through multiple pathways, including lowering blood glucose, modulating lipid metabolism, and supporting pancreatic β-cell recovery, highlighting its potential as a natural therapeutic agent for type 2 diabetes management.

***Zingiber officinale***

The antidiabetic potential of Zingiber officinale was evaluated in Sprague-Dawley rats with streptozotocin (STZ)-induced diabetes. Diabetes was induced via a single intraperitoneal injection of STZ at 60 mg/kg, resulting in fasting blood glucose levels exceeding 350 mg/dL. After confirmation of hyperglycemia, rats were administered daily aqueous extract of raw ginger at 500 mg/kg orally for seven weeks. Experimental parameters included body weight, fasting blood glucose, water intake, urinary output, and metabolic rate assessments, with stress minimized through optimized handling and intraperitoneal techniques [33].

Treatment with ginger extract significantly reduced serum glucose levels by 52% compared to diabetic controls. Additionally, total cholesterol and triglyceride levels decreased by 44% and 41%, respectively, indicating substantial hypocholesterolemic and hypolipidemic effects. Ginger extract also mitigated diabetic nephropathy, as evidenced by a 60% reduction in proteinuria and stabilization of body weight. These findings suggest that Z. officinale improves glycemic control, modulates lipid metabolism, and protects against renal complications associated with diabetes. The antidiabetic effects are likely mediated through enhancement of insulin secretion, improvement of peripheral glucose utilization, and antioxidant activity, supporting its potential use as a natural



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therapeutic agent for diabetes mellitus and related metabolic disorders [53].

## Conclusion

Indian medicinal herbs exhibit considerable promise as complementary or alternative strategies for diabetes mellitus management, largely due to their multifaceted mechanisms of action. Preclinical evidence from animal models indicates that these plants not only reduce hyperglycemia but also enhance insulin secretion, improve peripheral insulin sensitivity, modulate key enzymes in metabolism, and protect pancreatic β-cells from oxidative and inflammatory damage. Bioactive constituents such as flavonoids, alkaloids, terpenoids, and phenolic compounds contribute to these effects, often acting synergistically to regulate pathways including insulin receptor signalling, GLUT4 translocation, AMPK activation, and antioxidant enzyme modulation (SOD, CAT, GPx).

Despite these encouraging findings, several critical limitations hinder the translational potential of these herbs. Most studies rely on chemically induced diabetic animal models, which may not fully recapitulate human pathophysiology. Standardization of herbal extracts remains a challenge, as variations in plant species, extraction methods, and bioactive compound concentrations can significantly affect efficacy. Moreover, issues of bioavailability, pharmacokinetics, potential toxicity, and herb-drug interactions remain largely unexplored, emphasizing the need for rigorous safety assessments.

Future research should prioritize controlled human clinical trials, pharmacodynamic and pharmacokinetic profiling, and identification of active phytochemicals responsible for antidiabetic activity. Developing standardized, reproducible formulations and evaluating synergistic effects with conventional antidiabetic therapies will be essential to translate preclinical promise into clinically applicable interventions. By bridging traditional knowledge with modern scientific rigor, Indian herbs hold the potential to provide holistic, multi-targeted approaches for managing the complex, multifactorial pathology of diabetes, including hyperglycemia, dyslipidemia, β-cell dysfunction, oxidative stress, and inflammation.

## Disclosure Statement

No potential conflict of interest was reported by the author.

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